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Municipal Economic Complexity in Mexico: Productive Capabilities, Wealth, Economic Growth, and Business Sophistication*

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Abstract: In this study, we calculate the productive capabilities of Mexico's municipalities (i.e., their Economic Complexity Index, or ECI) and the productive capabilities required for their economic activities to be carried out (i.e., the ECI of their economic activities). We do this in order to determine whether or not the differences in the main municipal economic indicators (such as levels of wealth, economic growth rates, and salaries) are associated with differences in productive capabilities. Specifically, our results illustrate: i) a considerable heterogeneity, in terms of productive capabilities, across municipalities; ii) a positive relationship between the level of economic complexity of municipalities and their level of wealth and rate of economic growth, and iii) a positive relationship between the complexity of economic activities and the average salaries received by those employed in them. Furthermore, by finding that the majority of new firms in complex (non-complex) municipalities generally tend to engage in more sophisticated/higher-value-added (less sophisticated/lower-value-added) economic activities, we provide supporting evidence on the gradual accumulation of productive capabilities within municipalities to the literature on evolutionary economic geography. According to this literature, this is how economies generally develop, i.e., by gradually accumulating productive capabilities so as to become more diverse and be able to engage in more complex economic activities, allowing economies to grow and become wealthier.

Keywords: economic complexity, productive capabilities, economic growth

JEL Codes: O10, O47, O54

1. INTRODUCTION

Hidalgo and Hausmann (2009) and Hausmann et al. (2014) propose the concept of and methodology for calculating an ECI as a measure of the unobservable productive capabilities an economy possesses and uses to produce goods or services. Their results find that

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productive capabilities are one of an array of factors that determine an economy's level of wealth and long-term economic growth.

Providing more diverse goods and services requires a heterogeneous stock of productive knowledge. Consequently, economies with a broader range of productive knowledge are able to produce a wider variety of goods, while more sophisticated products or services (which require a greater diversity of productive knowledge) tend to be produced by just a limited number of economies, i.e., more complex ones. In contrast, less sophisticated goods, which require less productive knowledge, are produced by a greater number of economies, and economies with less productive knowledge tend to produce less sophisticated ones.

When new goods are created or developed (entailing the generation of new productive knowledge and/or the emergence of new economic activities), this is normally the result of combining existing productive knowledge. The generation of new productive knowledge occurs more frequently in economies with a greater stock of productive capabilities, the availability of which creates a climate more conducive to innovation and to productive diversification into more sophisticated sectors.

In their original study, Hidalgo and Hausmann (2009) measure the productive capabilities of more than 150 countries on the basis of country-specific data on goods exports (which provide an indication of their relative economic structures). Since then, their methodology has been used in various studies to analyze economic complexity at a sub-national level.[1]

Measuring economic complexity at a more geographically disaggregated level has shown local economies to be quite heterogeneous in this regard. Even the most complex of countries have regions with low levels of economic complexity, while it is also possible to find regions with a high degree of economic complexity in countries where the level of complexity of the overall economic structure is typically low.

There is empirical evidence to suggest that complex economic activities tend to be clustered within defined geographic areas (e.g., cities or municipalities). Balland et al. (2020) use historical data on U.S. patents to show how complex economic activities have become increasingly concentrated in certain urban areas of that country since 1850. In particular, they show that the higher the degree of complexity of an economic activity, the more it tends to be concentrated in cities. Complex economic activities such as biotechnology and semiconductors are more highly concentrated in cities than less complex ones such as garment manufacturing and furniture production. The concentration of the former has been increasing steadily since 1850, whereas the concentration of the latter has been decreasing since the 1970s.

So why does this clustering occur? More complex economic activities demand a more specific division of labor, one that is only possible in cities that boast a wide variety of productive skills. The clustering of knowledge in cities stems from the need for companies, institutions, and workers to share, pool, combine, and adapt their expertise in order to

[1]See Fritz and Manduca (2021) for an analysis of the complexity of metropolitan areas in the U.S.; Gao and Zhou (2018) measure the economic complexity of regions in China; Pérez-Balsalobre et al. (2019) do the same for Spain; Antonietti and Burlina (2019) calculate the complexity of regions in Italy; Herrera et al. (2021) analyze the complexity of Brazilian states; Chakraborty et al. (2020) measure the complexity of prefectures in Japan; and Chávez et al. (2017) study the economic complexity of Mexican states, to mention just a few of the many studies that exist.

produce more complex goods.

