INTERPRETIVE STRUCTURAL MODELING OF KEY FACTORS FOR ACADEMY-INDUSTRY LINKAGE PROCESS – THE MEXICAN CASE

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ABSTRACT

Innovation is a well-recognized key factor to increase country competitiveness. National innovation process has been described by the interaction among academy, industry and government in the triple helix model. In real world, it is difficult to implement the triple helix model in a region due to the existence of barriers that inhibit the linkage process. Literature has focused on academy – industry collaboration, because the proper link of these two actors generates more knowledge and innovation. However, academy and industry collaboration has not been implemented in a successful manner in many countries. The research purpose is to model the relationships of the key factors by using interpretative structural modeling (ISM). The main findings were that there is a significant division between academy and industry factors, the collaboration is made essentially within innovation poles with the participation of researchers, experts and students through technological extension services offered by academy. Regarding the model, it shows a good representation of the relationship among factors that helps academy and industry to understand the influence of one factor upon another, and develop strategies that create internal and structural changes that promote innovative collaboration, and that influence the environment in order to generate public policies that facilitate collaboration, creation of innovation poles, and increase public financing.

KEYWORDS: Innovation; triple helix; academy - industry; linkage; collaboration, interpretative structural modeling; Mexico.

1. INTRODUCTION

An innovation is determined when the product generates revenue, where by the exploitation of the technology and the protection are tasks where a company can obtain this revenue. These two tasks are known as technology transfer. Technology transfer can be defined as "the successful adoption of a technology package by a new organization i.e. when technology is purchased or licensed between companies" (Boer, 1999). Khalil (2000) defines technology transfer as a process that permits the flow of technology from a source to a receiver. Technology transfer process implies some sub-processes and interactions with other institutions; they can be other firms, customers, stakeholders, etc.

According to Jun (2008) "the interaction among university, industry and research institutions will produce a synergistic effect, greatly enhancing the capability of national innovation system". This means that the triple helix is a model that simulates in a macro level the national innovation system of any entity, as city, town or country. Also, he concludes that by establishing a triple helix model the national level of competitiveness can be increased and a platform for institution formation (Rodrigues & Melo, 2013). Triple helix model is constituted for three actors, university, industry and government.

The role of academy is the education of human resources with the purpose of acquiring and developing knowledge necessary to work in area of interest. Meanwhile industry is considered as profit generation actor, and sometimes is considered to take the academy role as provider of trained people (Lundberg, 2013; Etzkowitz, 2008). Most of the enterprises are looking to increase their sells and decrease costs, nowadays technology and innovation is considered a good mode to accomplish this. To undertake this, industry has to interact constantly with academy to access to knowledge and research infrastructure, and with government in order to promote industry development according to market needs.

Finally, government may drive the industry and academy to innovate through all kinds of means (Jun, 2008), promote social and economic development (Rodrigues & Melo, 2013), provide support making regulatory changes that promotes interactions among academy and industry and the creation of new markets (Lundberg, 2013). Meaning that, government may create public funds that encourage: basic research, applied research, innovation activities and collaboration between academy and industry. Academy needs to have a close relationship with government to promote, encourage and develop necessary policies for technological development (Merrit-Tapia, 2007).

Many authors as Hartmann (2014), Weisz & Carvalho (2013) and Vera Salazar et al. (2013) have identified that the major problem in the implementation of the triple helix model is among academy and industry. There have been many studies trying to identify the factors that inhibit and promote the linkage process between them. In Mexican context Amaro-Rosales & Villavicencio-Carbajal (2015) studied the relationship between governmental incentives and innovation specifically in agriculture and food sector. They concluded that regulatory institutional framework establishes more barriers than facilitators for developing innovations. On the other hand, De Fuentes et al (2015) determined dynamics of innovation and their correlation with productivity, focusing in service sector, concluding that a major investment leads to superior productivity performance and innovation output increase labor productivity.

