Introduction

Given that economic development strongly derives from innovation, public policy agendas privilege the support of the development of capacities and potentialities to detonate processes in this sense. This research is guided so, by the ample purpose of informing public policy makers in terms of innovation, from a territorial perspective. On the one hand, because it is in the territory where networks of actors are woven in which knowledge and abilities are exchanged and in which trust is built. Both factors are relevant in detonating innovative processes. On the other hand, because the public policies that support innovation often carry a sectorial bias, such as science and technology, infrastructure building or industrial fostering policies. From the territory, it is possible to generate novel arrays of governance that coordinate sectorial initiatives and result in integral policies that further innovation.

With the more commonly used innovation indicators, it is possible to observe a disadvantageous position of Mexico in the global geography of innovation. With this observation and from the perspective of designing public policies, the important question refers to the detection of niches to position the country in the matter. This issue poses the need to explore the potential of innovation at the sub-national level: turn our gaze to the region and local places, identifying the territories whose actives and processes favor or maximize innovation.

Conceptually, this research is sustained in the theoretical current of innovation systems at the regional and local scale, which centers itself in the institutional and political factors that are conducive to contexts prone to innovation and in the approach of evolutionary economic geography that explains the spatial evolution of companies, networks, cities and regions. It approaches the geographies of technological advances and dynamic competitive advantages.

In this framework, this research is centered in the geographic distribution of high-level human capital in the urban Mexican territory and its contributions to the local capacities of innovation. In a first stage, a convergence of high-level human capital in the urban territory of the country and technological-based industrial activity (TBIA) was shown. The geographic distribution of Mexican highly qualified labor
force, its expression in diverse forms of specialization, diversification or complementarity and their impact in the economic performance of cities are relevant issues, either from a public policy or an academic point of view. In this paper, work is carried out through the analysis of the geographical distribution of human capital. Starting from indicators organized in two dimensions: knowledge-intensive occupations and high-level education achievement. Furthermore, two typologies to classify metropolitan areas and their regional networks are proposed: the first, in terms of occupational patterns that the concentrations of knowledge-intensive activities form, and the second, in terms of the evolution of the concentration of high-level human capital in the younger generation. Both typologies are combined and the cities are characterized in four levels of human capital.

The indicators to measure high-level human capital

The measure of human capital per excellence has been formal educational achievement. This measurement besides being easy to implement, is a robust one: Gennaioli et al. (2011) in a comparative study on the determinants of regional development, conclude that “human capital, measured using education emerges as the most consistently important determinant of both regional income and productivity of regional establishments” (2011:2). However, recent studies show that educational achievement only partially captures the capabilities of persons, which include, besides schooling, “accumulated experience, creativity, intelligence, innovativeness and entrepreneurial skills” (Florida and Mellander 2008:3). Some of these competences are probably acquired through formal education, but their realization and empowerment derive from the skills and new forms of knowledge that people get through experience on the job or through their participation in creative, social and cultural activities. Florida and Mellander argue that “occupation is the mechanism through which education is converted into skill and labor productivity” (2008:7). Here, we combine both approaches for the measurement of human capital and integrate a set of indicators organized along two dimensions:

1. High-level educational achievement, measured by people who have started or completed undergraduate or graduate level degrees. This indicator corresponds to the more widespread measuring of human capital and that responds to the relevance of the economic contribution that formal education has for individuals, families, companies and society in general.

2. We look into people that are engaged in knowledge-intensive occupations as part of the high-level human capital. They possess this capital due to the competences and skills they acquire, put into play and increase along their occupational performance. This occupational ability is approximated by means of people that require, as a central element in their work, the application of knowledge and abilities. For instance, people that work with information
technologies and communications, engineers, legal, accounting, administrative or marketing consultants, people that carry out tasks of high direction in companies or public and private organizations, researchers and technologists, creative professionals such as architects, designers or performing artists, health or educational professionals, among others.

