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Linking HEIs with the production sector: A communication approach between key actors in Ciudad Juárez, Mexico

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Abstract

To keep up with rapid evolutions in technical and scientific developments, countries must create competitive dynamics that enable key actors to generate high-tech projects, boosting both a country's productivity and economic development. Higher education institutions (HEIs), with their intellectual capital and as core generators of knowledge, are one of the main actors in these dynamics, particularly given their societal responsibilities and contributions to intellectual development and technical knowledge in the community. This article aims to identify the relationship patterns required for actors to create a fully participatory and integrative process between HEIs and the production sector (PS). This integrative and linking process generates and improves technical projects in the region. Through a literature review and an analysis of current empirical evidence on the effectiveness of the relationship between these two sectors in the region, an interrelational map has been developed. This map aims to highlight key activities to be considered during the execution of the linkage and to identify an ecosystem of necessary elements to develop a diagnostic evaluation tool. This tool may be used to define the ideal conditions that should lead to project development between the HEIs and the PS. The article presents the region of Ciudad Juárez in Mexico as a case study.

Keywords

absorptive capacity, HEI–production sector linkage, innovation, Mexico, technical projects, technology transfer office

Ciudad Juárez is located in the north of Mexico and shares a border with El Paso, Texas, forming one of the largest metropolitan areas between Mexico and the United States. The city is geographically located at a favorable and strategic point for the assembly of products at an international level. Since the 1980s, it has experienced rapid growth in the number of manufacturing companies setting up operations in the area; currently, there are approximately 335 companies with headquarters located all over the world.[1]

The flexibility in the movement of supplies and products and the access to logistics systems in the supply chain have been determining factors for countries such as the United States and Canada to carry out manufacturing operations under a free trade market agreement: The United States-Mexico-Canada Agreement (USMCA). These commercialization facilities have driven economic growth in the region, generating medium-sized and small supply companies in both the service and production areas. These companies have created a productive and dynamic environment that in turn is spawning even more companies; there are currently more than 40,000 micro, small, and medium-sized enterprises in Ciudad Juárez (MiPyMEs, 2019).

Ciudad Juárez is clearly in an excellent position to promote the development of technological projects between the higher education institutions (HEIs) and the production sector (PS) (Calcagnini and Favaretto, 2015; Etzkowitz and Lewdesdorff, 2000; Morrissey and Almonacid, 2004), but unfortunately, despite the ideal conditions, HEI

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engagement has not been significant. The low index participation of national industry in the international manufacturing supply chain and the low indexes of intellectual property generation in the locality are evidence of this lack of engagement. These distinctive regional characteristics provide a good opportunity for analysis and study.

The manufacturing industry in Ciudad Juárez was established in the 1960s (http://www.index.org.mx/historia.html) and has been in constant development since. One of the main characteristics of the region is that its own manufacturing aims only to match the various products with the demand created by local social needs. However, the manufacturing dynamic has not yet been fully exploited. Data show that less than 5% of local small and medium-sized enterprises (SMEs) contribute to the supply chains of large international manufacturing companies (http://www.cambio.gob.mx). This indicates an extremely low participation in the supply chain of materials as well as in the technology used to manufacture the different products that are currently being produced. Therefore, more technological projects need to be generated to strengthen the participation of SMEs in Ciudad Juárez in the international supply market chain, creating significant challenges ahead for local companies. Local companies may face a competitive environment affecting four main areas in particular: (a) their innovation, (b) their absorptive capacity, (c) their technology transfer practices, and (d) government participation. It is important to explore and address these four areas if the region of Ciudad Juárez wishes to commit to providing support to the technological development of this important local sector of SMEs.

This work focuses on the region of Ciudad Juárez because it offers a promising scenario through which to discover the relationships that are important for generating linkages between HEIs and the PS. The article explores existing regional data and adopts existing contemporary literature related to the topic to propose ways to facilitate the development of this important linkage. Three maps are presented, which represent important relationship phases and the key activities that must prevail for successful HEI–PS linkage. The interrelations between these three phases give shape to a large and complex ecosystem, demonstrating the magnitude and scope of the key actors required to generate and develop joint technological projects between HEIs and the PS in Ciudad Juárez. The conceptual results of this exercise may be applicable to other national or international regions which are also seeking to increase HEI–PS linkages.

University–enterprise links (theoretical background)

The PS of a country depends on a combination of factors: investment levels, human resources, knowledge, and technological progress (Calcagnini and Favaretto, 2015). The link between knowledge and technology transfer has become a strategic issue for countries aiming to boost their PS. This strategy is critical given the impact and knock-on effect on the development of new research and teaching concepts generated in HEIs (Becerra, 2019; Pickernell et al., 2009). The efforts made by the public and private education sectors to conduct joint research with the PS have become the key to boosting economic development (Organisation for Economic Co-operation and Development (OECD), 2001). Within HEIs too there has been a shift away from stand-alone teaching and research toward an applied combination of both, which seems to have had a significant impact on knowledge production (Etzkowitz and Leydesdorff, 2000). The countries that have promoted this university–business link have obtained favorable results, which have had an impact on the economy and generated patents, blueprint models, and collaborations (Filippetti and Savona, 2017; Franco and Haase, 2015).

Contemporary researchers have identified the importance of HEI participation in the process of knowledge transfer to the production and social sectors, where activities that are developed interactively in an interdependent ecosystem generate benefits for all actors (Ankrah and Al-Tabba, 2015; Berbegal-Mirabent et al., 2015; Curley and Formica, 2013; De Fuentes and Dutrenit, 2014; Etzkowitz and Leydesdorff, 2000). Interdependence and interaction play an important role in strengthening, integrating, and advancing the HEI and PS relationship (Ankrah and Al-Tabba, 2015). This integration forces HEIs to increase their level of technological capacity, adjusting to the technological needs of companies (Plewa et al., 2005). In addition, the technology transfer processes that occur in this relationship play an important role in HEIs, in that they promote entrepreneurship and potential spin-off innovations created by students (Calcagnini and Favaretto, 2015).

According to Dutrénit and Arza (2010), there are four scenarios that capture the nature of interaction between HEIs and companies: (1) external services providing technological and scientific support to enterprises with an economic recompense (e.g. independent consultation, rent of laboratory equipment, and incubator space); (2) a traditional relationship, whereby knowledge sharing is unidirectional, flowing from the university to the PS via graduates, conferences, and publications; (3) a bidirectional relationship, whereby knowledge flows in both directions via collaborative research, development of joint projects, participation in networks, technological science parks, and similar activities; and (4) a commercial arrangement, represented by spin-offs, business incubators, technological licensing, and patenting (Dutrénit and Arza, 2010; Franco and Haase, 2015). For De Fuentes and Dutrenit (2014), the interactions that occur between HEIs and the PS are via the development of linked projects; human resources (students and teachers); networks and the dissemination of information via magazines, reports,

conferences, and the Internet; training and consulting; property rights; incubators; and spin-offs. Although with slightly different approaches, both Dutrénit and Arza (2010) and De Fuentes and Dutrenit (2014) find that, to achieve success in any of these interaction avenues, two conditions must be present: both parties must have trust and commitment (Plewa et al., 2005).