Also, most of the authors who have studied the triple helix have performed their research in developed countries such as US, Germany, Norway, but there are a few studies taking place in undeveloped countries. This study is focused in Mexico, a Latin-American country that even though has made changes in innovation policy; the efforts had not been enough to construct a functioning triple helix model. This article focus is on answering the question of: How do key factors affect the linkage process between academy and industry in undeveloped countries, as Mexico? The result was obtained using "State of the art matrix" (SAM) and "Interpretative structural model" (ISM) in order to obtain a model that allows understanding academy – industry interactions in Mexico. This analysis allows to recognize the main barriers and structures that limit the evolution of internal transformation to influence of one upon another; especially in countries where there are few technology based enterprises and poor knowledge culture, joint with low GDP rates and low rate of gross expenditure in Research and Development (R&D) activities.

2. METHOD

The methodology is divided in two; first the identification of key factors using SAM, and second, the ISM modeling. For identifying key factors of linkage process between academy and industry, SAM was used; this helped to identify similarities and differences between publications, and to classify the literature in a systematic way. Then the ISM models the relationships of identified factors from the SAM analysis. Both steps are described next.

2.1 Identification of factors

A SAM analysis has been used by Beruvides and Vincent Omachonu (2001) to manage research information; this method uses matrices in order to compile and classify the literature about a specific subject. In this research, 36 publications of the Mexican situation were identified and analyzed for the purpose to compile research-made related to the topic, and then classified into different factors. A literature search was conducted using Emerald, IEEE and ProQuest database was performed; articles from Mexican associations - ALTEC[1], ANUIES[2] - and international conferences- ISPIM[3] -, as well as books printed in Mexico were studied. The literature research was performed till July 2015. After reading and analyzing the articles, it was decided to classified the literature using the Freeman (1987); Rothwell and Dodgson (1991); and Barceló (1994) classification's (Pedroza Zapata & Suárez Núñez, 2003) to determine de key factors of successful innovation in academy and industry divided in internal, structural and environmental factors. After completing the review process there were found 157 factors for the academy and 82 for the industry, 239 in total. The SAM analysis proposes the use of matrices to compile factors, after organizing in matrices a total of 49 were found as shown in Table 1.

Table 1 Key factors of linkage process identification

	Code	**Academy**	**Code**	**Industry**
Internal	AI1	Institutional prestige	II1	Vanguard infrastructure
	AI2	Poor Intellectual property culture	II2	Technological development methodologies
	AI3	Capital human profiles away from business demand	II3	Poor Intellectual property culture
	AI4	Academic service offer	II4	Increase of R&D resources
	AI5	Individual prestige	II5	Development of technological projects
	AI6	Human resources	II6	Investment in innovation
	AI7	Focus on innovation of the academics		
	AI8	Industrial projects		
	AI9	Technological monitoring		
	AI10	Insufficient infrastructure		
Structural	AS1	Innovation leadership	IS1	Innovation leadership
	AS2	Knowledge diffusion	IS2	Technological absorption capacity
	AS3	Technological approach	IS3	Innovation culture
	AS4	Technological linkage	IS4	Technological approach
	AS5	Commercial exploitation of knowledge	IS5	Strategic innovation
	AS6	Strategic innovation	IS6	Knowledge culture
	AS7	Entrepreneurial culture	IS7	Financial resources
	AS8	Linkage process	IS8	Mobility of human resources
	AS9	Transparency in the linkage process		
	AS10	Mechanisms for linkage		
	AS11	System of incentives and stimuli		
	AS12	Financial resources		
Envi	AE1	Financial public support	IE1	Financial public support
	AE2	Innovation poles	IE2	Global vision
	AE3	International collaboration	IE3	Innovation poles

[1] Asociación Latino-Iberoamericana de Gestión Tecnológica
[2] Asociación Nacional de Universidades e Instituciones de Educación Superior
[3] International Society for Professional Innovation Management

	AE4	Technological extension services.	IE4	Strategy alliances
	AE5	Exposure of students to industrial environments.	IE5	Cooperation with government
			IE6	Cooperation with academy
			IE7	Access to qualified personnel
			IE8	Technological extension services.

2.2 Interpretative structural modeling

“Interpretative structural modeling enables individuals or groups to develop a map of the complex relationships between many elements involved in a complex situation” (Ravi Kant, 2015, pág. 162). ISM is generally used in groups of experts, for the development of this study; it was taken into consideration the literature analysis performed in the previous section. Warfield and Cárdenas (2002) identified five types of structure: problematic, enhancement, intent, curriculum and priority. Since the objective of this research is to identify the factors and their relationships that facilitate the linkage process, the structure that best suites, is the problematic type using the question “Does <factor A> help resolve <factor B>?.

