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The Role of Human Capital in University-Business Cooperation: The Case of Mexico

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Abstract The interaction between industrial firms and academia has long been extremely weak in Mexico in spite of the manufacturing revival sparked by NAFTA since 1994. This situation is paradoxical given the persistent efforts from the Mexican State to encourage university-industry linkages. Over the years, this uncoupling has produced two effects: on the one hand, university research has followed its own agenda, mainly driven by scientists' interests based on their career tracks, and on the other hand, most firms lack research and development capabilities because they have preferred to seek abroad for technological advice. Because human capital plays a crucial role in this phenomenon, we then focus on answering the following question: to what extent are Mexican industrial firms able to harness university knowledge? Analyses carried out on a survey of 39,336 enterprises, which were collected by the National Institute of Statistics and Geography (INEGI), suggest that larger firms are more capable of absorbing the knowledge generated by universities thanks to their higher level of human capital, whereas smaller firms face harder challenges to harness academic knowledge because of their lack of qualified engineers and technicians that can help them to address their innovative endeavours. The implication of these results for public policy is that collaboration between industry and academia in Mexico can be encouraged by selectively supporting the hire of relatively low-trained engineering graduates and technicians, whereas universities should also be able to promote key programming skills, technical training, infrastructure skills and even sales training and negotiation skills, much earlier in the academic process.

Keywords Mexico · University-industry cooperation · Human capital · Industrial innovation · Absorptive capacity

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Introduction

The economic recovery from the global financial crisis that broke out in 2008 has been unusually weak. Available data and official reports suggest that global economic growth has consistently been slower than that of the average pace during the dozen or so years before the crisis. According to the Organisation for Economic Co-Operation and Development (OECD), the failure to achieve a stronger cyclical upswing has had very real costs in terms of foregone employment, stagnant living standards in advanced economies, less vigorous development in some emerging economies and rising inequality nearly everywhere (OECD 2015a: 7).

The global financial turmoil has also affected the productive relationships around the world. As pointed out by Breznitz and Murphree (2013), the current world production landscape shows that global value chains, based on very complex productive relationships (mainly driven by China), have been eroding the economic and technological lead of developed nations, especially that of the USA. As a result, several governments are facing harder conditions to meet such important targets as limiting global pollution and improving people's welfare.

No wonder industrial innovation is increasingly seen as an engine for effectively achieving long-term economic growth, especially for emerging nations. In the case of Mexico, although the country has managed to become the 15th largest world merchandise exporter, public policies have not yet been sufficiently effective as to promote competitiveness across all sectors of the economy because the prevailing large disparities in income levels drag productivity performance down in many industries (OECD 2015b). Hence, a key issue for this paper is whether public policy would support the development of Mexico's innovation system generally, and, if so, could it address the national requirements for high-skilled human resources as well? In trying to answer these questions, a point to bear in mind is the influence of adverse structural conditions such as the persistently weak absorptive capacities of domestic firms. As the OECD has repeatedly pointed it out through the years, Mexico badly needs to improve its technical capabilities in order for productive firms to be able to absorb state-of-the-art technology for their innovation needs (OECD 1994; 2009; 2013; 2015b).

Clearly, higher education institutions have a role to play in strengthening technological capabilities. As the extant literature on industrial innovation has long remarked, universities are fundamental pillars of the innovation process by forming and training qualified scientists and engineers, who epitomise the very best definition of human capital (Rosenberg and Nelson 1994; Boulton and Lucas 2008; Philpott et al. 2011; National Research Council 2012). However, higher education institutions around the world are facing critical concerns. For instance, as a result of the 2008 economic crisis, a significant number of OECD countries have cut public spending on education (OECD 2014: 66).

United States' public universities have also experienced a continual erosion of state support in the face of increasing demands for expenditures in other areas (National Research Council 2012: 55); although their financial problems are not new. Since the mid-1980s, a deep economic recession forced the U.S. government to re-evaluate its support to basic and applied research because public budget became severely scrutinized (Cohen and Noll 1994). Because many other nations were facing similar fiscal restrictions, they had to follow suit and started to reduce the level of research funds for their universities and national laboratories (Armstrong 1992; OECD 1999; Litan et al. 2007).

It is worth mentioning that continual fiscal restrictions have generally pushed policy makers to re-evaluate governmental support to universities and their contribution to industrial innovation. To put it in other words, limits on public spending, increased competition and globalisation, changes in the drivers of the innovation process and a better understanding of the role played by science and technology in economic performance and societal change have led governments to pay stronger attention to the public universities' missions.

But universities have also been required to improve their administrative efficiency and accountability in response to the demands of different stakeholders like business, industry and labour unions, as well as students and parents (OECD 1999; Connell 2005). In the case of Mexico cyclical economic crises, and their fiscal effects, have not only forced public universities to undertake deep organisational changes in order to raise funds but also to align their traditional missions with the growing academic and professional demands posed by students and industrial firms. In this paper, we argue that Mexican universities are called to play an important role in straightening the technological capabilities of domestic firms amid growing financial and political concerns. Its purpose is, therefore, to examine the antecedents and consequences of policies to promote university-industry partnerships in Mexico, especially in relation with the supply of university graduates in science and technology. In doing so, we identify the type of technological capabilities that define the Mexican industry and what role human capital is playing in this case.

In the following section, we describe what roles universities play in the science and technology system and how these roles have evolved in time.

The Evolving Role of Universities in the Science and Technology System

Higher education has long been recognised as contributing to the social, cultural and intellectual life of society by improving the level of human capital (Hazelkorn 2005). To a large extent, the Western university model has provided an almost universal framework for higher education. The highly interactive social setting and operational freedom of such universities have stimulated a creativity that has made them one of the great entrepreneurial centres of the modern world (Boulton and Lucas 2008: 3–4). In many countries, universities have also become the principal locations for the national research base and have led the way in developing the cross-disciplinary concepts that are increasingly vital for addressing the complex challenges to their societies, and they are key elements in the science system as well (OECD 1999). By performing research and training scientists and other skilled personnel, they contribute to the enhancement of industrial competitiveness (Warner 1994; D'Este and Patel 2007).