Our study quantifies productive capabilities by municipality, the most specific geo-administrative level that Mexico's Economic Census data allow us to analyze. It also measures the economic complexity of economic activities at the most disaggregated level, namely the NAICS 6-digit national industry classification. Our goal is to link the great municipal disparities in terms of level of wealth, economic growth rates, and salaries to the economic structures of those municipalities. Our results provide a better understanding of the distribution of capabilities across Mexico and complement those of Chávez et al. (2017), who calculate economic complexity by state. This municipal-level analysis offers the additional benefit of providing a more detailed picture of the distribution of productive capabilities across Mexico, thus allowing a deeper understanding of economic disparities and more detailed characterization of local economies, which could help in the design of targeted industrial policies aimed at promoting structural change and municipal development. Additionally, our results provide empirical evidence in support of the arguments put forward by Hidalgo et al. (2007) in their paper *The Product Space Conditions the Development of Nations*. The authors of the latter argue that economies generally move through the "product space" by producing goods with a low level of complexity in their early stages, before gradually moving towards the production of goods with a higher level of complexity as they acquire new productive capabilities. We find that firms in Mexico's municipalities engage in economic activities consistent with the level of complexity of the municipality concerned, i.e., if the level of complexity of a municipality is low (high), the firms within its territory will generally engage in economic activities with a low (high) level of complexity. It is difficult to find companies engaged in complex economic activities in non-complex municipalities, or at least these are certainly not the norm.

Before the concept of economic complexity existed, other theoretical and empirical studies had analyzed the relationship among economic activity, agglomeration, growth, and productivity. There are certain similarities between the findings of both literatures (i.e., those on economic growth and economic complexity) and the following are a few examples of these and their explanations.

Martin and Ottaviano (2001) and Ciccone and Hall (1996) highlight the importance of geographic agglomeration of economic activities on economic growth and productivity. The first of these two studies shows theoretically how economic growth and agglomeration of economic activities reinforce each other. Their main finding is that the marked differences in labor productivity across U.S. states can be explained by employment density; specifically, the productivity of states increases with their employment density.

These results are related to those of Balland et al. (2020). According to the latter, the most complex economic activities, which are also characterized by having the highest labor productivity, are generally carried out in big cities or highly dense urban areas because, as explained earlier, they are activities that require more diverse specialized labor and those are the only areas where these can be found clustered.

Two studies, namely Hall and Jones (1999) and Easterly and Levine (2002), stress the role of something other than factor accumulation in economic growth. Both studies highlight the role of institutions and government policies. Their conclusion coincides with that of a number of studies that form part of the literature on economic complexity.

Hall and Jones (1999) study the important disparities in output per worker across countries. One of their main findings is that differences in physical capital and educational attainment account for only a small portion of the differences in output per worker. They conclude that most of the output per worker gap is driven by what they call social infrastructure. To quote the authors,

> . . . differences in [. . .] output per worker are fundamentally related to differences in social infrastructure across countries. By social infrastructure we mean the institutions and government policies that determine the economic environment within which individuals accumulate skills and firms accumulate capital and produce output."
> —Hall and Jones (1999)

In their original proposal, Hidalgo and Hausmann explain that the ECI quantifies the productive knowledge an economy possesses and uses to produce. It not only reflects the human and physical capital (communications, transportation, etc.), technology, and any other productive inputs economies possess, but also the existing structures that enable them to hold, utilize, and combine their knowledge, such as regulations, property rights, an effective justice system, enforcement of the rule of law, and so on. Meanwhile, Hartmann et al. (2017) suggest that the ECI can account for differences in per capita GDP, among other things, because it is an indicator of an economy's level of social capital, the quality of its institutions, the ability of its population to create social and professional networks, and so forth.

The relationship between the findings of these two literatures is clear, with both agreeing that institutions play a key role in the health of an economy.

Easterly and Levine (2002) define five stylized facts on economic growth. Among other results, they describe factor accumulation as more stable than economic growth, a fact that led them to conclude there must be something else besides factor accumulation that accounts for variations in economic growth. They go on to affirm that there is a strong link between macroeconomic, trade, financial development, and monetary policies on the one hand and growth on the other.

The remainder of the article is organized as follows. Section 2 describes the data and methodology used to calculate the economic complexity index of municipalities and of economic activities. Section 3 presents the results of the analysis of the economic complexity of municipalities and of their economic activities, as well as of the average complexity of the firms in each specific municipality of the country. Section 4 presents the concluding remarks and a number of suggestions for future research.

2. DATA AND METHODOLOGY USED TO ESTIMATE THE ECONOMIC COMPLEXITY INDEX (ECI)

2.1. Data

In this study, we estimate the ECI of municipalities and of economic activities and also calculate the average ECI of the economic activities in which the firms in each municipality engage. In estimating the former, we use municipality-level data to show the municipalities' relative economic structure. In order to verify the robustness of the metrics, the ECIs are calculated using three different variables: People Employed (PE), Gross Product per Worker (GPW), and Value Added per Worker (VAW).[2] These three variables are obtained from the 2009, 2014, and 2019 Economic Censuses conducted by Mexico's National Institute of Statistics and Geography (INEGI).[3] In their original paper, Hidalgo and Hausmann (2009) calculate the economic complexity of countries and products on the basis of data on the value of their exports. Since there is no data on the goods traded between municipalities, just as previous studies on Mexico have done, including Chávez et al. (2017), Gómez-Zaldívar et al. (2020), and Gómez-Zaldívar et al. (2021), we use the items of data above, which also provide a picture of the relative economic structure of the municipalities.