3. RESULTS

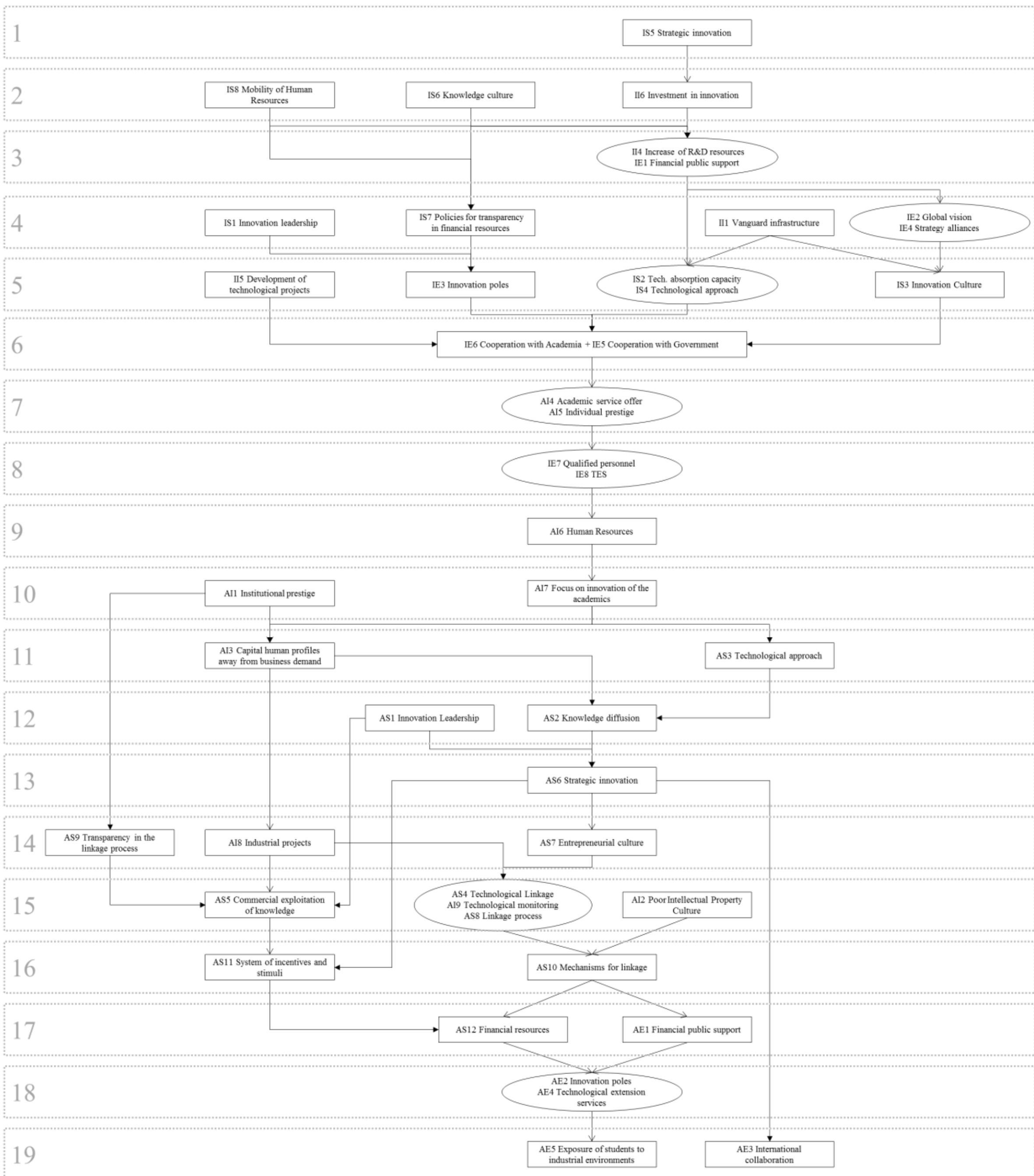
The resultant level set from ISM software is represented in Table 2. It is important to notice that most of industry factors are localized in the lower levels, signalizing that to develop a linkage process it is necessary the improvement of internal and structural organizations of the firms. This result is similar to the statement made by Salter et al. (2000), who affirms that innovations principal drivers are firms; they provide the demand to develop innovation activities and links outside business. Firms need to have innovative strategy in order to impulse innovation activities that influence the environment, in this case academy. Academy structure may be design in structured and coordinated to support collaboration with industry (Lawrence & Kirk, 2007).