Yet, significant changes in the university environment have affected their research-related missions. In particular, universities are becoming more diverse in structure and more oriented towards economic and industrial needs, while coping with higher student enrolments (Trencher et al. 2014), but these trends have also raised serious questions about how to ensure that universities can continue to make their unique contribution to long-term basic research and maintain an appropriate balance among research, training and knowledge transfer (Schofield 2013).

It is worth noting that universities have faced a number of challenges since the mid-1980s. According to several sources, some of the most important are (1) the changing nature of government funding, (2) increasing industry research and development (R&D) finance, (3) growing demand for economic relevance, (4) increasing systemic linkages, (5) growing research personnel concerns, (6) internationalisation of university research and (7) changing institutional roles as universities are entering into joint ventures and co-operative research with industry (Armstrong 1992; Etzkowitz 1998; OECD 1999; Poyago-Theotoky et al. 2002; Connell 2005; Litan et al. 2007; Trencher et al. 2014).

Government funding for academic research has became increasingly contract-based, especially in the USA. As a consequence, universities have been required to pay closer attention to output and performance criteria, which, in turn, have led academic researchers to privilege short-term, market-oriented research over long-term, basic research, as Rafferty (2008) has discovered. In addition, private industry is funding an increasing share of academic research (Litan et al. 2007), and this support, in the form of joint projects, contract research and financing of researchers, is also pushing universities to perform research more directed to potential commercial applications (Etzkowitz 1998; Philpott et al. 2011).

The sum of these events evolved into the so-called “third mission” in which universities, apart from their responsibilities to teach and research, were also asked to apply academic knowledge into commercial uses (Etzkowitz 1998; Etzkowitz et al. 2000; Trencher et al. 2014). The third mission paved the way to the creation of the “entrepreneurial university,” an organisational model that can be best understood by looking at universities such as MIT and Stanford, where the identification, application and commercialisation of intellectual property have become institutional objectives (Etzkowitz et al. 2000).

The origins of the entrepreneurial university can be traced back to the end of the Cold War, when the erosion of the credibility of national security as a rationale for public support of universities led to a rethinking of old missions (Rosenberg and Nelson 1994: 338). To many authors, the enactment of the Bayh-Dole Act on December 12 1980 marks the beginning of the institutional transformation of the United States research system because it uniformed the U.S. patent policy across all federal agencies, removing restrictions on licensing and allowing American universities to own patents arising from federal research grants (Shane 2004; Litan et al. 2007; Rafferty 2008). Given the growing financial rewards that almost immediately many U.S. research organisations began to receive from their intellectual property, a number of countries started to enact similar laws.[1]

[1] According to the Association of University Technology Managers (AUTM), the countries with similar Bayh-Dole legislation are Brazil, China, Denmark, Finland, Germany, Italy, Japan, Malaysia, Norway, Philippines, Russia, Singapore, South Africa, South Korea and the UK (data retrieved from http://www.autm.net/Bayh_Dole_Act1.htm [accessed on January 2, 2015]).

The transition towards the entrepreneurial university has not been frictionless, though. Requests for closer links between academy and industry have somehow provoked an intense debate about whether universities should lessen their traditional roles in teaching and research in order to commit their abilities to the third mission (Etzkowitz and Leydesdorff 2000; Etzkowitz et al. 2000; Garrett-Jones and Turpin 2012; Schofield 2013; Trencher et al. 2014).

The institutional efforts required to actively converting academic science into business opportunities have put additional pressure on universities' missions in several instances. Firstly, the shift towards the commercialisation of knowledge has clashed with the traditional disciplinary organisation of research. That is, laboratory's culture of meticulous and lengthy revisions of scientific results has clashed with businesses' urgency for economic profits. In this respect, Philpott and colleagues (2014) report that the underlying complexities of developing a unified entrepreneurial character may produce an increasing schizophrenic divide between disciplines, causing widespread disharmony amongst the academic community. They conclude that a strong top-down push towards the ideal of the entrepreneurial university would actually reduce overall entrepreneurial activity across the university. Secondly, demographic factors such as an ageing scientific workforce and declining interest in some fields of science on the part of younger students may affect the future development of potential scientific discoveries (OECD 1999; National Research Council 2012). Thirdly, the increasing globalisation of manufacturing and services has displaced traditional locations for conducting research towards emergent cities, mainly in Southeast Asia. In this regard, a wide array of universities, by harnessing the potential of information and communication technologies, have encouraged the formation of international academic links, contributing to the export of education and the increase in global research collaboration networks (Garrett-Jones and Turpin 2012; Paleari et al. 2015).

The implications of the entrepreneurial university paradigm for industry and government have been explained by the so-called "Triple Helix Model," which states that the university can play an enhanced role in innovation in increasingly knowledge-based societies. According to their proponents, Etzkowitz and Leydesdorff (2000), the model tries to capture the dynamics of both communication and organization by introducing the notion of an overlay of exchange relations that feeds back on the institutional arrangements. Although this conceptual framework helps us to understand how universities' missions need now to be aware of businesses' demands, the dynamic forces stemming from global competition can nonetheless alter much of their intended plans and goals (Connell 2005; Garrett-Jones and Turpin 2012). Besides, the increasing complexity of social interests has also pushed for a more comprehensive reform of universities' missions. For example, because of global warming, a growing portion of the society is very well aware of climate deterioration, and thus, claiming for the pursuit of environmental-friendly innovations. Hence, universities are also being called to embrace responsible research and innovation initiatives (Carayannis and Campbell 2010; Trencher et al. 2014).

Finally, due to the incessant waves of innovations in the information and technology sector, productive firms are increasingly recurring to novel practices and new tools in order to cope with these challenges, so universities have also been required to consider appropriate options to keep abreast of this dynamism as, for example, in embracing the upward innovation collaborative model in any of its different variations: product development by lead users (von Hippel 2006); the open innovation approach (Chesbrough and Brunswicker 2014) or the crowdsourced innovative solutions (Boudreau and Lakhani 2013). In view of these trends, the following section deals with the determinants of university-industry interactions, and what roles play both parts in the context of national systems of innovation with a special emphasis in the case of Mexico.