The calculation of the third measure (i.e., the average ECI of the economic activities in which the firms in each municipality engage) uses information on the new firms in each municipality and the economic activities they undertake. These data were obtained from INEGI's National Statistical Directory of Economic Units or "DENUE" (04/2020).[4] The DENUE contains data on the identity, location, economic activity, and size of active firms across the country.

2.2. The concept of economic complexity

Hidalgo and Hausmann (2009) argue that the productive capabilities of economies comprise a range of different features: human capital, people, books, all kind of infrastructure, the justice system, government effectiveness, rule of law, ease of doing business, collective knowledge, etc. Measuring and comparing economies based on all these characteristics is quite difficult, given that many of these attributes are intangible, among other things. For this reason, the authors proposed an alternative method aimed at measuring the relative productive capabilities of economies by simply incorporating information on the relative mix of products that the economies export.[5] Given that each of the aforementioned characteristics is important to the economies' productive process, the degree to which they are present/absent greatly shapes how those economies work, and ultimately the type of products each economy is able to produce and export. The underlying idea is that productive capabilities are reflected in the number and quality of the products that a country produces and exports.[6]

This methodology has become quite popular in the last decade; it has been employed

[2]The PE variable is taken directly from the Census. The GPW and VAW variables are constructed by taking the information on Total Gross Product and Census Gross Value Added and dividing by Total Number of People Employed.

[3]The 2009 and 2014 Censuses provide information on 2,453 municipalities and 883 economic activities. The 2019 Census provides information on 1,490 municipalities and 759 economic activities; there is less information due to INEGI's principle of confidentiality, which limits the disclosure of a respondent's sensitive financial information in order to safeguard his or her identity.

[4]In the final part of the results section, we explain how this variable is calculated, when it is used.

[5]In their original work, Hausmann and Hidalgo use data on countries' exports. Similar to previous studies that calculate the economic complexity of Mexican states, in this work we employ data on the number of people employed by states in the diverse economic activities.

[6]Later, when we explain the methodology for calculating the ECI, the number and quality of the products is referred to as diversity and ubiquity.

by studies that belong to the fields of economic geography and international development. The findings of the studies in which it has been applied include the following: i) there is a high correlation between GDP per capita and level of economic complexity, a finding that is true at both the country level and the subnational level; ii) an economy's level of economic complexity anticipates future economic growth; iii) economic complexity is associated with an economy's level of income inequality; specifically, more complex economies tend to have fairer income distribution; and finally, iv) there is an association between economic complexity and the flows of Foreign Direct Investment (FDI) that economies receive; specifically, the more complex the economy the greater the flows of FDI.

In the words of one of the codevelopers of this concept, the study of economic complexity makes two main contributions. First, the introduction of metrics of relatedness, which measure the relationship between economic activities and locations. Second, the methodology is able to extract key information from country data that reflects the level of sophistication of their relative economic structures, data on things such as exports, people employed, production, and so on.

Country-level studies are able to include the majority of countries in the world because export data is so widely available. At the subnational level, there are many studies that analyze states, municipalities, or metropolitan areas within one country; in their analysis, they use either export data or data for some other economic variable, as the first is not extensively available at the subnational level. The only recommendation with this type of study is not to include very dissimilar economies or economic activities in the analysis. For example, the metrics obtained with this methodology could be distorted if the analysis includes countries such as China and Vatican City, as the former exports a disproportionate amount of goods compared to the latter. In this case, the recommendation is to include countries that have a minimum volume of exports and minimum number of economic activities.

2.3. Methodology for calculating the ECI of municipalities and of economic activities

Each variable is arranged in a matrix, which we denote by $M_{m,c}$.[7] The rows of these matrices contain the country's diverse municipalities (n_m), while the columns contain the various economic activities (n_c). In the case of the first variable used (PE), cell $m_{(m,c)}$ of the matrix is the number of people employed in economic activity c in municipality m.

The matrix $M_{m,c}$ is transformed into binary matrix $M^b_{m,c}$ made up of zeros and ones. This reflects what the municipalities specialize in or the location of the economic activities. If a particular cell of the matrix takes the value of one ($m^b_{m,c} = 1$), this means that municipality m is specialized in economic activity c or that the municipality has a significant number of people employed in that economic activity; otherwise, it takes a value of zero.[8]

We use this binary matrix ($M^b_{m,c}$) to define the two vectors, diversity and ubiquity, required by the Method of Reflections to calculate the economic complexity measurements. The initial measure of municipal complexity (i.e., the diversity vector) is the sum of each of

[7] We have nine data matrices, three variables in three different years.