Table 2 ISM resultant level set

Level	Elements
1	(II2) (II3) (AE3) (AE5) (AI10)
2	(AE2)←→(AE4)
3	(AS12) (AE1)
4	(AS10) (AS11)
5	(AI2) (AI9)←→(AS4)←→(AS8) (AS5)
6	(AI8) (AS7) (AS9)
7	(AS6)
8	(AS1) (AS2)
9	(AI3) (AS3)
10	(AI1) (AI7)
11	(AI6)
12	(IE7)←→(IE8)
13	(AI4)←→(AI5)
14	(IE5) (IE6)
15	(II5) (IS2)←→(IS4) (IS3) (IE3)
16	(II1) (IS1) (IS7) (IE2)←→(IE4)
17	(II4)←→(IE1)
18	(II6) (IS6) (IS8)
19	(IS5)

The resultant is shown in Figure 1; all the relationships are modeled, single factors are represented by rectangles, and double aggravation relationship is represented by ovals. Arrows indicate the relationship between factor the direction of the arrow represents that factor "A" helps to resolver factor "B".

Figure 1 ISM Model of Key factors of linkage process between Academy and Industry



3.1 Industry factors

The first factor is the implementation of strategies that promote innovation and knowledge transfer as a competitive advantage (Nilsson & Dernroth, 1995). This factor helps to implement investment in innovation by creating commercial monitoring activities to determine technology market demand and, designate resources to invest in R&D. These internal changes in conjunction with generation of knowledge culture and employees' mobility in innovation projects affect the implementation of mechanisms to seek founding. Also, it is priority for the industry to increase human and financial resources on R&D activities that promote the implementations of mechanisms for seeking founding and vice versa. Once firm increases its human and financial resources and have the necessary equipment to implement theoretical knowledge, the firm can promote an innovative culture.

Increase of human and financial resources on R&D influences positively the national and international commercial monitoring, by extending business vision to meet domestic and international's needs; and technological capacity of firms. Corona Treviño (2005) establishes that firms have a lack of global vision that obstructs that national and international companies and universities want look forward collaborate with them. According to the model, establishing policies for research and collaborations has a mutual aggravation with global vision, meaning that having a global vision to implement policies, acquiring infrastructure and training human resources increases its technological capacity, in order to meet market needs.

According to the model, the innovation capacity of the firms is determined by having the necessary equipment to implement theoretical knowledge and the creation of polices to establish research and collaborations with other entities. Supporting this point Merrit-Tapia (2007) mentioned the main factor that inhibits the linkage process is that firms have a deficient technological capacity to absorb new technologies or knowledge.

On the other hand the implementation of polices that ensure transparency in the use of financial resources requires mobility of human resources and knowledge culture within the firms. Knowledge culture and mobility of human resources promote the creation of standards and procedures that assure the efficient use of resources. López Martínez et al (1994) mention that most of the enterprises used linkage process to avoid taxes, making the firms lose confidence with government in order to gain funds to develop innovation projects. Guadarrama and Woolfolk (2013) describe that this problem is caused due the low assignation of financial resources within firms in innovation projects.

The creation of innovative poles is determined, according to the model, for policies about financial resources usage and leadership. Soto Velázquez et al (2007) establish that a firm requires transformational and intellectual leadership to eliminate technological barriers in firms. An innovative leader can promote the creation of spaces, projects, activities and events that facilitate communication and interaction with educational institutions, government and society to the realization of innovation activities development in firms.