The Linkage University-Industry

As mentioned above, universities' primary mission has been to carry out research and disseminate knowledge by providing highly educated and qualified scientists and engineers to industry (OECD 1999); yet, an influential stream of thinking has argued that universities, in the pursuit of the so-called third mission, convey the highly important responsibility of encouraging research collaborations with industrial firms (Etzkowitz et al. 2000; Carayannis and Campbell 2010; Trencher et al. 2014). Opinions favouring university-industry links consider that closer collaboration contributes positively to the solution of innovation market failures by helping to realise the full social returns of R&D investments (Shane 2004; D'Este and Patel 2007), but the nature of this relationship is nonetheless complex. To begin with, the divergence between firms' objectives and universities' missions tends to hamper effective interchanges. This divergence stems from the different focus on knowledge's usefulness that each party has. For enterprises, knowledge must be susceptible of commercial exploitation, whereas academia sees knowledge as a moving target that requires a methodical dedication to grasp it, with more setbacks than gains (Merritt 2014).

As sketched above, the contrasting expectations of both parties define the collaborative trajectory, with industry playing the anxious role and university the parsimonious one. It is hardly surprising, therefore, that trust tends to determine the success of the partnership, as Tatiana Schofield (2013) has pointed it out. According to her, there are three broad elements affecting potential collaboration between academia and industry: internal, external and relational/cultural factors. Internal factors stem from organisational processes that can be partly controlled. External factors relate to market conditions, political, economic and legal risks, which can be mitigated though due diligence. Relational and cultural factors can ultimately enhance or inhibit success and are critical for creating viable collaborations. Schofield also observes that university-industry collaboration in developing countries faces additional hurdles such as market instability, weak knowledge absorption capacity, unsatisfactory local education, lack of technological capabilities and wide variations in cultural values. She still finds that cultural empathy and trust are key conditions for successful linkages (Schofield 2013: 52). Figure 1 depicts how complex the university-industry interrelation can be.

According to Fig. 1 above, universities' core competence is in conducting basic and applied research, while businesses are stronger at exploiting useful knowledge through market commercialisation. Therefore, mutually beneficial relationships should focus on encouraging knowledge interchange. That is, the flux must go from knowledge creation to knowledge application and from business opportunities to research endeavours. It is worth noting that this representation does not intend to describe all phenomena involved in the relationship but to simply highlight the rate and direction of the fluxes.

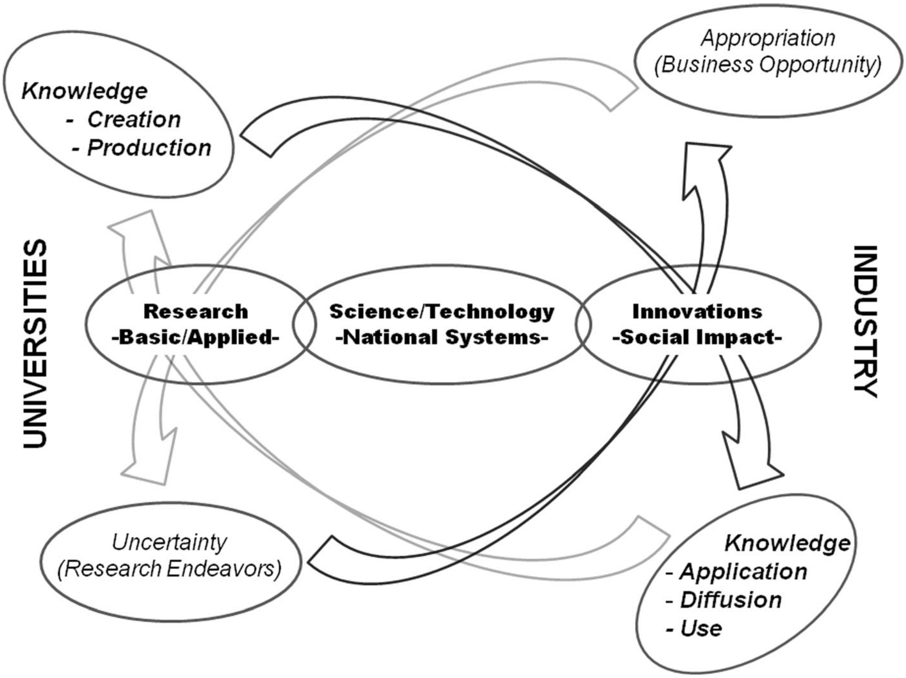

Fig. 1 Contrasting goals in university-industry collaboration

Yet, interrelationships may materialise in one of the following outcomes: (1) technology transfer, (2) academic patenting, (3) royalty income and/or (4) industrial sponsorship of academic research (Etzkowitz et al. 2000).

Furthermore, the collaboration tends to follow an iterative pattern where universities generate new knowledge, enterprises absorb it, transform it and seek to make profits of it and universities get the feedback. In this framework, the transmission is clearly not lineal because recipients must dominate the transferred knowledge before market opportunities can be materialised. Figure 2 depicts how this process is realised until the innovation reaches the market.

Figure 2, above, introduces government as a third player into the scheme. Its role is to facilitate the transmission of the knowledge flux. It is a functional way of describing the Triple Helix model. This scheme attempts to simplify the dynamics of the interplay by introducing the notion of a juxtaposition of exchange relations that feeds back on the institutional arrangements. According to Etzkowitz and Leydesdorff (2000), the institutions and their relations provide a knowledge infrastructure that supports the knowledge base. Then, each of the helices develops internally but they also interact in terms of exchanges of both goods and services, and in terms of their functions. As pointed out by Etzkowitz et al. (2000), and also suggested in Fig. 2, functional and institutional roles can be traded off on the basis of knowledge-based expectations that each agent has, as in the case of the entrepreneurial university.