[8] Appendix 1 outlines how the binary matrix, $M^b_{m,c}$, is calculated from the original matrix, $M_{m,c}$.

the rows of the binary matrix. Each of the values in the resulting vector shows the number of economic activities in which each municipality specializes,

$$Diversity: \qquad k_{m,0} = \sum_{c=1}^{n_c} m^b_{m,c} \tag{1}$$

The ubiquity vector (the number of municipalities that specialize in each economic activity) is obtained by adding each of the columns of the binary matrix,

$$Ubiquity: \qquad k_{c,0} = \sum_{m=1}^{n_m} m^b_{m,c} \tag{2}$$

These vectors are denoted by subscript zero because they are the initial values of the diversity and ubiquity.

Method of Reflections (MR)

The MR consists of iteratively calculating the subsequent values of diversity and ubiquity based on previous measurements, starting with the initial values, (1) and (2). This iterative process is defined in Equations 3 and 4:[9]

$$k_{m,N} = \frac{1}{k_{m,0}} \sum_{c=1}^{n_c} m^b_{m,c} \cdot k_{c,N-1} \tag{3}$$

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{m=1}^{n_m} m^b_{m,c} \cdot k_{m,N-1} \tag{4}$$

The subscript N represents the number of iterations needed to reach the last value. The iterations stop when a fixed point is reached.[10] The ECI of the municipalities is the vector $k_{m,N}$ and the vector $k_{c,N}$ the ECI of the economic activities.

3. ECI RESULTS BY MUNICIPALITY AND ECONOMIC ACTIVITY

The calculated ECIs are robust, i.e., they are not dependent upon which variable is used in the calculation.[11] Table 1 shows the strong correlation between the indexes calculated using each of the three variables.

[9] After the pioneering contribution of Hidalgo and Hausmann, alternative algorithms for calculating the ECI have been proposed in the literature.

[10] This occurs when the classification of the municipalities, $k_{m,N}$, and of the economic activities, $k_{c,N}$, remain unchanged for three consecutive iterations.

[11] Due to space constraints, we do not show the complexity results by municipality and economic activity. There are 2,453 municipalities in the country and 883 economic activities. The results are available upon request.

Table 1: Correlations between the calculated indexes*

	2009			2014			2019		
Variable	PE	GPW	VAW	PE	GPW	VAW	PE	GPW	VAW
PE	1	0.9495 (0.9510)	0.9513 (0.9469)	1	0.9471 (0.9482)	0.9396 (0.9438)	1	0.9663 (0.9354)	0.9694 (0.9418)
GPW		1	0.9929 (0.9932)		1	0.9919 (0.9949)		1	0.9973 (0.9962)
VAW			1			1			1

* Correlations not in parentheses correspond to municipal complexity and those in parentheses to the complexity of economic activities.

3.1. Geographical distribution of complexity (productive capabilities) across the country

Calculating economic complexity at the municipal level adds to and allows for a better understanding of the distribution of productive capabilities across the country, given that these are distributed heterogeneously within each state (i.e., among the municipalities).

Figure 1 shows that economic complexity within the country is not homogeneous. Almost all states, regardless of their level of complexity, have municipalities with a low level of complexity. A high concentration of low-complexity municipalities is primarily found in Oaxaca, Guerrero, Michoacán, Chiapas, and Veracruz, which are the states with the lowest level of complexity in the country. The states with an average-to-low level of complexity and a significant number of low-complexity municipalities are Hidalgo, Nayarit, Zacatecas, and Yucatán. Even in the most complex states—Coahuila, Chihuahua, Jalisco, Nuevo León, Sonora, and Tamaulipas—there are also municipalities that have a low level of complexity.[12]

Figures 2 and 3 show the heterogeneity in the distribution of productive knowledge among municipalities. The first shows the level of municipal complexity in the most and least complex states in the country in 2009, Nuevo León (NL) and Oaxaca, respectively.

Figure 2 shows that Apodaca, the most complex municipality in NL, has the highest level of productive knowledge. Moreover, a total of 14 municipalities in NL are more complex than all 570 of Oaxaca's municipalities. However, Oaxaca also has a number of municipalities that are relatively complex compared to those of NL. In fact, there are 57 municipalities in Oaxaca with a higher level of complexity than the 19 least complex municipalities of NL.

Our general aim is to show that the country's most complex states also contain municipalities with low levels of economic complexity. Conversely, one also finds municipalities with a high degree of economic complexity in states where the overall level of complexity is low. This empirical finding holds true for all 32 of Mexico's states, as shown in Figure 3.

[12]For a better understanding of this paragraph, compare this map against Map 1 in Chávez et al. (2017), p. 207, which shows the states' level of complexity.