Those establishing and leading these relationship interactions should also consider critical human resources values, such as communication, understanding, and credibility, since these factors impact on the success of the relationship (Fateh et al., 2015). An important step to consider in the communication between HEI and PS is to acknowledge the potential increase of intellect that in turn generates successful collaborations among those involved (Fateh et al., 2015). In developing countries, where there is little collaboration between university and business, the reputation and leadership of innovative managers is more important than in first-world countries, where this communication occurs through collaborative networks (Fateh et al., 2015).

Innovation

Innovation is a process of knowledge or idea transformation that produces new companies, new products, new markets, and commercial income flows (Jones et al., 2014; Reaiche et al., 2016). HEIs, like the government, industry, and research centers, play a fundamental role in the national innovation system of most industrialized countries, driving economic and technological development (Calcagnini and Favaretto, 2015; De Gortari and Santos, 2004; Etzkowitz and Leydesdorff, 2000; Fateh et al., 2015; Kerry and Danson, 2016). For Plewa et al. (2005), the rapid change in competitiveness and the speed of innovation around the world has promoted the creation of links between the research community and the private-sector companies (Plewa et al., 2005). Their research results, based on an Australian case study, indicate that, despite the increased link between HEIs and the PS, the flow of research dedicated to this area is still limited (Plewa et al., 2005). Companies must establish and increase their cooperation with HEIs and research centers to alleviate the effects of barriers to innovation, particularly those related to knowledge and its dissemination that could affect innovation and economic development (Filippetti and Savona, 2017).

According to Etzkowitz and Leydesdorff (2000), an important factor in the HEI–PS relationship is to position mentors in innovation in key leadership roles. These mentors must demonstrate a passion for change, possess good project management skills, be creative and innovative, have a good understanding of the project, and be capable leaders. HEIs possess a unique advantage over businesses in that student turnover guarantees an endless source of new people and innovative ideas (Etzkowitz and Leydesdorff, 2000). Cognizant of this constant supply of potential innovators, those responsible for policy are now focusing on finding the best ways to maximize the effectiveness of interactions between companies and public education and research institutions at the regional and national levels (Filippetti and Savona, 2017; Kaklauskas et al., 2018).

The effectiveness of these collaborative relationships will depend somewhat on the government actively promoting, supporting, and sustaining the adoption of open innovation (Kerry and Danson, 2016). Likewise, to accelerate the adoption of a successful innovation process in companies, organizations must also establish strategies that neutralize resistance to change (Kerry and Danson, 2016). In a regional development policy study conducted by Henton et al. (2002), it was found that successful development practices in three HEIs in the United States showed evidence of strong network collaborations between entrepreneurs, investors, university researchers, lawyers, and accountants. Those who know how to generate collaborative ideas and transform them into tangible new products or services recognized the need to integrate every actor to assure successful networks. These types of networks are critical for entities that want to be at the edge of the innovation curve (Henton et al., 2002). The formation of networks plays an important role in the generation of strategies and ideas. Contact between the actors is important to achieve an effective interaction and represents an opportunity to access innovations and carry out knowledge transfer that should boost a company's level of absorptive capacity in terms of technological knowledge.

Entrepreneurial universities

As the main generators and disseminators of knowledge, HEIs play an important role in the innovation processes of companies (Torres et al., 2011). Linkages between university research and development and local companies are fundamental for creating an impact on the economic and social development of a region. In addition, the knowledge that modern society demands seems to require a new style of university – one that not only provides qualified employers to companies but also participates in the processes of innovation and economic development in the region (Etzkowitz and Leydesdorff, 2000). An entrepreneurial university can be defined as a versatile institution which constantly finds new solutions to ongoing societal problems and challenges that arise from an unpredictable environment (Hannon, 2013). One of the current challenges in the region of Ciudad Juárez is to transform universities into entrepreneurial education entities with the key mission of generating, disseminating, and applying knowledge to create new products, processes, and services for social benefit (Amaral et al., 2011).

Universities promote an entrepreneurial culture and are catalysts for the creation of new companies and businesses (Lahikainen et al., 2018). It is therefore important for university administrators to define the attributes of entrepreneurship that must be consciously considered when making linkages with companies. Entrepreneurial universities must also establish the appropriate mechanisms and reforms, restructuring current conditions to support and foster academic entrepreneurship (Nlemvo et al., 2002), as well as generating and disseminating innovation (Pickernell et al., 2009).

Absorptive capacity

Some authors affirm that companies that invest more in research and development have greater absorption capacity to learn and interact with HEIs, preferring to carry out this interaction with high-quality HEIs regardless of their location (Bowen et al., 2004; De Fuentes and Dutrenit, 2014; Pickernell et al., 2009). According to De Fuentes and Dutrenit (2014), Mexican companies with the greatest number of relationships with public research organizations and institutions have departments or personnel that follow up on research and development in their company. Eight-five percent of these companies hire staff with high capacity and ability to carry out research and development activities. In addition, De Fuentes and Dutrenit (2014) found that the companies that received economic incentives to carry out research and development initiatives had a high tendency to collaborate and establish networks reaching up to 84% of links.

Laursen et al. (2011) confirm that companies with greater absorptive capacity are in a better position to identify and approach institutions with the greatest capacity to form linkages, regardless of their location (De Fuentes and Dutreit, 2014; Laursen et al., 2011; Pickernell et al., 2009). The aim for companies is to find the mechanisms that will drive and maintain a competitive level of innovation and development. Micro, small, and medium-sized enterprises continuously struggle to carry out research and technological development for the improvement of their products, given the complex infrastructure required. These enterprises could save money and access valuable infrastructure and experience by linking with HEIs (Berbegal-Mirabent et al., 2015; De Fuentes and Dutreit, 2014; Jones et al., 2014; Lahikainen et al., 2018; Lin et al., 2015).

Business financing is an effective conduit for the transfer of knowledge generated in HEIs and can function as a substitute for government or angel investment (Jones et al., 2014; Lahikainen et al., 2018). However, this is not an effective mechanism for large companies. In the studies conducted in Mexico by De Fuentes and Dutrenit (2014), it was found that foreign investment companies preferred to collaborate with large national corporations rather than with public research institutions and centers, possibly because of the privileged access they could gain to the technology located in their engineering centers (De Fuentes and Dutrenit, 2014). The current reality is that the absorptive capacity of companies, regardless of their size, economic condition, or location, has become a critical factor for their survival, especially in an environment in which markets are increasingly competitive. Hence, the importance of establishing strategies and roles that foster an organizational culture which is able and willing to adopt and sustain a continuous innovation process.

The third mission and technology transfer offices (TTOs)

In first-world countries, the successful HEI–PS relationship that results in the commercialization of knowledge is currently known as the third mission of HEIs (Berbegal-Mirabent et al., 2015; Etzkowitz and Leydesdorff, 2000; Henton et al., 2002). This third mission, which is a relatively new phenomenon for Latin America (Becerra, 2019), focuses on building relationships and collaboration between HEIs and the PS, so that research can be converted to commercial endeavor (Pickernell et al., 2009). This mission may involve activities related to technology transfer or education innovation.