For the analysis of the geographic distribution of human capital in Mexico we depart from 59 metropolitan zones -which we will refer here as ‘cities’-, each one with more than 100 thousand inhabitants. We approach these urban agglomerations as labor markets where economic agents have attained different levels of formal education and perform a variety of occupations; collectively, they give rise to patterns of occupation and educational attainment which characterize the nature of the economic and cultural activities performed in such places. But this human capital is not a fixed stock of each city. Rather, it moves in space. Focusing in the conceptualization of a relational space, which is implicit in the model of networks of cities, we extend the conceptualization from a local market bounded by the administrative borders of each city, to the scale of the urban areas involved in a network.

**Geographical distribution of knowledge-intensive occupations**

We approximate the geospatial distribution of the knowledge-intensive occupational ability taking as a starting point the technique of location quotients. These quotients allow quantifying the concentration of an occupational activity in a city’s market, relative to its market share given by the aggregate of the 59 cities considered in the study, same that are taken as our reference economy. This reference economy expresses the average or expected distribution that is supposed to hold sufficient conditions to satisfy the demand of goods and services that the occupation produces.¹ Because of how they are constructed, location quotients (or coefficients) moderate the eclipsing effect of large cities when the distribution is studied in percentage terms. This is particular relevant when we take into account that Mexico City’s Metropolitan Area concentrates nearly 18% of the country’s population.

Location quotients allow knowing which cities stand out in the concentration of occupations. A quotient larger than 1 indicates how many more times an occupation is concentrated in a city compared to the average of the reference economy. The concentration of knowledge-intensive occupations in a market points to the performance of a variety of industries that employ people with the abilities involved in such occupations. This concentration might help circulate

¹The location quotient is the ratio between the percentage share of occupation i un a city j and the corresponding share for the reference economy
money already in the city or bring new money from the outside. This issue can be approached by means of the size of the basic employment. When a high quota of basic employment is found in a city, we can assume there is a potential, an economic base focused from the workforce, to bring new money into the city and to generate synergies between the main industries that employ these people. It is worth noting that this economic base can be linked to the specialized occupational demand of one or more industrial branches or be associated with a broader range of them.

We select both knowledge and creative-intensive occupations from data of the 2010 Mexican General Population Census and we use location quotients to disclose the geographic distribution of occupations among cities and networks. From the location quotients, we were able to identify 17 relevant cities in terms of knowledge-intensive occupations (Graph 1). Mexico City stands out among them, with a robust economic base in terms of its occupied population and its basic employment in occupations related to research and development (R&D), information technologies and communications (ITC), finance, marketing and management, creative and health professionals. Monterrey and Guadalajara follow and have an economic base with engineers, people in high-level direction or company or organization ownership. Monterrey also has an economic base in ITC, finances, marketing and management, while Guadalajara has one in creative professionals, although in an incipient fashion. Other smaller metropolitan areas start to stand out in a differentiated way. For instance, Puebla positions itself on engineering, or Xalapa in R&D. It is clear that these positions are still weak and accentuate the need to structure public policies that allow their securing and better evolution to be able to guarantee their contributions for the prosperity of the cities.
The graph includes cities with a location quotient greater than 1.15 and whose basic employment in occupation j is greater than 1% of the corresponding occupation’s share in the reference economy.

Source: Own elaboration with data from INEGI Censo de Población y Vivienda 2010

But these cities are not isolated markets. They rather form a functional structure derived by interactions in time and space that give rise to regional networks that overlap, intersect or cross, generating complex structures of material and symbolic transactions. The huge size of Mexico City Metropolitan Area -with more than 20 million inhabitants-and its political, socioeconomic, cultural and historical role, place it as a core node that brings together relevant functional relationships with virtually every city in the country. It also exerts a size effect that hides the regional relevance of other cities. Garrocho (2012) identifies regional city networks that emerge when the eclipsing effect of this metropolitan area is removed from his model. We use his results and place the selected cities in the regional networks he
proposes and add the 16 urban markets of the regional city networks to our analysis. These networks and the Mexico City Metropolitan Area, jointly represent 55.5% of the nation’s population and nearly 55% of the productive occupation. The patterns of concentration of occupational ability in these networks are shown in Graph 2.

When the aggregate market of cities that belong to a network is considered, it is possible to observe different cases:

1. A first one is derived from cities which are head of a network and have a relevant economic base in a given occupation but that disappear when its market is integrated with that of its regional subordinated cities. Such is the case of Guadalajara, for top management occupations and engineering, or Querétaro in ITC. This situation points to a possible relevance of the occupation in the regional market.