Figure 1: Municipal complexity in Mexico (2009)

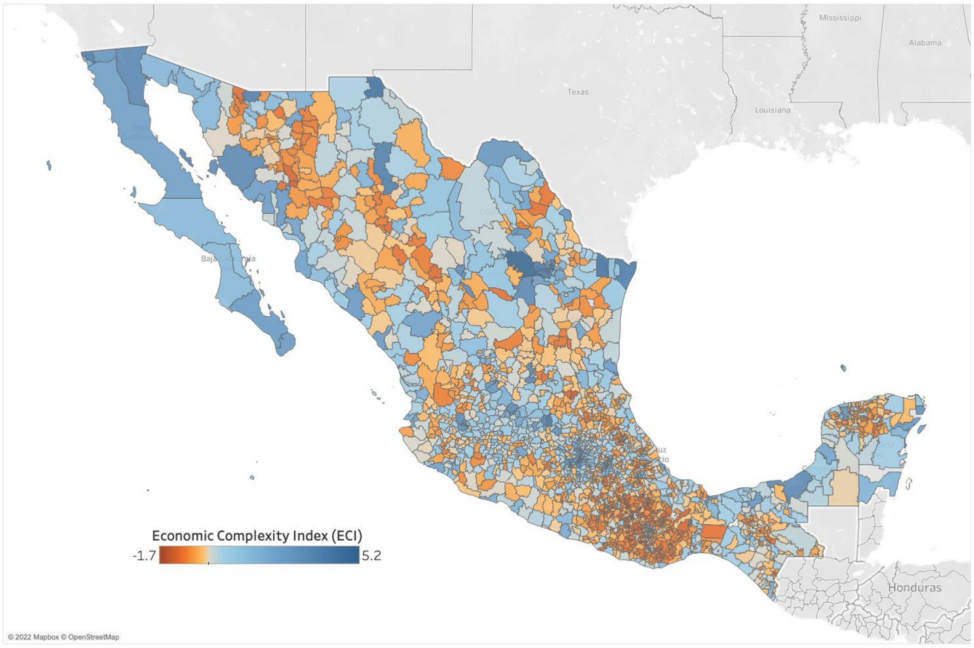
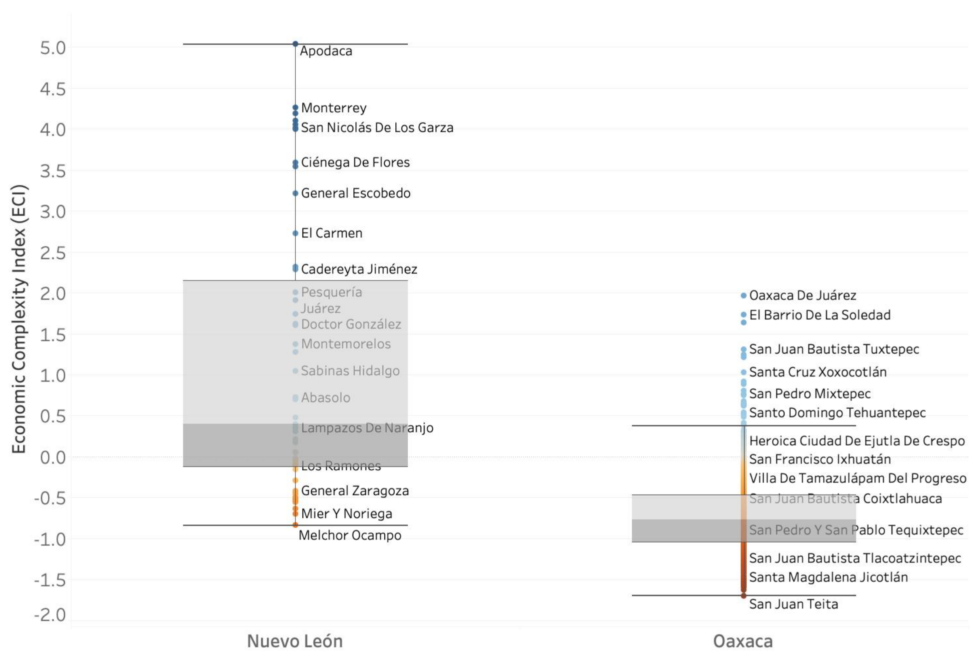
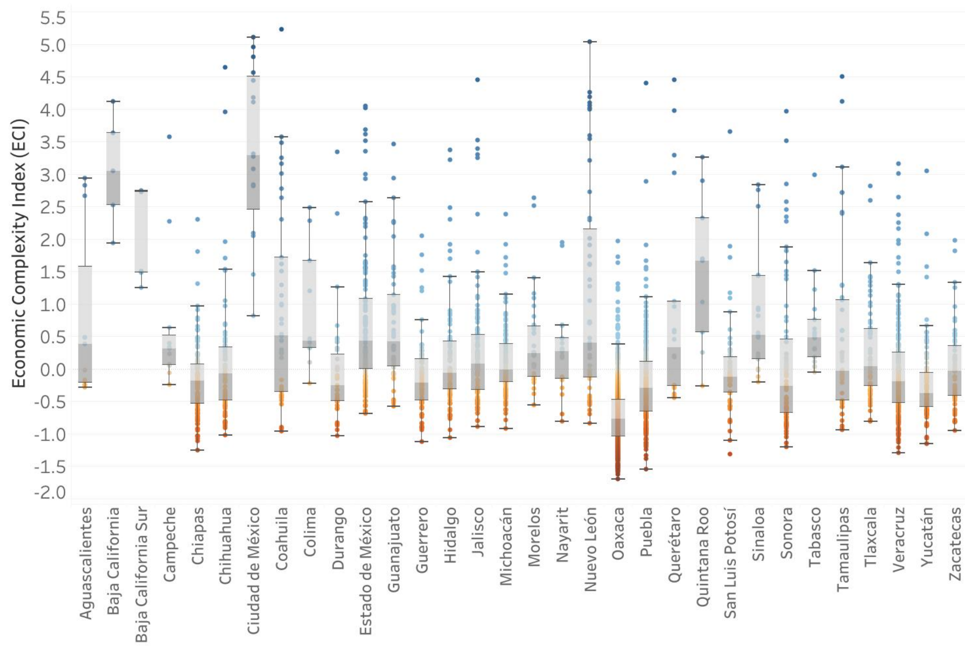