To be successful in third mission objectives, HEIs must develop structures and policy that eliminate communication barriers and facilitate the transfer of research outcomes and innovations (Nlemvo et al., 2002; OECD, 2001; Pickernell et al., 2009). Many HEIs are currently adapting their capabilities and infrastructure to provide improved research and development services through, for example, establishing TTOs (Algieri et al., 2013; Berbegal-Mirabent et al., 2015). In Brazil, for example, an innovative law, "Technology Innovation Centers," was enacted for the creation of TTOs to strengthen and support the PS.

Therefore, university TTOs emerge as a sound platform for the development of public and private businesses and a legal and systematic means of commercializing knowledge, given that they are located at the interface of the internal and external environments, but without being separate from the institutional scientific–technological approach (Algieri et al., 2013). The adoption of these changes, for Ciudad Juárez in particular, is a challenge that must be resolved by aligning the logistics of institutional competitiveness in the region with core practices of the education, research, and entrepreneurship sector (Lahikainen et al., 2018). The current poor condition of HEI–PS linkages in the Ciudad Juárez region implies the need for HEIs to adopt and formalize legal representation via more TTOs, which can facilitate, streamline, and formalize the linking process between the parties. Equally, the PS and government (Lahikainen et al., 2018) must become agents that stimulate and support the establishment of more TTOs to boost the development of innovation projects in the region.

Table 1. Benefits that can be achieved through successful HEI–PS linkages.

Benefits	HEI	PS	References
Development of human capital that is better qualified and prepared	X	X	Plewa et al. (2005); Prigge (2005)
Boosting entrepreneurship and generating new companies (start-ups, spin-offs) with the participation of students, teachers, researchers, and the community in general	X	X	Dutrénit and Arza (2010); Lahikainen et al. (2018); Pickernell et al. (2009)
Boosting the generation and formalization of intellectual property (patents, utility models, copyrights, others)	X	X	Becerra (2019); Dutrenit (2016); Franco and Haase (2015); Lahikainen et al. (2018); Prigge (2005)
Promotion of community participation (students, teachers, researchers) as a result of economic recognition from participation in the development of joint projects with the production sector	X		Dutrenit (2016); Franco and Haase (2015); Pickernell et al. (2009)
Financial support to sustain students and researchers during the gestation and development of new projects	X		Franco and Haase (2015); Prigge (2005)
Economic support for strengthening the infrastructure of the institution	X		Franco and Haase (2015)
Recognition, reputation, and prestige for students, researchers, and the institution	X	X	Franco and Haase (2015)
Participation and the promotion of scientific and technological independence and national economic development in the country	X	X	Pickernell et al. (2009); Prigge (2005)
Encouragement of a research and development culture	X	X	Becerra (2019); Franco and Haase (2015)
Participation in research and work networks	X	X	Becerra (2019); Franco and Haase (2015)
Potential access to infrastructure, innovation, research, and development of the product or process at affordable costs		X	Prigge (2005)

Note: HEI: higher education institution; PS: production sector.

The government

The role of governments in this regard is to establish and facilitate policies that promote linkages between HEIs and the PS. These need to be continuously updated to keep pace with rapid change and should be understood as a reflexive feedback to the system (Etzkowitz and Leydesdorff, 2000). Policy-makers must establish methods of consolidating partnerships between HEIs and businesses and increase access to knowledge for SMEs. It may also be effective to provide financial incentives to motivate teachers and students alike to participate in collaborations (Arvanitis et al., 2008; Berbegal-Mirabent et al., 2015).

The United States provides an excellent example of government policy playing a pivotal role in collaboration success. Since a shift in policy in the 1980s, US HEIs have established a successful track record of generating patents, licenses, and spin-offs (Algieri et al., 2013; Prigge, 2005), generating billions of dollars' worth of profit. Policy-makers there consider the scientific and technological knowledge that is produced in educational institutions and public research centers as raw material for regional and national economic and technological development (Allahar and Sookram, 2019; Nlemvo et al., 2002; Prigge, 2005). Etzkowitz and Leydesdorff (2000) proposed the Triple Helix model for relationships between HEIs and companies, whereby the government also plays an important role and each party maintains a relationship with the other two parties, forming a strong network between all (Allahar and Sookram, 2019; Etzkowitz and Leydesdorff, 2000; Kerry and Danson, 2016).

The government must take leadership in creating regional innovation networks where the participation of HEIs in the research and development of technological projects is ensured in accordance with the profile and characteristics of their capacity and knowledge domain (Henton et al., 2002; Kaklauskas et al., 2018). Support programs and access to public funds for research and development activities in companies must be informed and promoted by government representatives in a timely manner to facilitate the linking of companies, allowing them to interact and access the contemporary needs of technology transfer.

Potential benefits of links between HEIs and the PS

After an extensive literature review, 11 different perspectives were identified with regard to the advantages and benefits achieved by actors when linkages are created between HEIs and the PS (see Table 1; De Fuentes and Dutrenit, 2014; Franco and Haase, 2015; Lahikainen et al., 2018; Pickernell et al., 2009; Plewa et al., 2005; Prigge, 2005). Of course, these benefits are general and theoretical, since their extent will depend on the degree and intensity of the collaboration and the capacity of the organization to create innovations from the knowledge transfer (Plewa et al., 2005). As a result of an extensive analysis of

Table 2. Challenges that must be overcome to achieve successful HEI–PS linkages.

Challenges	HEI	PS	References
The demand for linkage support results in increased pressure and stress for those involved	X	X	Plewa et al. (2005); Prigge (2005)
Conflict of interest	X		Plewa et al. (2005); Prigge (2005)
Commitment to academic integrity	X		Prigge (2005)
Inhibition of research results due to intellectual property controls	X		Prigge (2005)
Conflicts regarding the definition of priorities in the development of research	X	X	Franco and Haase (2015); Prigge (2005)
Diversification of academic resources	X		Prigge (2005)
Lack of empowerment to lead and provide directions	X		Prigge (2005)
Financial obligations for contractual agreements	X		Prigge (2005)

Note: HEI: higher education institution; PS: production sector.

the literature, Table 1 lists a summary of key benefits that can be achieved during a successful HEI–PS bonding (see, e.g. De Fuentes and Dutrenit, 2014; Franco and Haase, 2015; Lahikainen et al., 2018; Pickernell et al., 2009; Plewa et al., 2005; Prigge, 2005).

Challenges to overcome

Although research on the development of HEI–PS linkage projects generally emphasizes the benefits, enablers, and inhibitors of collaboration, the risks associated with the relationship have also been identified (Ankrah and Al-Tabba, 2015; Prigge, 2005). This article argues that there is a general sense that educational institutions should focus solely on teaching and learning and carrying out theoretical research, limiting innovation to the education sector. In fact, it has been recommended that HEIs minimize the traditional norms in the academic system constituted via research funding benefits and devote themselves instead to traditional research negotiations and learning (see Benner and Sandstrom, 2000, on this debate; also Etzkowitz and Leydesdorff, 2000).