Also, having an innovative culture promotes the establishment of innovative poles. According to Sadegh Sharifirad & Atei (2012), innovative culture is multidimensional context that implies that an institution has the intention to innovative as well as the infrastructure to support innovation, and the necessary organizational and operational level to influence the market. While the companies develop innovative culture, they start influencing the environment through an innovative culture as well, and innovation poles, also known as innovation systems, emerge.

As it can been seen, the willingness for searching the linkage with government and academy from industry is generated for the combination of activities to solve problems through innovation, implementation of programs that encourage employees to generate ideas, technological capability, and innovation poles. The promotion of industrial projects with academy and government resulted from internal and structural changes done by the industry in a proper environment that impulse innovative collaboration. According to Soto Velázquez et al (2007) most industries look forward for collaboration only when they have an emergency, and not as part of a strategy to solve problems, and/or create new products or services.

3.2 Linkage between academy and industry

It is interesting noting that from level 7 to 9 of the ISM model, the key factors correspond to similar activities from both academy and industry. It was decided to call these relationships as “linkage between academy and industry” because the relationships happen in mutual activities such as academic extension services which offer to industry employees’ training, not only in innovative themes but also in any area of interest.

Model shows a double interaction between the promotion of academic services offered to the industry and the participation of academics in research contract. This interaction implies that if academy increases its efforts to improve academic services, also participation of academic in innovative projects will increase and vice versa. Academics are more focus on individual prestige, (López Martínez et al, 1994) and when they are willing to develop a project is based in their own research and not necessary on markets need’s (Solleiro, et al, 2012).

When academy increases quality in TES, industry starts promoting links with academy, as access to specialized high-level researchers. Many authors support that one of the main motivations of industry to collaborate with academy is access to specialized human resources (Guillén Guzmán, 2012; Vázquez Lombera & Vázquez Pérez, 2012); but also to technical knowledge (Torreblanca Rivera & Trujillo Corona, 2012), and to establish connections with researchers (López Martínez et al, 1994) and future aspirants (López Parra et al, 2012). These links are facilitated with continuous employee training and vice versa.

The continuous training of employees promotes technical capacity of human resources to aim the promotion of students’ mobility between academy and industry. Mobility of students aims to complement knowledge, experiences and capabilities (Weisz & Carvalho de Mello, 2013); also to form professionals that promote economic development of the country (Sánchez Puentes, 1990).

3.3 Academy factors

Once the industry made internal and structural changes, and influence the environment, according to the model, the next part is that academy also make changes in order to facilitate the linkage with industry. The promotion of students’ mobility influences academics, most of the times academics are more focus in teaching activities that in research, there is a remarkable difference of priorities between teaching and researching in universities (Sánchez Puentes, 1990; Soto Velázquez et al, 2007). The mobility of students or academic personnel stimulates to have an industrial culture. According to Torreblanca Rivera & Trujillo Corona (2012) one of the principal factors that obstacle professor collaboration is that professors are looking to increase their prestige through publication or patents, and they rather make innovation projects externally to the institution where they work causing low human resources mobility (Guadarrama & Woolfolk, 2013). When academics change their focus from only teaching to collaboration, they help to give a technological approach to academy by creating programs that encourage students to generate innovative ideas for creating technology-based companies. Academic innovation activities are looked as isolated activities that don't generate benefit or value to the institutions (Llorens Báez, 1992).

Focus of academic institutions in increase their prestige through excellence research activities and individual prestige of academics allow to create updated academic curricula. Academic competitiveness forces universities and technological centers to offer future aspirants to satisfy the requirements and needs of the future (Castañeda Santibáñez, 1996). These relationships are interesting because even tough research is important, it is also important to have human resources experts in academic themes in order to generate and manage student curricula. For this point, it is necessary for both teaching professors and researchers training to accomplish mutual objectives when redesigning curricular programs (Soto Velázquez et al, 2007; Vera Salazar et al, 2013).

When academy has a technological approach, it encourages the generation and transmission of knowledge. Programs that promote among students the generation of ideas to solve industry problems, pushes the diffusion of knowledge through publication in journals or conferences (Hartmann, 2014). The diffusion of knowledge in academy has a positive effect in the innovative process and patents in industry (Lööf & Broström, 2008). According to Almeida and Kogut (1999) individuals have the major paper in patenting, and publishing, but also the degree of participation is influenced by the structure of the institutions as of their localization.