Figure 2: Municipal complexity, most and least complex states in the country (2009)



No complete listing of the municipalities is provided for either state due to space constraints. NL has 51 municipalities and Oaxaca 570. The figure above shows the most complex and least complex municipality in each state, as well as a sample of those in between.

Figure 3: Municipal complexity in all Mexican states, 2009



3.2. Empirical findings

The analysis is illustrative in nature. Our results show that municipal indicators and economic complexity are correlated, just as they have been found to be in previous studies that analyze country-, region- or state-level data.

Finding 1. Diversity and ubiquity of the activities in which municipalities are specialized

Proponents of the complexity measure assert that economies with higher levels of productive knowledge tend to be more diversified, i.e., they specialize in a greater number of economic activities. In the same way, they specialize in economic activities that are not quite so ubiquitous (i.e., ones that few other economies specialize in). In contrast, economies with less productive knowledge tend to be less diverse and specialize in economic activities that are more ubiquitous (i.e., ones in which many other economies also specialize). This means that the relationship between the measure of diversity of the municipalities ($k_{m,0}$) and the average ubiquity of the activities in which these municipalities specialize ($k_{m,1}$) must be negative. As shown in part A of Appendix 2, the correlations between this pair of variables are always negative and significant, similar to the results found by Hidalgo and Hausmann (2009), as shown in Figure 1, p. 10571 thereof.

The most diverse municipality in the country is Guadalajara, which specializes in 371 of the 883 economic activities included in the 2009 Economic Census. Its ubiquity average is 194, meaning an average of only 194 municipalities specialize in the same activities as Guadalajara does. This figure is quite low if we consider that the census covers a total of 2,453 municipalities. Table 2 shows the 10 most and least diverse municipalities in the

Table 2: Most/least diverse municipalities in the country, PE 2009

Municipality	Diversity ($k_{m,0}$)	Average ubiquity ($k_{m,1}$)	Municipality	Diversity ($k_{m,0}$)	Average ubiquity ($k_{m,1}$)
Guadalajara	371	197	Santo Domingo Roayaga	4	1460
Monterrey	303	133	Santos Reyes Yucuná	4	1690
Mérida	300	211	Trinidad Vista Hermosa	4	1496
Morelia	298	328	Magdalena Ocotlán	3	1370
Puebla	297	281	San Francisco Chapulapa	3	1806
G. A. Madero	285	302	San Miguel Tecomatlán	3	1960
Iztapalapa	277	290	San Pablo Cuatro Venados	3	1265
Aguascalientes	275	260	Santa María del Rosario	3	1729
Querétaro	275	156	Santa María Nativitas	3	1341
Cuauhtemóc	267	145	Santa María Zaniza	2	1960

country, along with the average ubiquity of their economic activities.

The 10 least diverse municipalities in the country are located in the state of Oaxaca and specialize in very few economic activities (between 2 and 4 each). The lowest ranking municipality has an average ubiquity of 1,960, meaning an average of 1,960 other municipalities across the country specialize in the same economic activities as it does. Having such a high average ubiquity implies that it has a very basic economic structure with little productive knowledge. The municipality has such a low level of productive knowledge that 1,960 other municipalities specialize in the same activities it does. In the case of the least diverse municipality, Santa María Zaniza, the two economic activities it is specialized in are i) water collection, treatment, and supply, and ii) retail trade in grocery stores.

In contrast, a low average ubiquity indicates that an economy has an economic structure characterized by a high level of productive knowledge. An average of only 194 municipalities in the country specialize in the same economic activities as Guadalajara does. Few of them have the capacity to carry out the kind of economic activities Guadalajara specializes in because the latter's activities are more sophisticated, have a higher average value added, or require a greater level of productive knowledge. Guadalajara specializes in highly complex economic activities, e.g., software publishing and integrated software publishing and reproduction (economic activities in which only 14 other municipalities are specialized), and industrial design (an economic activity in which only 20 other municipalities in the country are specialized).