2. A second case is when the economic base of a head city is weakened when the cities of the network are included. Monterrey shows this behavior in ITC. In this case, Monterrey’s economic base is sufficiently wide to show, even when its network is integrated, an extra potential that can be guided towards other regional markets.

3. A third case happens when a network shows a more relevant economic base than its head city. Education in Puebla and health in Oaxaca are examples of this, since their isolated markets do not display an economic base, but the network does. In this case, subordinated cities add their potential to that of the head city to contribute to the potential of the corresponding region.
Graph 2. Networks of cities whose concentration of knowledge-intensive occupations may point to an economic base.*

*The graph includes networks with a location quotient greater than 1.15 and whose basic employment in occupation j is greater than 1% of the corresponding occupation's share in the reference economy.

Source: Own elaboration with data from INEGI Censo de Población y Vivienda 2010

A possible complementarity among occupations can be observed in Graph 3, which shows a network formed by the significant coefficients of correlation among the networks. In the center of the network, a first order node stands out in terms of finances, marketing and management, which is associated to the networks of R&D, engineers, ITC and creative professionals. These last profile themselves as a second order node, because of its complementarity that their additional association with people occupied in ITC or those in charge of top management of companies and organizations represent. The association of those working in R&D and health professionals also stands out. The occupations that position themselves in the central nodes point out the fact that the concentration of these knowledge-intensive occupations occurs in the large metropolitan areas: finances, marketing and management form an economic base for Mexico City’s Metropolitan area; creative professionals in Mexico City and Guadalajara; ITC in Mexico City and Monterrey; R&D in Mexico City.
If we take into account the functional relevance of the occupations in the country, that is, the sum of location quotients over the cities, we can observe, in Graph 4, that the occupation showing more dispersion between cities is education (which does not have a significant correlation with the rest of the knowledge-intensive occupations), while professionals in ITC, creative or finance, marketing or management occupations tend to concentrate in a smaller number of cities (Map 1).

**Graph 4. Functional relevance of knowledge-intensive occupations**

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010
Following Growe (2010), we add the location quotients of knowledge-intensive occupations in each urban market. This was done in order to measure the importance or functional relevance of the whole set of knowledge-intensive occupations in the cities that lead a network. We include in this universe the subordinated cities whose functional level is above the average of the leading cities in this index. By means of the Herfindhal-Hirschman index, we calculate a measure of the strength of the occupational specialization of the set of knowledge-intensive or creative occupations in the selected cities. Then we use both indices as dimensions to classify cities and propose four types of urban markets in which

\[ \text{The Herfindahl-Hirschman index is the sum of the squares of knowledge-intensive occupations } j=1,\ldots,n \text{ in a city} \]
Knowledge-intensive occupations are relevant: balanced hubs, specialized hubs, cities with emerging diversification and cities with emerging specialization. Table 1 shows the average pattern of knowledge intensive occupations in each of the city’s types. It is possible to observe that the diversified group tends to concentrate people occupied in ITCs and creative professions, while the ones occupied in education, health, R&D and engineering have a more relevant concentration in the specialized hub. Emerging hubs position themselves below the average functional relevance of the reference economy. Among them, the diversified hubs show a bias toward the concentration of top management activities, which may be an indicator of small businesses activities. Cities classified in the emerging specialized type derive their major strengths from the professionals in education. In this typology 29 cities are placed– Mexico City, 18 cities that lead a regional network and 10 which are subordinate nodes in one of Garrocho’s regional networks- and the 16 regional networks. Map 2 shows a representation of this description.

Table 1. Typology of cities according to the functional importance and strength of the specialization of knowledge-intensive occupations

<table>
<thead>
<tr>
<th>Functional importance $\sum (LQ)$</th>
<th>Strength of specialization (HHI)</th>
</tr>
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<tbody>
<tr>
<td>Low (Below the median)</td>
<td>High (Above the median)</td>
</tr>
<tr>
<td>High (Above average)</td>
<td>Diversified</td>
</tr>
<tr>
<td></td>
<td>Emerging-diversified</td>
</tr>
</tbody>
</table>

Top managment, Finance, marketing and…
Health, R&D, Engineers, Creatives, ITCs

Legend

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010
Map 2. Typology of cities and networks according to the functional importance and strength of the specialization of knowledge-intensive occupations.