Diffusion of knowledge in conjunction with leadership influence the creation of strategies for implementation of innovative activities and knowledge transfer. According to Howell and Avolio (1993) a transformational leadership is necessary in order to propose and develop an innovation strategy within institutions. According to the model, leadership influences the innovation strategies and commercial exploitation of knowledge. Finally a strategic innovation improves international collaboration not only for exchange programs but for research projects, plus entrepreneurial culture and the creation of an incentive system (Vera Salazar et al, 2013).

According to Lars Lindvist (2015) the creation of an entrepreneurship culture is focused on combining resources and people in new ways that generate ideas, products, services and firms. Innovation strategies influence cultural entrepreneurship and they later influences technological linkage, technological monitoring and linkage process. These three factors have mutual aggravation relationship, referring that the implementation of technological monitoring technics, promote links for applied research and have an interactive structure to reduce bureaucracy.

Most of the authors (Solleiro et al, 2012; Guillén Guzmán, 2012; Meza Olvera, 2012; Sánchez Puentes, 1990) determined that one of the main inhibiting factors is the administrative activities that have to be performed to develop projects within institutions. The bureaucracy is influenced by cultural entrepreneurship and the participation of academy in industrial projects, meaning that involvement of students and professors in developing and generating innovation projects in industrial environment plus adequate culture, promotes interactive structures that facilitate implementation of policies and development of research in academic institutions.

Technological monitoring is influenced by academic structures, because it implies the creation of structured monitoring techniques in academy. According to López et al (1994), industries do not look forward to collaborate with universities due to the low amount of successful experiences; however high technology firms will to collaborate with higher education institutions, because they play an important role creating and encouraging formal links (Westhead & Storey, 1995).

It can be assumed that if an academic institution eliminates the structural barriers that allow the implementation of technological monitoring which in turn promotes links to do applied research within institutions, this may also promote the reduction of administrative barriers and so on. Traditional academic mechanisms inhibit collaboration with industry (Solleiro et al, 2012). However, some studies suggest that increasing the number of patents in academy stoppage research collaborations with industry and the quality of patents decrease over the time (Salter et al, 2000).

Poor intellectual property culture in academy takes into consideration lack of policies to protect knowledge and also low participation of lawyers in the realization of linking conventions. The lack of policies promotes the implementation of them in order to increase collaboration between academy and industry, but also influences negatively due the fact that without polices, industries don't consider academic institutions as strategic allies decreasing linkage between them (Vázquez Lombera & Vázquez Pérez, 2012).

On the other hand, policies that ensure transparency in the linkage process are influenced by the institutional prestige of institutions, meaning that according to level of prestige the university may have better promotion, creation and implementation of policies that ensure transparency in the use of resources in linkage projects. Transparency policies plus industrial projects result in a raise of policies to commercialize academic products.

Commercial exploitation of knowledge combined with a strategic innovation impulse the implementation of systems of incentives and stimuli for professors working in linked projects. Incentives have been used widely to attract researcher and students to collaborate with industry in innovation projects. A system of incentives plus a mechanism for linkage impulse the implementation of polices that assure financial resources and therefore human resources during collaboration projects and in technology transfer process. Amaro-Rosales and Villavicencio-Carbajal (2015) affirms that most of innovation projects not come to an end because the lack of resources during project development.

Mechanisms for linkage not only promote increments in financial sources but also impulse mechanism for seeking funding and public support for technological projects. Most academics institutions have limited resources to develop research plus they don´t have laboratory equipment and technology (Sánchez Puentes, 1990). To solve this problems most institutions hunt for alliances with industry in order to put in practice theoretical knowledge resulting in the creation of innovation poles from academy. As mentioned before, innovation poles propitiate environments for actors to interact. According to the model innovation poles in academy have a double aggravation interaction with technological extension services (TES). This relationship seems to be logical: the more interaction institution has the more competitive TES offers.

The innovation poles with TES impulse the creation, dissemination and implementation of academic programs that foster interaction with companies to enable students to acquire work experience. Exposure of students to real industry problems develops a global vision of real needs and prepares them to face competitive markets. In their study Pei-Lee and Chen-Chen (2008) state that the exposure of students to real environment influence the development of an entrepreneurial culture. Besides, this interaction promotes communication academy and industry, internship, and government through public funding's.