We should bear in mind, however, that universities should not disregard their key role in the supply of qualified human capital, especially in the context of growing

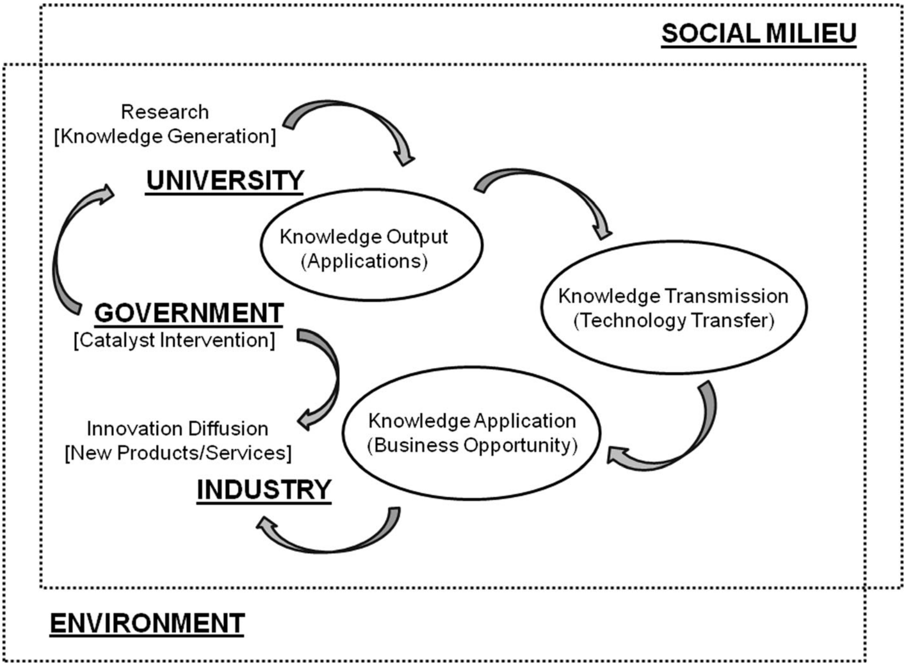

Fig. 2 The knowledge transmission in the university-industry relationship

concerns on the part of industrialists of the perceived shortages of skilled labour to fill actual positions.[2]

The supply of qualified human capital is crucial for enterprises to generate and successfully commercialise innovations. This is because firms must synthesise a wide variety of expertise and knowledge produced by different complementary sources. For example, firms learn from internal sources of knowledge, such as R&D activity, as well as from a wide variety of external sources such as higher education institutions, government laboratories and agencies, competitors, suppliers and customers (Santiago and Alcorta 2012). Therefore, firms' collaboration with external organisations expands their range of expertise, helping them to support the development of new products (Schultz 2012; OECD 2013). However, in order to successfully absorb new knowledge, firms must master the capabilities required to search, find, access and interpret for their own use, information embodied in external organisations (Muscio 2007).

Although absorptive capacity is an important issue for successful university-industry links, not all nations show the same priority to include it in their policy agenda. In the case of Mexico, preference has been given to the strengthening of the legal framework that protects intellectual property (see, e.g. OECD 2009, p. 86). This does not mean that protecting intellectual creation is irrelevant but certainly it is not a sufficient condition to trigger industrial innovation, as the case of China shows (Breznitz and Murphree 2013).

[2] See, for example, the letter from Simon Hill to the Financial Times editor on May 20, 2015, titled "Reports on poor productivity ignore shortages for skilled roles," available at http://on.ft.com/1GXBea0 [accessed on 18 June 2015].

We then shall proceed to assess the role of human capital in the case of Mexico. The following section reports the methodology of this paper.

Method and Data

The article mainly draws on the National Survey on Research and Technological Development, which was carried out in mid-2010 by the National Institute of Statistics and Geography of Mexico (INEGI 2013). The survey's sample size was 39,336 Mexican enterprises randomly chosen from the manufacturing and service sectors across the country. By request of the National Council for Science and Technology (CONACYT), INEGI included 1000 firms known by conducting research and development within their premises. Firms were classified under the United Nations' ISIC system (revision 3.1). INEGI asked firms to answer the questionnaire for years 2008 and 2009 only. Table 1 shows the number of firms surveyed by sector and their size (measured through the number of employees) for 2009.

Because this paper is primarily based on the results concerning the stock of scientists and engineers involved in industrial innovation, the empirical evidence presented here is based on the use of levels of education attainment as proxies for absorptive capacity. The paper's analyses are reported in the following sections.

Science and Technology Education in Mexico

Mexico has one of the largest and most complex education systems in Latin America, composed of federal and state education institutions, decentralised organisations, private education institutions and a number of public universities. The system provides education at three levels: basic education, upper-secondary education and tertiary (higher) education (Bradley 2010). As regards the education structure, Mexico has four main types of educational institutions: federal public, state public, autonomous public, and private. Private institutions must be officially accredited by the Secretariat of Public Education (SEP), by the corresponding state government or through accreditation by the National Autonomous University of Mexico (UNAM) or the National Polytechnic Institute (IPN), if the offered education cover the tertiary level (OECD 1994).

Table 1 ESIDET's summary of firms and total staff, 2009

Sector	Number of firms (Total) A	Employees (Total) B	Average staff size (B/A)
Manufacturing	16,961	2,936,999	173.2
Services	21,692	2,692,829	124.1
Other activities	683	5,865,772	8,588.2
Totals	39,636	11,495,600	292.2

Source: INEGI, National Survey on Industrial Research and Technological Development (INEGI 2013: 23), available at the URL: http://bit.ly/1JkWGbR [accessed 16 June 2015]

Mexico's higher education was established and consolidated during the post-revolution era. The most important public and private universities, such as UNAM, IPN, the Technological Institute of Higher Studies of Monterrey (ITESM), the Metropolitan Autonomous University (UAM), and various state universities were established between 1930 and 1980. The number of universities grew from 26 to 84 from 1950 to 1980 due to the demographic explosion of the 1970s. The latter part of the twentieth century saw an unprecedented expansion in the higher education level in terms of the number and variety of institutions, students, faculty and research. In 2005, Mexico had 2807 universities, of which 40 % were public and 60 % were private, located all over the country. While fewer in number, in 2006, public universities attracted nearly 68 % of undergraduates and 58 % of postgraduate students. The proportion of students attending private universities is on the rise, however. Private enrolment increased from 18.5 % of the undergraduate total in 1990 to 32 % in 2006 (OECD 2009: 139). Yet, Mexico's overall rate of tertiary educational attainment is far below OECD averages. The country also has the highest disparities in tertiary education rates among OECD countries (OECD 2014).