One of the main arguments against the academic research focus system is the potential risk of commercialization and a financial conflict of interest, particularly with the PS, impacting the focus and objective of HEIs of producing intellectual talent and knowledge in the community (Prigge, 2005). Also, according to the results of a study carried out by Plewa et al. (2005), the differences in organizational environment (motivators, time management, market orientation, organizational bureaucracy, and flexibility) between HEIs and the business sector have a negative influence on their relationship (Plewa et al., 2005). Further, Prigge (2005) states that conflicts can occur over research priorities; the allocation of personnel, materials, and resources due to an incompatibility in values; discipline; confidentiality; communication; and property rights claims. Prigge (2005) also supports the argument of Plewa et al. (2005) concerning organizational incompatibility between industry and university (Prigge, 2005). For them and other researchers, this incompatibility represents a risk for HEIs in terms of distracting students and teachers from their purely academic pursuits.

It is important to acknowledge that technology transfer mechanisms in HEIs also have the potential to generate additional internal transaction costs by encapsulating knowledge through patents that otherwise should flow freely into industry (Etzkowitz and Leydesdorff, 2000). In addition, there is a risk that the government will come to expect and indeed measure HEIs' contribution to regional economic development through standards and performance (Etzkowitz and Leydesdorff, 2000). Franco pointed out, after interviewing members of the professional staff in HEIs, that academics already have an excessive teaching and administrative workload, so research and industry linkage activities are difficult to accomplish if workload implications are not considered (Franco and Haase, 2015).

From the analysis of existing literature on the risks involved in HEI–PS linkages, it can be determined that the challenges faced by HEIs in particular require immediate attention. A systemic change needs to be developed in the way projects are generated, developed, and evaluated. Table 2 introduces a summary of potential risks recognized by researchers that represent challenges that must be overcome in order to achieve successful HEI–PS linkages (see, e.g. Franco and Haase, 2015; Plewa et al., 2005; Prigge, 2005).

An analysis of the information presented so far gives us an overview of the importance and seriousness with which this issue is regarded by different countries, in different scenarios at the regional, national, and international levels. With regard to Ciudad Juárez, the challenge is to jointly develop a strategy to improve HEI–PS linkages with input from all three levels of government, the HEIs, and the PS. The proposal to establish communication mechanisms among the actors of these three sectors forms a preamble to the development of a diagnosis of the situation that

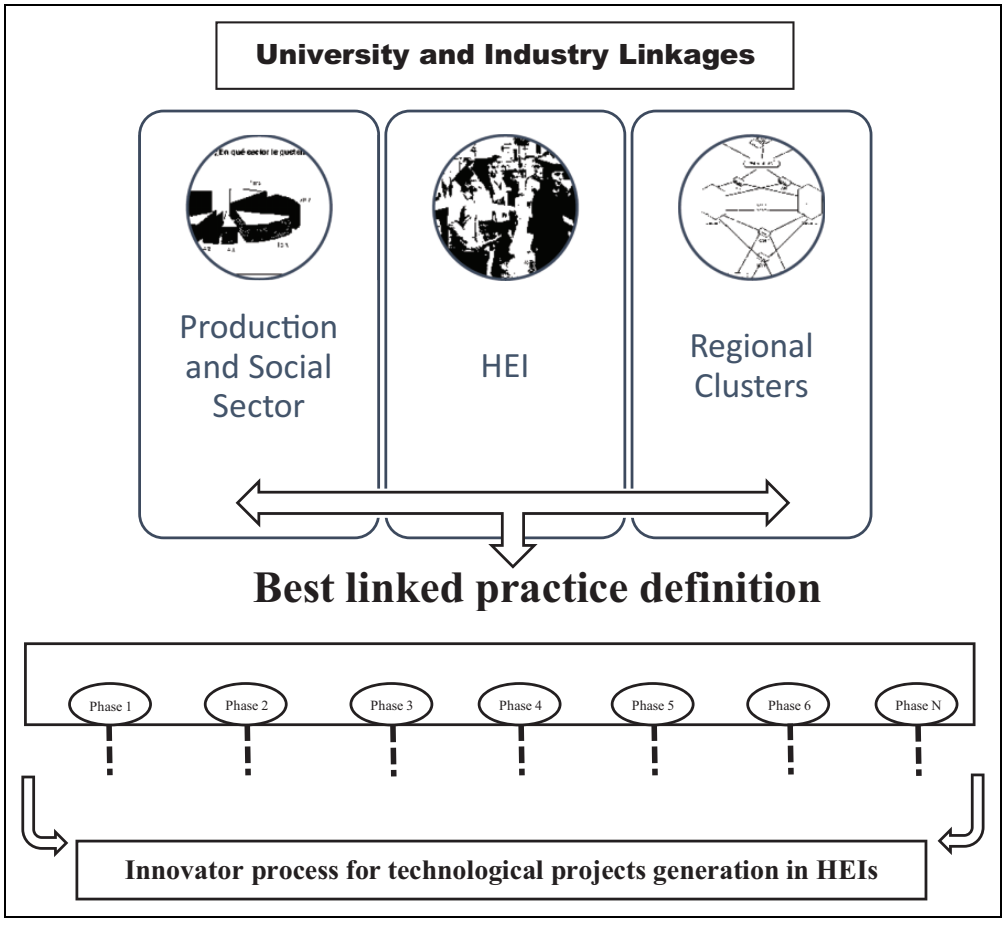

Figure 1. Simple arrangement of actors for definition of structural linkage best practice.

currently prevails in the region of Ciudad Juárez, highlighting successes, strengths, weaknesses, and areas of opportunity for linking HEIs with the PS.

Method and approach: Ciudad Juárez region

A qualitative research approach was adopted based on the combination of a literature review and an exploratory study of the region of Ciudad Juárez supported by structured interviews. Activities occurring within the region of Ciudad Juárez are the focus of this research. The exploratory stage adopted the Triple Helix as a model, with Ciudad Juárez's universities, networks, and actors evaluated against industries and governments in the knowledge production process. Sixteen interviews were conducted, involving universities, SMEs, and the local government.

The information in the three dimensions of the Triple Helix enabled us to explore and measure the prevailing condition of the actors' interactions. Emergent themes from the analysis of these interactions were clustered and correlated with the literature to help define inhibitors and barriers that appear to be affecting the development of successful communication processes. Eight of the common themes were grouped and are listed in Table 2 under the "Challenges to overcome" heading.

The associativity between HEIs and the PS, in terms of the development of joint technological projects, is potentially an area of opportunity for Ciudad Juárez that merits review. A diagnosis of the main actors in the region was conducted, synthetized, and discussed (see Figure 1). According to the Triple Helix model, representatives of the PS (such as managers, administrators, presidents of associations, cluster representatives), government, and the education sector must converge and jointly address the factors that act as barriers to the development of links between HEIs and the PS. They must also jointly consider what actions should be taken to strengthen and support existing links and how to encourage participation by all actors.