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010

An import thing to note from Map 2 is that large cities tend to be more diversified in their occupations. Also, the networks formed by cities clearly define regions throughout the country: the central-north region of the country is dominated by diversification, while the east and west portions tend to be specialized, with some
emergent networks in the middle. It would be interesting to make a revision of the criteria for cities to be included, since with the current definition, there were no cities in a large portion of territory in the north-west, and hence this would be helpful in better understanding the dynamics of knowledge-intensive occupations and the patterns of networks in the country.

The functional importance of Mexican cities shows a high specialization in knowledge-intensive occupations in few of them. In the last quartile of its distribution we only find 15 cities (Graph 5). Out of them, 9 are classified as specialized hubs in knowledge-intensive occupations. That is to say, they show high concentrations of specific occupations and deficits in others. In these cities, the HH index takes high values, because the functional surplus concentrates in one or few occupations, indicating a stronger weight in specialization. In the 6 that are classified as diversified hubs, the functional surplus of knowledge-intensive occupations shows a more balanced evolution, with a concentration of human capital distributed in a wider range of occupations.

Graph 5. Cities in the highest quartile of knowledge intensive occupations functional importance

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010

The majority of head cities (two thirds) maintain their classification when their markets are integrated to those of their subordinated cities in the network. The remaining third loses functional importance (Coatzacoalcos), in specialization force (León), or in both measures (Mérida, Cuernavaca and Querétaro). Only Morelia
gains strength in specialization when the markets of its subordinated cities are integrated (Graph 6).

The geography of knowledge-intensive occupations is displayed in heterogeneous patterns. Some occupations have affinities with certain cities whose market is specialized in one or few occupations; in other cities the pattern is more diversified (Map 3). The patterns of knowledge-intensive occupations for the aggregate cities and networks included in each type corroborate the expected balances, shortages and specialization biases (Graph 7). Specialized hubs show a large bias for engineering and educational occupations, while diversified hubs show a structure similar to the economy of reference (the average pattern) with greater shares in occupations related to ITC, creative professions and in a lesser extent, finance, management and marketing; the emerging specialization cluster is left behind in precisely the aforementioned occupations but holds a share of professionals in education close to the average level of the reference economy. Finally, the emerging diversification cluster shows a better position in creative and top management occupations than the emerging specialization one.

Graph 6. Typification of cities leading a network and networks according to the functional importance and strength of the specialization of knowledge-intensive occupations

![Graph showing typification of cities]

Source: own elaboration
Map 3. The geography of the specialization of knowledge-intensive occupations

Source: Own elaboration

Graph 7. Patterns of knowledge-intensive occupations for the aggregate of cities and networks included in each type (location quotients)

Source: Own elaboration
**Geographic distribution of educational achievement**

By looking at human capital accumulation in terms of educational achievement, we find that some cities have improved their position over time, while others have fallen behind or have a deteriorated position. We analyze the change in the cities' concentration of people with high educational level over 30 years by comparing the location quotients of young people (ages 25 to 34) with university or postgraduate studies and the percentage change between this share and the corresponding one for old people (ages 55 to 64). With this comparison we give account of the growth, replacement or diminishing of the stock of human capital with higher education and graduate studies in the urban markets contemplated in this research.

Graph 8 shows the results for the aggregate types of cities and networks. The first quadrant groups the 'outstanding' ones that have a concentration of young people with higher education above the average and that have been concentrating more of this kind of capital over time. The second one brings together the ones with a concentration of this kind of human capital above the average but whose share has been declining, so they are 'at risk'. The third one groups the 'deteriorated' aggregate type, which requires strategic actions to catch up. Finally the fourth one clusters the emergent ones: those that are improving their share of young people with high educational level though this share is still less than the average. Cities located near the origin in any quadrant could be further differentiated from those moving away from this point. Also, cities with values of the location quotient above and around 1 have a share of this kind of human capital that shows a potential for a critical mass formation. Emergent cities are a promise because its evolution in the concentration of highly educated human capital in the young generation is positive and if it can be maintained or reinforced, eventually might form an economic base. Cities at risk are losing human capital with high educational level and deteriorated cities find themselves in a critical situation; both need public policies to level their situation to that of the reference economy.