Finding 2. Level of wealth and municipal complexity

Previous studies have shown that economies with higher levels of complexity also enjoy a higher level of wealth per capita (measured in this paper as gross product per capita per municipality).[13]

[13]Though GDP per capita is generally used as a measure of wealth, in the case of Mexico there is no official

Table 3: Most/least complex municipalities in the country, 2009

15 most complex municipalities		15 least complex municipalities	
1	Ramos Arizpe, Coahuila	2440	San Francisco Nuxaño, Oaxaca
2	Miguel Hidalgo, CDMX	2441	Santa María Yosoyúa, Oaxaca
3	Apodaca, Nuevo León	2442	San Pedro Topiltepec, Oaxaca
4	Álvaro Obregón, CDMX	2443	San Juan Lajarcia, Oaxaca
5	Azcapotzalco, CDMX	2444	Santiago Nundiche, Oaxaca
6	Juárez, Chihuahua	2445	Santa Catarina Zapoquila, Oaxaca
7	Cuajimalpa, CDMX	2446	Santa María del Rosario, Oaxaca
8	Reynosa, Tamaulipas	2447	Santa María Nativitas, Oaxaca
9	El Marqués, Querétaro	2448	San Miguel Ixitlán, Oaxaca
10	El Salto, Jalisco	2449	San Miguel Tecomatlán, Oaxaca
11	Benito Juárez, CDMX	2450	Santa María Texcatitlán, Oaxaca
12	Cuautlancingo, Puebla	2451	San Pedro Jaltepetongo, Oaxaca
13	Monterrey, Nuevo León	2452	Santiago Tepetlapa, Oaxaca
14	S. Catarina, Nuevo León	2453	Santa María Zaniza, Oaxaca
15	Cuauhtémoc, CDMX	2454	San Juan Teita, Oaxaca

Since the economic complexity of municipalities reflects the productive knowledge contained in their economic structures, the literature establishes that there should be a positive relationship between the level of wealth of a municipality and its level of complexity. More complex municipalities (i.e., those with greater productive capabilities and specialized in more sophisticated economic activities) should have a higher level of wealth because they are capable of producing a wider variety of goods, goods that are more sophisticated, i.e., with a higher value added. Evidence of this result is shown in part B of Appendix 2.

Table 3 shows the 15 most and least complex municipalities in the country. All of the most complex are located in states that are also the most complex,[14] either in the center of the country or along the northern border, and all of these have the highest levels of gross product per capita in the country. The least complex municipalities are all in the state of Oaxaca, the least complex Mexican state in 2009,[15] and each of these has one of the lowest gross products per capita in the country.

Finding 3. Growth rate and municipal complexity

There is a positive relationship between municipal growth rates in the years 2009–2019 and their level of economic complexity in the initial year, 2009. In the words of Hidalgo and Hausmann (2009), economic complexity is highly predictive of future growth, just as Chávez et al. (2017) showed for Mexican states.[16] Evidence of this result can be found in part C of Appendix 2.

measure of municipal GDP per capita.

[14] See Chávez et al. (2017), Table 1 and Map 1, pp. 206 and 207, respectively.

[15] Ibid.

[16] Chávez et al. (2017), Table 3 and Figure 5, pp. 212 and 213, respectively.

More complex economies are more productively diverse and produce goods with higher value added. Moreover, in economies with more productive knowledge, it is more likely that knowledge can be pooled and give rise to the creation of new products and/or economic activities with higher value added. Consequently, such economies will tend to have higher growth rates.

Finding 4. Relationship between earnings per worker and the complexity of economic activities

According to the literature on economic complexity, there should be a positive relationship between the level of complexity of economic activities and the average earnings of the workers employed in them.[17] Since economic activities that are more complex or produce goods with higher value added generally require better-skilled workers or workers with greater productive capabilities, we should find that those employed in them receive higher average salaries. Conversely, less sophisticated activities, which employ workers whose productive skills are more basic, would be expected to pay their employees less.

The empirical evidence on the relationship between these two variables is presented in part D of Appendix 2. It is clear that more complex economic activities tend to pay their workers higher average salaries. The empirical evidence in this subsection illustrates the importance of having a more complex economy. The more complex the economic structure, the more value added the goods produced and the higher people's wages or earnings.

Table 4 shows the ten economic activities that pay the highest and lowest average salaries in Mexico. Most of the highest paying economic activities correspond to either the financial and insurance services sector or that of head offices. These results are consistent with those of Chávez et al. (2017).[18]

3.3. Relationship between municipal complexity and the complexity of the companies located there

The aim of this subsection is to analyze the types of companies/economic units found in the country's municipalities. Specifically, we look at the relationship between the productive capabilities of the country's municipalities (municipal economic complexity) and the average complexity of the new economic activities of the firms located in each.

Is it common for there to be companies in municipalities with low productive capabilities that are engaged largely in highly complex economic activities? For example, some municipalities in the Isthmus of Oaxaca,[19] which are generally characterized by a low level of

[17] Average earnings are calculated by dividing the total earnings of each economic activity by the total number of people employed in it. This information is also calculated using data from the Economic Censuses.