Ciudad Juárez has four public HEIs with industrial career development programs: Instituto Tecnologico de Ciudad Juárez, Universidada Autonoma de Ciudad Juárez, Universidad Autonomoa de Chihuahua, and Universidad Tecnologica de Ciudad Juárez. Data were drawn and

analysed from all four institutions. There are also three private HEIs with industrial career development programs: Tecnológico de Monterrey, Universidad Regional del Norte, and Tec. Milenium. Currently, links with industry generally take one of the two forms: (a) students undertake short placements during their studies or (b) students undertake professional practice residencies at the end of their studies. A link with industry is of great value to students as they are able develop their skills, abilities, and practical knowledge directly in their chosen PS. This helps them to be more effectively prepared in practice and more competitive at the end of their studies.

Another traditional form of linkage and technology and knowledge transfer is the provision of services by an HEI to the PS – for example, through the development of training courses, specialized advice, and project development (Ankrah and Al-Tabba, 2015). For the management of this transfer, most institutions have liaison departments in charge of the development of these activities with the production and social sectors. Currently, Ciudad Juárez has a strong position in the higher education sector given the large number of HEIs in the region. This can be considered an important asset which can be utilized in developing research, collaboration, and technology skills transfer and should be seen as an opportunity for the future generation of innovative technological projects in the region.

Development of joint technological projects

The challenges preventing full technological development as well as freedom of research faced by countries like Mexico call for urgent attention in all the country's strategic sectors. While all the Ciudad Juárez HEIs do encourage links and interactions with the PS, more needs to be done to strengthen and stimulate collaborations. Even with recent efforts by government agencies to establish programs to support the PS (De Gortari and Santos, 2004) and its links to HEIs, there have been few positive results. Therefore, it is important that HEIs, as knowledge-makers, reinforce their commitment to the community and act as drivers of technological development in the PS, especially in SMEs (Berbegal-Mirabent et al., 2015).

Given this climate in Ciudad Juárez, it is important to establish an interrelational map that defines the main activities that should be developed dynamically by the main actors involved in the process of linking HEIs and the PS. As mentioned earlier, this study adopts a qualitative research method that analyzes an issue in a real environment (i.e. the region of Ciudad Juárez), considering evidence from multiple sources as recommended when a social and personal context is essential for the understanding and interpretation of the phenomenon. The empirical data for this case study were collected via structured and personalized interviews (primary sources), as well as documents and materials (secondary sources). The interrelational map generated is divided into three phases, each of which will provide the main characteristics that the study proposes may be used to define key elements required to evaluate the performance of the region. Simultaneously, these key elements are then summarized in the form of a survey which, when conducted, will facilitate an understanding of the prevailing conditions required to develop successful projects between HEIs and the PS.

Main actors

Analyzing and conceptualizing activities among the actors is fundamental in establishing the different collaboration approaches currently being used in the region. After an extensive literature review and data analysis, and after taking into consideration local information, the following interrelational map of actors in Ciudad Juárez was developed:

1. At the first level and phase (Figure 2), activities occur between private-sector companies (owners, managers, project leaders, R&D managers, engineers) and HEIs (directors, project managers, heads of linking, TTO managers, researchers, students).
2. At the second level and phase (Figure 3), activities occur between the clusters (president, secretary, manager, treasurer) and the HEIs (director, project manager, heads of linking, TTO managers, researchers, students). It is necessary to clarify that clusters are a fundamental and strategic part of the PS in any region; however, in Ciudad Juárez, the formation and articulation of the seven regional clusters is in an operational structuring process (Limones and Flores, 2019), in which most of the associate members are micro, small, and medium-sized enterprises, strategically agglomerated to provide services and products to the maquiladora companies in the region.
3. At the third level and phase (Figure 4), no less important, feedback occurs. This should take place via interviews and conversations with leaders and sector representatives (representatives from all levels of government and of commerce chambers and business associations and experts in the subject).

Individually, the analysis and conceptualization exercise for each phase is represented by a figure showing a communication structure that formulates the main activities to be considered during the completion of the linkage. The combination of the three representative figures of each phase generates the interrelational map (Figure 5), which depicts an ecosystem that is proposed as a general alternative to the current scenario faced by Ciudad Juarez to define the necessary elements when evaluating the region in terms of HEI–PS projects.