The need for far-reaching reforms in Mexico is more obvious in view of the poor competitive edge of the whole education system. This situation is best explained by the low ranking that Mexican universities hold in the "Times Higher Education BRICS and Emerging Economies Rankings 2014." According to this widely acknowledged international classification, the best ranked universities are the (public) National Autonomous University of Mexico (UNAM) and the (private) Monterrey Technological and Higher Studies Institute (ITESM) in 59th and 99th place, respectively.[3]

In order to have a better perspective of the Mexican education system, Table 2 shows the number of older people with, at least, tertiary education. As these figures show, the proportion of Mexican citizens aged 15 years and older with higher education has been growing over the years. These figures also suggest, however, that industrial firms may be facing a limited pool of skilled human capital when choosing to hire specialised employees. That is, only a sixth of the Mexican adults have, apparently, a competent level of education attainment as to be able to understand, analyse and solve more sophisticated working conditions.

By following the concept of human capital as "the knowledge that individuals acquire during their life and use to produce goods services or ideas in market or non-market circumstances," proposed by Miller (1996: 22), we were able to peruse in more detailed data to find out that the availability in Mexico of qualified human resources is indeed limited. Take, for example, the cumulated stock of graduate and postgraduate students from 2001 to 2013 in the six different fields of knowledge that CONACYT uses to classify the education expertise: agricultural sciences, natural and exact sciences, health sciences, engineering and technology, social and administrative sciences and education and humanities. According to the figures released by CONACYT (2013) for the 12-year period, graduates from the social and administrative sciences with a bachelor's degree add up to more than 50 % of the total, whereas

[3] The Times Higher Education BRICS and emerging economies rankings 2014 are available at the following URL: http://www.timeshighereducation.co.uk/world-university-rankings/2014/brics-and-emerging-economies [accessed on 18 June 2015].

Table 2 Population of older tertiary-educated Mexican adults (totals and percentage)

Year	Total population aged 15 and older	Population with tertiary education	(As % total)
2000	62,842,638	6,849,848	10.9
2005	68,802,564	9,357,149	13.6
2010	78,423,336	12,939,850	16.5

Source: INEGI, Population and Housing Census 2000, 2005 and 2010. Data available at the URL: http://www3.inegi.org.mx/sistemas/sisept/Default.aspx?t=medu10&s=est&c=26365 [accessed 16 June 2015]

graduates from the natural and exact sciences account for by only 4 %; these proportions vary, however, when we look at postgraduate degrees. In the case of the natural and exact sciences, its share grows more than proportionally as the education attainment rises. Yet, graduates from the social and administrative sciences are still in the majority but what is even more important, the bulk of doctoral postgraduates go for soft sciences such as economics, administration, education and humanities, which all together account for by almost 60 % of the category. These proportions can be better understood by looking at figures on Table 3, next.

After briefly inspecting the situation of human capital in Mexico, we shall proceed to analyse how the existing human capital stock determines the interrelation between industry and academy. The following section discuses this phenomenon by harnessing the main findings of INEGI's research and technological development survey (INEGI 2013).

As pointed out by Hazelkorn (2005), while many universities worldwide have increasingly adopted managerial approaches to cope with the growing technical demands from industry, several developing nations are still reluctant to reform higher education institutions due to vested interests and organisational inertia. According to Connell (2005), there exists an underlying tension between the collegial and the managerial approaches to decision-taking in most universities, and these tensions tend to grow as universities establish closer linkages with external organisations, including business and industry. In the case of Mexican universities, they are in fact facing growing demands for accountability. Not surprisingly, many of them have recognised

Table 3 Cumulated total graduates from bachelor, master and doctoral programmes by field of knowledge in Mexico, 2001–2013 (totals and percentage)

Field of knowledge	Bachelor's degree	As % of total	Master's degree	As % of total	Doctoral degree	As % of total
Agricultural sciences	84,568	2.0	8653	1.8	2020	5.1
Natural and exact sciences	139,810	3.4	18,923	4.0	6854	17.4
Health sciences	384,328	9.3	17,472	3.7	2215	5.6
Engineering and technology	1,114,691	27.0	51,636	10.8	5144	13.0
Social and administrative sciences	2,098,244	50.9	248,658	52.1	11,842	30.0
Education and humanities	304,155	7.4	132,333	27.7	11,351	28.8
Total	4,125,796	100	477,675	100	39,426	100

Source: Author's elaboration based on CONACYT 2013, pp. 220–223 that radical changes can be unavoidable, so resolving the tension between the pursuit of financial autonomy and academic freedom remains a continuing challenge for their institutional settings (Merritt 2014).

University-Industry Co-operation in Mexico

Research linkages are important for the development and diffusion of innovations. The innovative activities of a firm partly depend on the variety and structure of its links to sources of information, knowledge, technologies, practices and human and financial resources. Many firms are prone to establish links to other actors in the innovation system: government laboratories, universities, policy departments, regulators, competitors, suppliers and customers (see, e.g. D'Este and Patel 2007; Schultz 2012; Schofield 2013). According to the OECD, three types of external linkages can be identified: (1) Open information sources provide openly available information that does not require the purchase of technology or intellectual property rights, or interaction with the source. (2) Acquisition of knowledge and technology results from purchases of external knowledge and capital goods (machinery, equipment and software) and services embodied with new knowledge or technology that do not involve interaction with the source. (3) Innovation co-operation requires active co-operation with other firms or public research institutions on innovation activities (and may include purchases of knowledge and technology) (OECD 2005: 20).

In Mexico, university-industry linkages are rare. In some way, this situation is paradoxical given the continuing government's support for strengthening professional bonds between businesses and the public research sector (i.e., academy), as in the case of the 2008 Act that Mexico's congress approved in order to encourage publicly-funded technology research centres to seek for public-private partnerships (OECD 2009: 137). It is worth mentioning that international financial agencies, such as the World Bank, have repeatedly suggested that stronger technological linkages between private-sector firms and public research organisations can best be achieved through forcing public organisations to seek external sources for greater revenues by cutting public funding.[4]

It may well be the case that international agencies were seeking to induce tough budget restrictions for the public research sector in order to keep at bay fiscal deficits; yet, we are more inclined to think that the problem lies elsewhere. Although Mexico is a middle-income country with an emerging economy that is closely intertwined with the much larger market of the USA, its economic performance has been very inconsistent in the last 30 years. For example, in the early 1990s, the nation underwent various far-reaching market-oriented structural reforms, including the privatisation of hundreds of state-owned enterprises, the liberalisation of foreign investment laws, the deregulation of the financial services sector and across-the-board reductions in tariffs and non-tariff trade barriers. Most of these reforms culminated in the ratification of the North

[4] See the World Bank's May 22, 1998 report titled "Project appraisal document on a proposed loan in the amount of us $300 million to Mexico for a knowledge and innovation project," especially at page 25. The report is available at the URL: http://bit.ly/1MVzzlE [accessed on 18 June 2015].