Grouped in the outstanding type and in very favorable position we can find medium size cities or networks as Oaxaca and its network, Xalapa, Villahermosa and its network, Tampico, Chihuahua and Pachuca. 7 of the 11 largest metropolitan zones, with more than 1 million inhabitants (Valle de México, Guadalajara, Monterrey, Puebla, Toluca, Querétaro and San Luis Potosí) stand out for its on-risk positioning; as if their size were a force pulling them downwards and to the left. 5 of these cities lead a network that is also placed in this at-risk position (Graph 8). From them, only Puebla leads a network that manages to ascend in both dimensions and gets a position as an outstanding one. Among the deteriorated type, the extreme case is the city of Juárez, whose concentration of young people with university and postgraduate educational level (location quotient) is 36% less than the average and has 48% less than the current concentration of old people at the same educational level; therefore it lies outside the scale presented in Graph 8; however the network that Juárez leads, although in a deteriorated position,
improves in both dimensions. Tijuana, concentrating a small share of highly educated young people, shows a favorable evolution in the educational attainment of new generations, evolution that improves when considering the impact in the indices of the cities integrated in its regional network.

Graph 8. Typology of cities and networks according to the evolution of highly educated human capital

![Graph 8: Typology of cities and networks according to the evolution of highly educated human capital](image)

The size of the sphere corresponds to the number of young people with university or posgraduate educational level.

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010

At the crossroads of both typologies

In order to look at the intersection among both typologies, Graph 9 shows the evolution of highly educated human capital in the aggregate types of knowledge-intensive occupations. Diversified hubs have the largest quota of highly educated young people; however the average evolution of their concentration puts those cities or networks at risk of losing their positive advantage in this matter. Specialized aggregates of cities or networks are positioned in the outstanding quadrant, thus show a good position in both formal education attainment and functional importance and strength of specialization. The aggregate of emerging diversified cities lies in the deteriorated quadrant, but when we consider the grouping of networks of this type, this position improves towards the emergent
quadrant, thus showing the contribution of subordinate cities in the size of the stock of this kind of human capital. A similar situation can be seen for the aggregate type of the emerging specialized type.

Graph 9. Evolution and distribution of human capital of the young generation with university or graduate educational achievement between types of knowledge-intensive occupations

Map 4 shows these positions disaggregated by city and network. Cities that concentrate talent have people with formal high educational achievement and people that are in charge of activities whose performance requires the application of knowledge and abilities. Their presence in high rates positively feedbacks the stock of high level human capital in the urban market by means of local or regional exchange of explicit and tacit knowledge and by attracting more prepared individuals to the market. In this case cities that concentrate occupational ability and are, at the same time, positioned as outstanding in the evolution of high level educational achievement can have relevant human capital to contribute to
innovation processes to the extent that they can detonate knowledge and ability circulation processes through the intervention of policies guided for said goal. There are the 12 cities and 2 networks marked in green and labeled as ones with a good level in highly qualified human capital.

On the other hand, 9 cities and 4 networks marked in yellow show those with an acceptable concentration of human capital in one of the dimensions, but that require additional efforts in the other one to increase feedback processes between the knowledge derived from formal education and that generated from the ability or the tacit knowledge obtained through experience in the performance of their occupations. These are labeled cities with medium level of high level human capital. It is important to induce the balanced evolution in both dimensions of human capital in these cities, since even though scientific and technological advancements is often backed up by people with high academic achievement, innovation more frequently occurs in the practice of productive processes that are the result of a combination of knowledge acquired through formal education and that acquired by means of practical experience.

On the other end of the spectrum, 5 cities and 4 networks are located in the emergent region and have a low concentration in knowledge-intensive occupations, but are positioned as emergent or outstanding in high level educational achievement. A specialized city shows a deteriorated situation in terms of educational achievement. These cities are labeled as low level human capital. Finally, two cities that are part of the 11 large metropolitan areas were labeled as very low level high qualified human capital: Juárez and Toluca. 4 more networks urgently require bridging the gap that locates them in the most disadvantageous position in terms of both dimensions (Table 2).