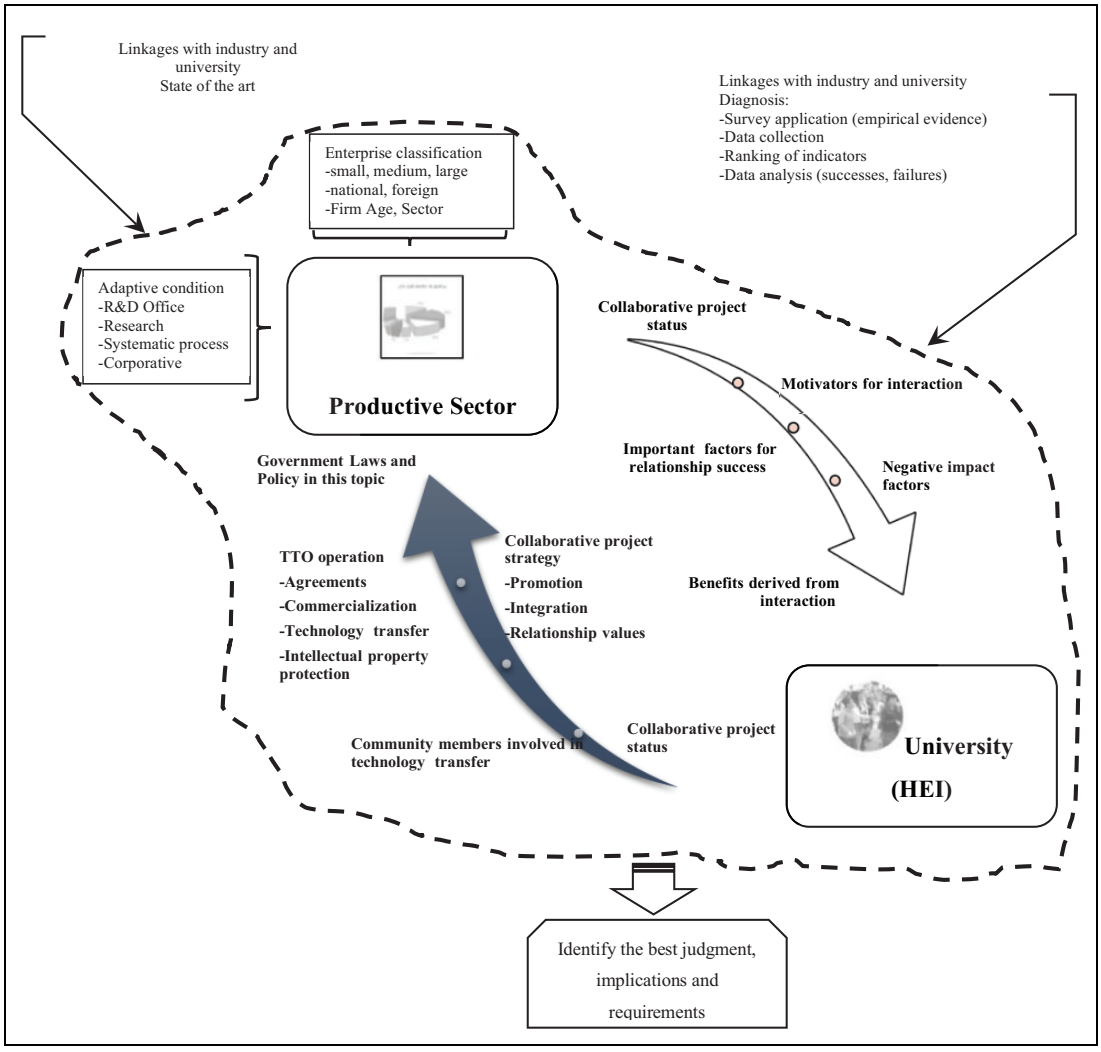

Figure 2. Ciudad Juárez: input–output activities, HEI–PS linkage phase 1, framework. HEI: higher education institution; PS: production sector.

Definition of drivers

The classification of drivers for the definition of the elements to be considered for evaluation in the current relationship between the PS and HEIs is carried out considering the main actors involved: the productive sector, the HEIs, and the clusters.

Productive sector perspective

The three driver classifications in the productive sector (see Table 3) define different activities that are required for a full understanding of the relationship between HEIs and the PS in Ciudad Juárez:

a. *Enterprise classification*: This classification defines the main characteristics of the firm that will be part of this exercise, in terms of the size (small, medium-sized, large), origin (national, foreign), age, and sector (electric, electro domestic, metal mechanics) (Torres et al., 2011).
b. *Adaptive condition* (Galán and Todd, 2019): Defines the level of R&D activity in the firm, the specific level of scientific researchers involved in that activity, the processes defined and used during linkage activities with the HEI on the project development.
c. *Valorization mechanisms* (Galán and Todd, 2019): Defines the current condition of the firm with regard to its collaborative projects, motivators to interact with the HEI to develop technological projects, benefits derived as a result of this interaction, and the factors that should be considered to ensure a successful relationship. It also provides a diagnosis of the factors negatively affecting the relationship.

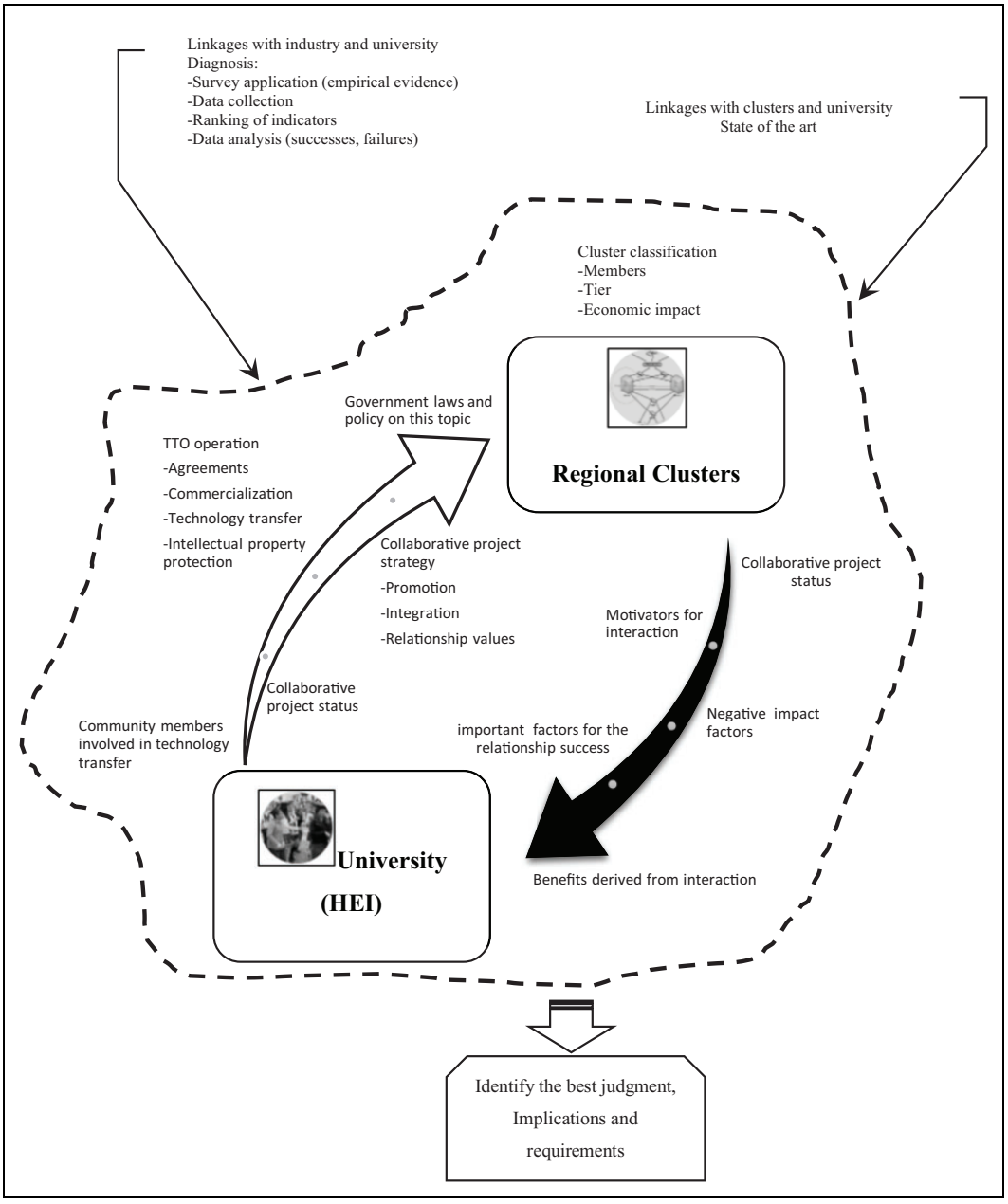

Figure 3. Ciudad Juárez: input–output activities, HEI–cluster linkage phase 2, framework. HEI: higher education institution; PS: production sector.