American Free Trade Agreement (NAFTA) in 1994, which attracted an influx of US $148 billion in foreign direct investment; yet, a big economic crisis burst in 1995 (Bradley 2010). After that, the country underwent great fiscal restrictions that hampered growth recovery and job creation. Due to the stagnant economy, firms have been reluctant to commit financial resources to long-term investments, in particular in technology and research (OECD 2013: 11).

This situation has produced a large human capital deficit, which manifests itself in a burgeoning informal sector where low wages and low productivity prevails. No wonder income distribution remains highly unequal, with about half of Mexico's population living in poverty (OECD 2015a).

Interestingly, Mexico's export model has heavily relied on cheap labour, which has created a vicious cycle for exporting firms because cheap labour translates into low-skilled labour, which, in turn, is of little help when competition lies more on innovation capabilities than on low prices. Hence, highly qualified staff is small in many specialised activities, including university research (Merritt 2014).

In order to have a grasp of the size of problem, Fig. 3 shows how Mexico compared in 2011 with other OECD countries in terms of total researchers in full-time equivalent per thousand total employment, an indicator that it is usually used for measuring technological capabilities (OECD 2005). For Mexico, the proportion was only one person for every thousand employees, which has put it in the lowest position in the OECD ranking.

It is noteworthy that full-time researchers help to gauge a country's R&D potential. Therefore, figures shown in Fig. 3, above, can serve as a proxy for measuring the size of human capital in Mexico. So, according to these data, there is an evident lack of skilled personnel devoted to conducting research in Mexico, and the gap is

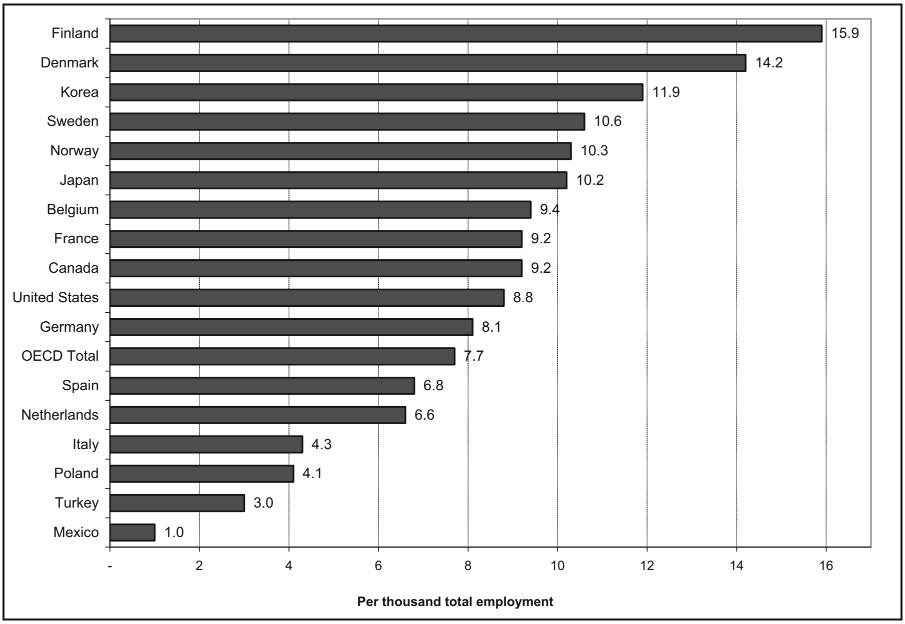

Fig. 3 Total researchers in full-time equivalent in selected OECD countries, 2011

considerably large if one takes into account what the figures are for the rest of OECD members (7.7 in average), with the Nordic countries and South Korea at the top.

Sadly, the biggest problem for Mexico is that the supply of researchers is likely to remain limited in the coming years because young students seem not be as strongly interested in science and technology as it needs to be because PhD graduates in the so-called STEM fields (science, technology, engineering and mathematics), as a proportion of the total population, remains too low (OECD 2015b). Moreover, postgraduate students enrolled in STEM fields have been overtaken by those enrolled in social sciences and humanities. As Fig. 4, below, shows, in the last 5 years, the rate of PhD graduates from the education and humanities fields has had an astonishing growth and currently becoming the second most important field of knowledge for researchers in Mexico.

Based on these figures, it is fair to say that Mexico's higher education policy badly needs to engage with industrial firms in order to encourage the formation of qualified human resources. Although universities play a crucial role in supporting productive clusters and innovation systems in many OECD nations, in Mexico, this "third mission" of entrepreneurial engagement is underdeveloped, at least from the human resources perspective. While the Secretariat of Public Education does not explicitly use policy to promote engagement, other federal actors, such as CONACYT and, to a lesser extent, the Ministry of Economy through the small- and medium-sized enterprises fund, do offer incentives. According to the OECD (1994; 2009; 2013), Mexico must increase the industrial engagement of its universities. This can be done by adjusting its higher education policy to support cluster-based approaches with a focus on specialised training and research. The following section analyses INEGI's survey results regarding the structure of qualified human resources in Mexican firms.