From this map it can be seen that the highest educational achievement is currently taking place in the southern region of the country. It is worth noting that the largest cities in the country currently do not show a high level in educational achievement because they concentrate the more educated population in the country and have not significantly increased this level in the last 10 years. In other words, the networks of cities that used to have lower education, have a more positive change in their indicators and seem to be in a better position than those aforementioned.
Map 4. Crossed typologies for education and knowledge-intensive occupations

Source: Own elaboration with data from INEGI Censo de Población y Vivenda 2010
Table 2. Crossed typologies for education and knowledge-intensive occupations for cities and networks

<table>
<thead>
<tr>
<th>Types according to the relevance KIO</th>
<th>Types according to the evolution of the concentration of highly educated human capital in the young generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversified</td>
<td>Emergent: Chihuahua, Puebla, Tampico, Network Puebla</td>
</tr>
<tr>
<td></td>
<td>At risk: Cuernavaca, Guadalajara, Monterrey, Querétaro, Valle de México, Veracruz, Network Guadalajara, Network Monterrey, Network Morelia</td>
</tr>
<tr>
<td>Specialized</td>
<td>Villahermosa, Xalapa, Network Oaxaca, Network Villahermosa</td>
</tr>
<tr>
<td>Emerging diversified</td>
<td>León, Tijuana, Network Reynosa, Network Coatzacoalcos-Minatitlán, Network Orizaba</td>
</tr>
<tr>
<td>Emerging specialized</td>
<td>Reynosa, Network Tijuana, Minatitlán, Orizaba, Network Mérida</td>
</tr>
</tbody>
</table>

**As a conclusion**

Behind innovation processes there are people that have knowledge and abilities, they know how to apply them, how to accrue them, and how to combine them in exchange and collaboration processes with other people. High level human capital in a city is a core element of its innovation capacities.

In this presentation, and as part of a wider research, we explore the distribution of high level human capital in urban regions of Mexico, as well as the positioning of cities and regional networks of cities in terms of the stock of human capital in their markets.

The analysis of the distribution of the human capital in networks of cities shows, on the one side, the regional relevance of the leading cities of the networks and, on
the other, cases in which the strengths of these cities are built in terms of the contributions of human capital of subordinate cities.

One work hypothesis, derived from this exploration, is that when cities have certain critical mass in key occupations, attract related or complementary occupations and evolve towards certain patterns of specialization or diversification. In this sense, there are key knowledge-intensive occupations; mainly, those related with the intermediate financial sector, marketing and management and creative occupations. It is worth noting that both are associated in a significant way with the utilization of ITC, which turns out to be the most concentrated knowledge-intensive occupation, representing a potential to export goods and services that these people produce only in Monterrey or its network and Mexico City. This is a topic of the utmost importance for the role these technologies play in competitive processes.

It is also worth to note that, as a knowledge-intensive occupation, education professionals do not correlate with the rest of the types of occupations considered here, while cities that concentrate more of this human capital tend to show more progress in educational achievement. Comparing Graphs 1, 2 and 7, it is possible to observe that 2 out of 4 cities in 4 out of 6 networks in which education professionals have potential to form an economic base, position themselves as outstanding in educational achievement.

Even though it has been shown that the relationship between scientific and technological advance and innovation is not linear, a central component to innovation systems is integrated by science and technology, which in turns makes synergy with the productive sector and with an institutional framework that favors the detonation of innovation. In this sense, it is pertinent to point out that those cities whose people occupied in R&D activities have potential of forming an economic base, also have a tendency to show an outstanding position in the evolution of its highly educated human capital.

The younger generation has more undergraduates and graduates in more cities than the older generations, proof of the educational advancement of the country's higher education system. Educational advance in this generation is very relevant since it replaces and forwards the accumulation of this capital. The three largest metropolitan areas concentrate the highest quotas of this high level human capital, but lack the flexibility present in smaller cities to significantly advance in terms of educational achievement.
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