HEI perspective

The driver classification from the HEI perspective (see Table 4) defines different activities that should be studied to obtain a full understanding of the relationships between HEIs and the PS in Ciudad Juárez:

a. Community members (Galán and Todd, 2019): Here it is important to determine whether the HEI has enough community members with the capabilities and scientific and knowledge skills required to fulfill the expectations of the PS during the development of the linkage project. A combination of researchers, academics, and students is the ideal scenario. Researchers can provide scientific knowledge and experience, and academics/professors can support the project development by providing a collaborative workspace in which they can share their knowledge and practical experience. Students offer their innovative ideas and skills.
b. TTO operation (Berbegal-Mirabent et al., 2015): Then TTO provides an excellent platform to

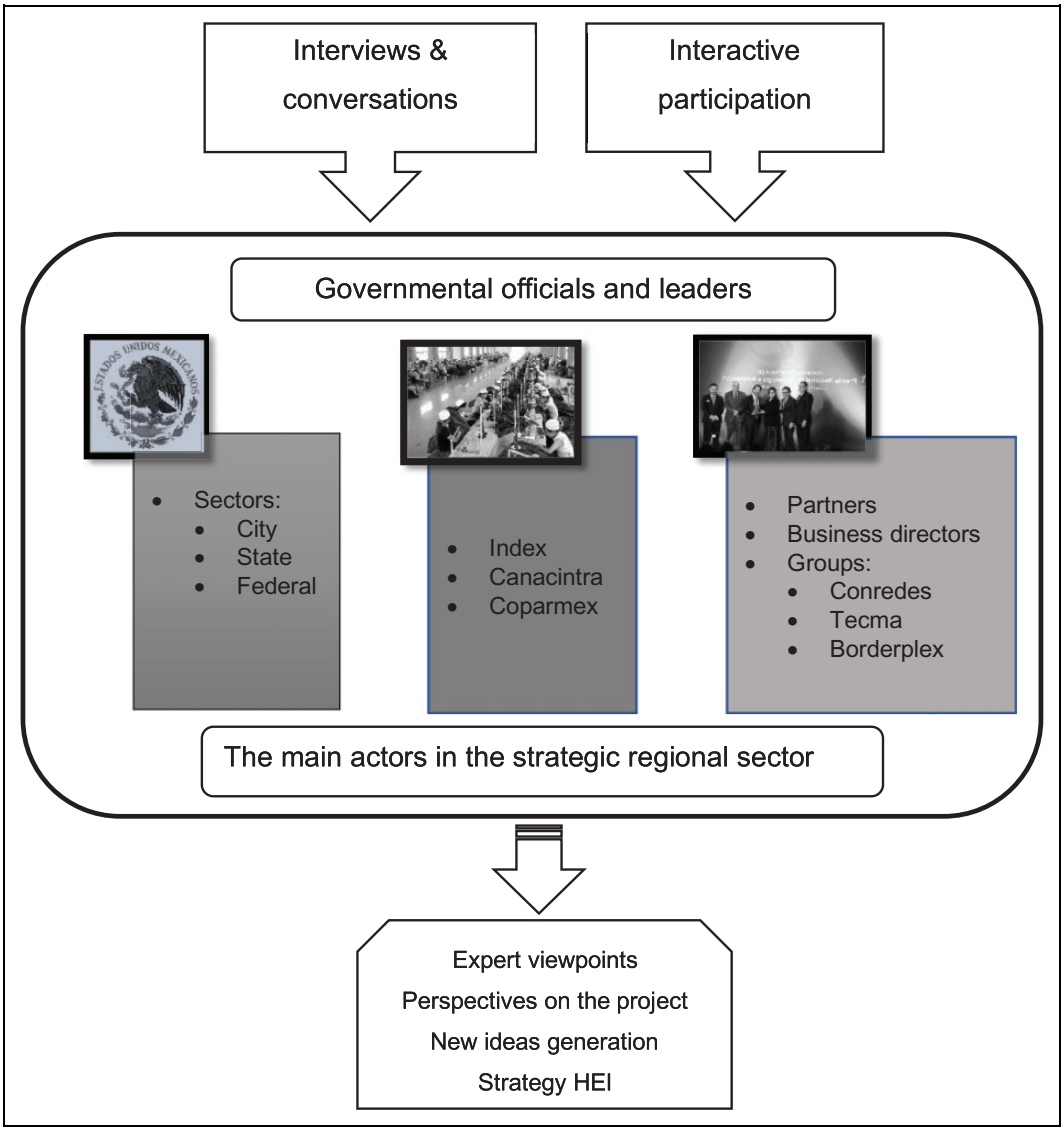

Figure 4. Ciudad Juárez: input–output from experts concerning HEI–PS linkage phase 3, framework. HEI: higher education institution; PS: production sector.

formalize the relationship between the HEI and the PS during the project development. It is important to define the responsibilities of the TTO in the HEI, bearing in mind the credibility and trust that are required for a successful project management process. Technology transfer, intellectual property, and commercialization are also important areas usually defined in the context of the business relationship between the HEI and the firm: these form the basis of the agreements consolidating the collaborative project strategy.

c. Valorization mechanisms (Galán and Todd, 2019): Defines the current condition of the HEI. It is important to identify whether the HEI has a specific methodology and/or a formal process for managing the project. These mechanisms verify the government and policy laws that encourage and help to generate technological projects, the systems, and processes in place that help to formalize project development and collaboration and the promotion system that disseminates information and makes it accessible to others.

Cluster perspective

The driver classification from the cluster perspective (see Table 5) defines the different activities that should be studied to obtain a full understanding of the relationship between HEIs and existing clusters in the region of Ciudad Juárez:

a. *Cluster classification (self-organized)*: Defines the main characteristics of the cluster that will be part