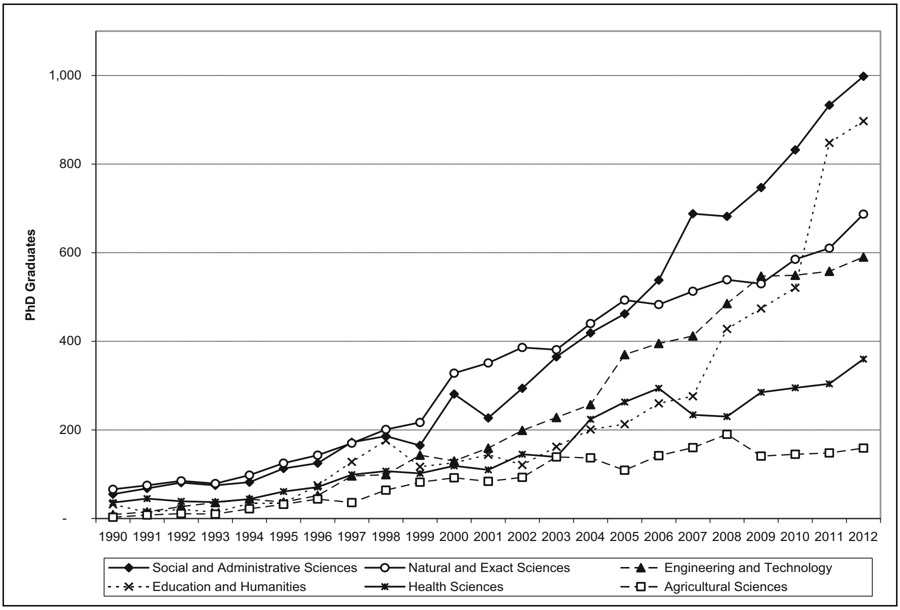

Fig. 4 PhD graduates in Mexico by field of knowledge, 1990–2012

Results of Survey Analysis

The evolution of the human capital formation in Mexico has two main effects on the shape and strength of the industry-academy link. Firstly, the innovation-absorption capacity of industrial firms is vital to raise productivity. And, as pointed out by Muscio (2007), absorptive capacity is largely determined by the quality and quantity of human resources. In Mexico, micro, small- and medium-sized enterprises (MSMEs) account for over 95 % of the nation's industrial sector. However, Mexican MSMEs have traditionally been poorly staffed, especially in relation to R&D personnel (OECD 1994; 2009; 2013). Secondly, collaborative research is a two-sided phenomenon. It obliges parties to manage a functional knowledge, which is, in turn, determined by the degree of technical sophistication of the industrial sector involved. So, the more sophisticated the industry is, the more complex the collaboration turns out to be. Pharmaceuticals, telecommunications, automotives and aerospace are among the most sophisticated sectors in Mexico. Unfortunately, only a handful of national firms are capable of mastering such an intricate knowledge. As a result, effective collaborations are rare in Mexico (Merritt 2014).

The main barrier for establishing collaborative links between industry and academy is the lack of incentives for many firms to recruit highly qualified human resources. As mentioned above, incessant economic crises and mediocre recoveries have produced a stagnant market milieu for the larger part of the economy. As a consequence, Mexican businesses are more interested in cost-cutting, short-term actions than in long-term technology intensive investments, especially in relation to hiring scientists and engineers to conduct research.

In this respect, analyses from INEGI's survey on research and technological development (INEGI 2013) show that the effects of the persistently weak economic milieu are clearly visible on the composition of the human capital in the productive sector.

INEGI surveyed 39,335 firms and asked them to answer R&D-related questions. Table 4, next, shows the sample's composition by type of sectoral activity (i.e. manufacturing, services and other activities), and if they invest financial resources to conduct research-related activities either in 2008 or 2009.

As figures from Table 4 show, less than 10 % of the firms surveyed by INEGI actually spent money in research-related activities. The high proportion of firms in the research and development sector (it includes consultancy firms and private labs), which declared to have spent resources to that activity is not surprising but the interesting case is the basic metals sector, whose firms were actually more active in R&D-related activities that the other sectors, including computers and machinery and equipment. Table 4 also allows us to detect that most sectors increased their expenditures from 2008 to the year after, except for basic metals and communications.

We now shall analyse the case for human capital in the survey. Table 5 displays the relevant information for 2009.

As Table 5 shows, by perusing INEGI's data, we can see that 39,635 persons can be classified as full-time science and technology personal, which somehow represents the size of human capital in the Mexican industry and, from that figure, only 40.8 % were identified as full-time researchers (16,181). By any standard, these numbers are clearly very low. According to Table 1 (above), INEGI reported that surveyed firms employed

Table 4 Number of firms surveyed by sector and percentage of firms spending in R&D, 2008–2009

Sector	Number of firms	Did your firm spend in R&D?				
		Yes, in 2008	(As % of sector's total)	Yes, in 2009	(As % of sector's total)	Variation 2008/2009
Food, beverages and tobacco	2470	263	10.6	374	15.1	4.5
Textiles, leather, shoes	3821	78	2.0	120	3.1	1.1
wood products, paper, printing and publishing	1761	20	1.1	38	2.2	1.0
Coal, oil, chemicals and plastics	3368	512	15.2	614	18.2	3.0
Non-metallic mineral products	691	48	6.9	49	7.1	0.1
Basic metal industries	257	47	18.3	46	17.9	−0.4
Metallic products (not equipment)	1637	172	10.5	173	10.6	0.1
Machinery and equipment	2381	367	15.4	396	16.6	1.2
Furniture and other industries	577	82	14.2	81	14.0	−0.2
Communications	495	21	4.2	20	4.0	−0.2
Financial services	1,530	90	5.9	91	5.9	0.1
Real state services	285	0.0	0.0	0.0.	0.0	0.0
Computers and related services	1088	180	16.5	190	17.5	0.9
Research and development	94	86	91.5	88	93.6	2.1
Social, personal and communal services	7294	795	10.9	1040	14.3	3.4
Other services	10,903	2	0.0	3	0.0	0.0
Other economic activities	683	38	5.6	43	6.3	0.7
Totals	39,335	2801	7.1	3366	8.6	1.4

Source: INEGI, National Survey on Industrial Research and Technological Development (INEGI 2013: 33), available at the URL: http://bit.ly/1JkWGbR [accessed 16 June 2015]

Table 5 Qualified staff in manufacturing and services in Mexico, 2009

Sector	Total staff	R&D personnel	(as % of total staff)	Technicians	(as % of total staff)	Administrative staff	(As % of total staff)
Manufacturing	25,129	9144	36.4	11,258	66.0	4731	74.1
Services	14,043	6792	48.4	5659	33.2	1593	24.9
Other activities	462	248	53.7	152	32.9	63	13.6
Totals	39,635	16,181	40.8	17,068	43.1	6386	16.1

Source: Author's elaboration based on INEGI, National Survey on Industrial Research and Technological Development (INEGI 2013: 68), available at the URL: http://bit.ly/1JkWGbR [accessed 16 June 2015] almost 11 and a half million people in 2009 (INEGI 2013: 23), which is less than 0.14 % of total employment.