Finally, it is important to mention that there are factors that do not have input, as Knowledge culture, mobility of HR, vanguard infrastructure and innovation leadership from industry and institutional prestige and innovation leadership from academy. This means that these factor may have other elements that influence and impulse them. On the other hand, in the last level (19), there are three elements that are not showed in the Figure 1; (1) technological development methodologies have eight positive relationships in ISM model construction but it does not appear in the final model; (2) poor intellectual property culture in industry does not present any interaction derived from literature and (3) lack of infrastructure in academy which has negative relationship according to the initial factor definition, hence no relationship appear in the final model; they may not appear due the ISM software algorithm.

4. DISCUSSION

Triple helix model has been useful to define the interaction between academy, industry and government but in many regions and countries have failed in developing adequate environments and policies that make these interactions possible. In order to understand the relationships among university and industry, this paper describes the process of modeling key factors of linkage process between them using ISM software. This research generated an academy-industry interaction model showing a good representation of the relationships among factors that benefit academy and industry to understand the influence of one factor upon another. The model has practical implications by suggesting the main factors to develop strategies that create internal and structural changes which promote innovative collaboration, and influence the environment in order to generate public policies that facilitate collaboration, creation of innovation poles and increase public resources.

The theoretical implication of the model is that the results strengthen the literature about academy and industry collaboration and also remark that first it is required structural and internal transformation of industry in order to create innovation strategy that increases its technological absorption capacity. Some of the most important relationships seem to be global vision plus strategy alliances that promote the generation of an innovative culture within enterprises. As it can be observed in the model, industry cooperation with academy and government depend on industry culture, the participation of industry in innovation poles, and technological characteristics necessary to develop innovation projects.

On the other hand, the model displays that the major interaction between academy and industry are the services offered by academy, as technological extension services and access to qualified personnel, making fundamental to academic institution the improvement of services and the generation of researchers and professional resources portfolio so enterprises could contact them and generate collaboration. Also, academic institutions should implement policies and structures that gather information from environment, and markets need aiming to increase students and professor participation in industrial projects through human profiles that meet industry requirements.

Academic relationships are more complex than industry relationships, meaning the major amount of factors and complex relationship between them, representing that they are closely related. In most of universities research is done independently from industrial projects, generating good ideas in basic science. These ideas need adequate personnel to conduct them to generate a project or a service that generates revenue thereof an innovation. Academy doesn't take in to consideration the marketing of its products, resulting in low interest from industry to collaborate with it. It is essential to academy to open its structure and change its objectives in order to acquire experts and resources in linkage and technology transfer process. As Hermmert et al (2014) establish, it is difficult to generate trust among academy and industry with a short history of successful cases, so academy must make efforts to build trust and breakdown collaboration barriers through the implementation of mechanisms that facilitate incursion of industry into research activities.

Finally, triple helix don´t relapse in only one actor, as the model affirms innovation process implies the interaction of the three. In this ISM model, it was taken only two actors due the fact that most literature is based on the benefits of improve and increase interaction between academy and industry. But it is important to notice that government also may monitor national and international markets in order to construct policies that foster innovation between academy and industry. Also, government is known as environment regulator by fomenting and facilitating the generation of spaces and interaction between enterprises, stakeholders, entrepreneurs and researchers. As Perkmann et al (2013) affirms "different transfer or collaboration mechanisms may require different support structures and incentive mechanisms", this becomes into a major challenge not only for policy makers but also to enterprises that need to make internal changes and to promote policy initiatives that allow government to interact and direct country research into principal industrial sectors.

4.1 Limitations

Some of research limitations are that the model is formed using information from literature, meaning that many authors may be interested in some particular problems or opportunity areas according either to their experience or their point of view implicating that some relationships are not taken into consideration during the study. But it is important to mention that these relationships are still valid from authors' points of view. Also, the results represent the relationships and recommendations of a specific country, in this case Mexico, so results may vary from one country to other. And the model was formed using a positive relationship, so a further research could be done using positive and negative relationships among factors.

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