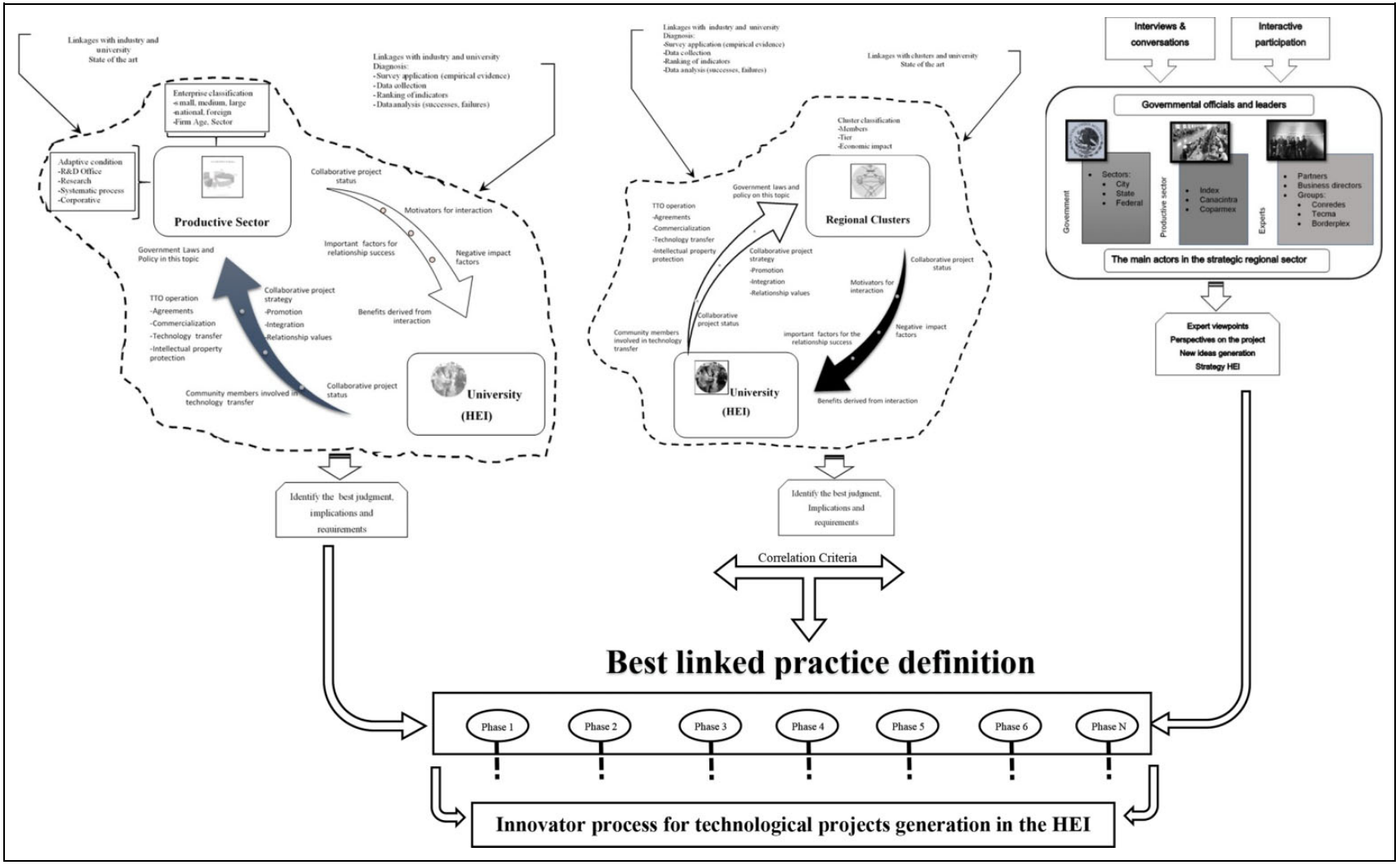

Figure 5. Interrelational ecosystem map for Ciudad Juárez: HEI–PS linkage for technological project generation. HEI: higher education institution; PS: production sector.

Table 3. Classification of drivers: the PS perspective.

Enterprise classification	Adaptive condition	Valorization mechanisms
Small, medium, large	R&D office	Collaborative project status
National, foreign	Researchers	Motivators to interact
Firm age, sector	Systematic process	Benefits derived from interaction
	Corporate	Important factors for relationship success
		Negative impact factors

Note: PS: production sector.

Table 4. Classification of drivers: the HEI perspective.

Community members	TTO operation	Valorization mechanisms
Researchers	Technology transfer	Collaborative project status
Students	Intellectual property	Government and policy laws
Professors	Agreements	Integration
	Commercialization	Promotion
	Collaborative project strategy	Relationship value

Note: HEI: higher education institution; TTO: technology transfer office.

Table 5. Classification of drivers: the cluster perspective.

Cluster classification	Adaptive condition	Valorization mechanisms
Members	R&D office	Collaborative project status
Tier	Researchers	Motivators to interact
Economic impact	Systematic process	Benefits derived from interaction
	Corporate	Important factors for relationship success
		Negative impact factors

of this exercise, as well as its relation to the members' characteristics, the level in the local supplier chain, and the economic and social impact on the region.

b. *Adaptive condition*: According to Galán and Todd, (2019), the adaptive condition defines the level of R&D activities developed within the cluster, the specific number of scientific researchers involved in those activities, and the process defined and used during the linkage activities with the HEI on the project development.

c. *Valorization mechanisms*: Defines the current condition of the cluster in relation to the status of the collaborative project. It defines the existing motivators that trigger the interaction with the HEI to develop technological projects, the benefits derived as a result of this interaction, and the factors that should be considered to ensure a successful relationship (Galán and Todd, 2019).

Interrelations between the actors

Figures 2 to 5 show the main characteristics of the linkage activities. Figure 2 presents the main characteristics required to establish trust in the relationship between HEIs and the PS, Figure 3 the main characteristics required to develop confidence in the relationship between HEIs and regional clusters, and Figure 4 presents the main activities that should be considered to generate feedback by experts and people involved in regional development policies and plans, providing points of view, new ideas, and recommendations on the linking of HEIs with the PS. Finally, Figure 5 is an amalgamation of the former three figures. Their interrelation shapes an ecosystem that is proposed as an alternative to the current scenario of Ciudad Juarez to define the elements that need to be taken into account for a diagnostic evaluation of the region. This diagnostic tool allows us to identify the current prevailing situation with regard to the development of HEI–PS projects in Ciudad Juárez.

Conclusions

The freedom of HEIs to commercialize the results of research should be a trigger that generates more technological projects linked to the PS. Through such commercialization, HEIs can generate additional income which in turn can be reinvested in infrastructure, such as laboratories, classrooms, and equipment, for the benefit of the institutional community. HEIs should also be able to manage intellectual property more effectively; this issue needs general attention in Mexico. Of course, these developments cannot take place unless the administrative representatives in the participating HEIs have the knowledge, skills, and capacity for decision-making that promotes an atmosphere of cordiality and confidence with regard to collaborative activities. In addition, improvements in the educational process should be considered, so that graduates can emerge from their courses with new strengths and abilities to fulfill new roles in the innovation processes of companies.

All the necessary factors in HEI–PS linkages must be considered to avoid the risk of failure and loss of reputation (Pickernell et al., 2009). Representatives of all three sectors (education, productive, and government) must combine their efforts to reach a consensus that promotes the generation of new or reformed public policy (Henton et al., 2002; Kerry and Danson, 2016). These efforts will encourage HEI participation in regional development, allowing them freedom to commercialize knowledge with the companies that

request it. In turn, there will be economic remuneration for students and researchers (Lahikainen et al., 2018). With regard to implications for policy, this study suggests that government representatives should consider improvements in policies relating to strategies and forms of innovation for SMEs in the region of Ciudad Juárez (Pickernell et al., 2009). Policies supporting fiscal incentives might influence entrepreneurs to change their business culture and adopt new competitive strategies – such as investment in technology and knowledge transfer – as well as the development of projects with HEIs. At the same time, internal HEI policies should be revised to establish processes that can potentially eliminate communication barriers and facilitate the transfer of research outcomes into the SMEs of the region.

Future research

One limitation of this study is the adoption of only a qualitative approach. A study of this scale could benefit from a larger quantitative approach. Hence, it is suggested that a structured survey be developed, addressing all actors of the proposed ecosystem in Figure 5. After conducting the survey, a new study would then be needed to analyze the data collected. This would generate information that could be analyzed with statistical tools to identify the factors that stimulate and inhibit the development of technological projects between HEIs and the PS in Ciudad Juárez. The information obtained from the survey could be complemented with new results obtained from workshops, conferences, learning exercises in action, and action plans that would help us to develop recommendations and practical management solutions. The actions that must be taken jointly by the different actors based on these results should lead us to new ways of linking, leading to an increase in successful product and process innovation in companies and enabling the implementation of new strategies that will shift the economy of SMEs in Ciudad Juárez from the tier 1 supply level to the following tiers 2 and 3.

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Note

1. For a complete list of these representing companies, please refer to https://indexJuárez.com/wp-content/uploads/2018/03/Marzo-2018-1-2-2.pdf.

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