Nonetheless, the service sector seems to have a larger proportion of R&D personnel than that of manufacturing, although neither of them reaches the 50 % mark, only the third sector (other services) does. The reason is that INEGI included the public utilities in that sector, which are some of the largest enterprises in Mexico, like PEMEX (the oil firm) and CFE (the national electricity company).

In any case, it is important to bear in mind that firms collaborating with external organisations tend to have higher numbers of R&D employees and higher numbers of graduates. They are also more likely to be committed to continuous training (Muscio 2007).

Therefore, the service sector might be closer to establish a collaborative relationship with universities, although a more detailed examination is needed. Table 6 shows the disaggregated figures of the previous table but only for the R&D personnel. From Table 6, it is now possible to identify which the most R&D intense industrial sectors in Mexico are.

Table 6 shows the huge differences that exist among Mexican firms in relation to their technological capabilities, as measured by the intensity of their R&D personnel. As expected, machinery and equipment have the largest mass of R&D employees, although its intensity is lower than that of the whole country (35.1 % vs. 40.8 %), whereas the financial sector exhibits the greater intensity (95.9 %), with almost everyone allegedly dedicated to perform research activities but researchers in the

Table 6 R&D personnel in manufacturing and services in Mexico, 2009 (ordered by R&D personnel)

Sector	Total staff	R&D personnel	(As % of total staff)
Machinery and equipment	11,882	4167	35.1
Social, personal and communal services	8424	3612	42.9
Coal, oil, chemicals and plastics	5153	2545	49.4
Computers and related services	2992	1833	61.3
Food, beverages and tobacco	2406	962	40.0
Metallic products (not equipment)	2913	864	29.7
Financial services	764	733	95.9
Research and development	1802	583	32.4
Textiles, leather, shoes	1210	278	23.0
Other economic activities	462	248	53.7
Basic metal industries	399	129	32.3
Non-metallic mineral products	533	94	17.6
Furniture and other industries	421	58	13.8
Wood products, paper, printing and publishing	203	42	20.7
Communications	61	31	50.8
Transport and storage	9	5	55.6
Total	39,634	16,184	40.8

Source: Author's elaboration based on INEGI, National Survey on Industrial Research and Technological Development (INEGI 2013: 68), available at the URL: http://bit.ly/1JkWGbR [accessed 16 June 2015] research and development sector only account for by 32.4% of total staff. On the other hand, furniture and other industries exhibit the lowest proportion of R&D personnel, which highlights the very low R&D intensity of this activity in Mexico.

According to these figures, very few sectors seem to be good candidates to establish fruitful collaborative linkages with the academy because of its high proportion of R&D staff, among these are the computer industry and the communications sector. In this regard, incipient contacts have already begun to happen in terms of universities now becoming aware of stronger specialisation in computer-oriented careers as well as tailor-made staff training (OECD 2013).

With regard to governmental initiatives to support public-private interaction in R&D, in 2012 CONACYT spent almost 1,950 million Mexican pesos (around 160 million U.S. dollars) to support 522 collaborative projects, of which 90% (473) were between universities and industrial firms (CONACYT 2013: 118). Although this type of initiatives have been common in the past, its catalyst effect is uncertain because, as the figures analysed above show, the probability of collaboration is low given the scant human capital available on the part of Mexican firms. Therefore, the problem for universities seeking to establish collaborative relationships is that most enterprises are not yet well staffed as to harness scientific knowledge produced at the academy. Furthermore, because universities are now induced into moving into a new paradigm, where multiple industrial demands need to be fulfilled, their future looks dim. As pointed out by Garrett-Jones and Turpin (2012), the pressure comes mainly from the government and other funding bodies seeking to diminish the fiscal burden.

The new entrepreneurial paradigm represents that universities, apart from their obligation to offer up-to-date academic formation, are now also urged to conduct research on industrial topics and its concomitant professional advice. All of which clearly exceeding their traditional missions. As seen before, the challenge for Mexican universities is that most industrial firms have not been able to invest in human capital in order to keep abreast of technological changes. As a result, university-industry collaboration is rare because both parts are still unable to understand each other.

Conclusions and Recommendations

Since 1994, when the NAFTA treaty started operating, Mexico began to experience an astounding manufacturing exporting boom; yet, industrial innovation has been practically non-existent. While most OECD nations spend an average of 2 % of their gross domestic incomes on research, Mexico devotes a meagre 0.5 % of its GDP to conduct R&D, and this figure is mainly covered by the public purse because the business sector has always played a very marginal role. Among the chief reasons for this situation is the lack of highly qualified R&D staff in the Mexican business sector. Therefore, the possibilities for fruitful university-industry relationships are poor.

The empirical analysis presented here provides evidence that research collaboration should represent a vital source of knowledge for industrial enterprises since they need to engage in continuous collaborations with other organisations.

However, when Mexican firms are analysed, abrupt differences in the quality of their human capital emerge.

The lack of qualified human resources is evident for the biggest part of the manufacturing and service sector in this country. Only a handful of sectors are mildly prepared to embark in research collaborations with the academy.

In economic terms, universities face a highly inelastic demand for their services given the lack of strong technical capabilities among industrial firms. Therefore, in view of the long-lasting economic stagnation, the design of policies targeted at encouraging industrial innovation must recognise, above all, the weakness of the demand side. In this respect, Mexican policy makers should bear in mind that university-industry linkage is a two-sided equation, so the insistence of pushing for supply-side-only policies can just produce a rather limited impact, hence the necessity to encourage the application of demand-side policies as well.

A novel departure would be the introduction of incentives for firms to trigger the relationship. For example, one can think of the introduction of "technology vouchers" made available to industrial firms (preferably to the smaller and less affluent firms), which could guarantee the acquisition of technological services from universities. Besides, the government should demonstrate that academic links are beneficial in the long-run based on the existing evidence.

Finally, universities should also pay more attention to the actual needs of the business sector in order to stimulate technological linkages and knowledge sharing. Mexico has several prestigious universities that can contribute to this innovation effort if only they were also offered with attractive conditions too. Therefore, this nation badly needs to abandon for good the "cheap labour paradigm" to decidedly embrace the "investment for innovation paradigm," especially in relation to its huge education challenge.

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