[18] See Chávez et al. (2017), Table 2, p. 209. In their analysis of complexity by state, they find these two sectors to be the most complex in the Mexican economy. The ten listed include economic activities in the *Mining*, *Manufacturing*, and *Transportation sectors.* Most of the ten economic activities that pay the lowest per capita salaries correspond to the *Other Services sector*, though some correspond to the *Public Administration* and *Retail Trade sectors.*

[19] The main wind energy-generating municipalities along the Isthmus are Santo Domingo Ingenio, Juchitán de Zaragoza, Unión Hidalgo, El Espinal, and Asunción Ixtaltepec. These rank 1,928th, 346th, 1,465th,

Table 4: Workers' earnings by economic activity, 2009

10 highest-paying economic activities		10 lowest-paying economic activities	
1	Air navigation services	10	Footwear and other leather goods repair
2	Central bank	9	Natural hard fibers preparation and spinning
3	Oil and Gas extraction	8	Retail trade of used goods
4	Petroleum and natural gas maritime transportation	7	Manufacturing of flags and other textile products, not elsewhere classified
5	Finantial fund and trust	6	Retail trade in grocery stores
6	Corporate	5	Bicycle repair and maintenance
7	Petroleum refining	4	High sea transportation, except petroleum and natural gas
8	Manufacturing of basic petrochemicals from natural gas and refined petroleum	3	Self-help organizations for alcoholics and persons with other
9	Development bank	2	Wicker products manufacturing, except palm
10	Scheduled air transportation, domestic airlines	1	Services related to forestry

economic complexity, house companies involved in wind energy production, a highly complex economic activity. Is this typical of most municipalities in Mexico or just an isolated case? If it is the first, it would be logical to conclude that municipal growth could be achieved by attracting companies that engage in complex economic activities, which, as we saw earlier, pay their employees higher salaries.

According to the literature on complexity,[20] the municipalities of the Isthmus of Oaxaca must be isolated cases, the companies engaged in those complex economic activities having set up in the region as a result of very specific conditions. The accumulation of productive knowledge and the generation of complex economic activities is generally a gradual process that takes time to unfold. For more complex activities to develop, a greater pool of individual expertise is required and, in general, it should be impossible to find less complex municipalities with a majority of firms engaged in highly complex activities. To verify the veracity of this argument, we provide empirical evidence of a positive relationship between the ECI of municipalities and the average complexity of the economic activities of the firms operating in them, which we will denote as $(\bar{k}_m)$.

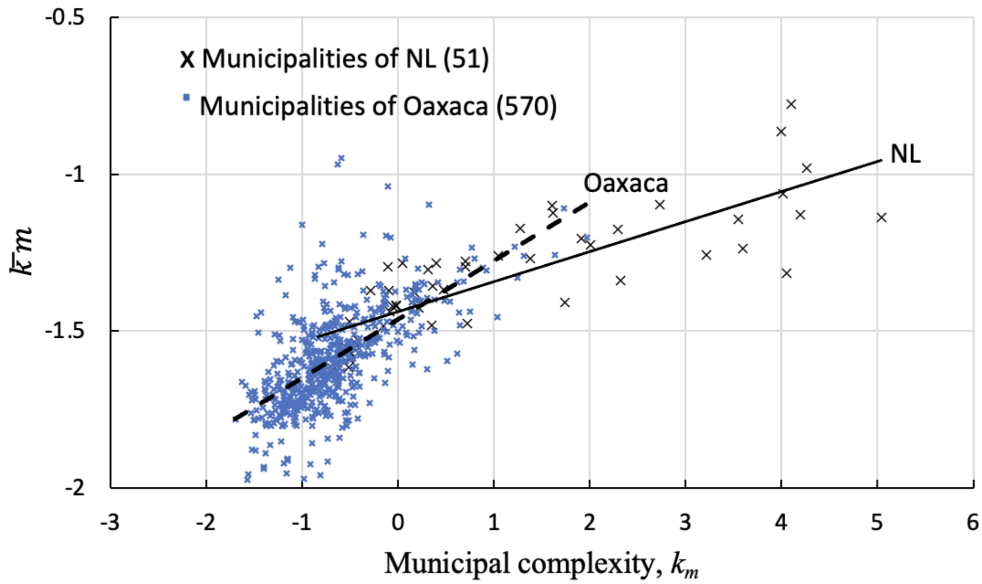
To calculate the variable corresponding to the average complexity of the economic activities of the firms in each municipality, $\bar{k}_m$, we turned to the DENUE.[21] The variable is

790th, and 764th respectively in the municipal complexity rankings, meaning most have a low level of complexity.

[20]See Hidalgo et al. (2007).

[21]The DENUE is the most complete and up-to-date record of economic enterprises or firms that exists in

Figure 4: Relationship between k_m and $\bar{k}_m$, the most and least complex states



The trend between the two variables is shown by the solid line for the municipalities of NL and by the broken line for the municipalities of Oaxaca.

calculated as per Equation 5,

$$\bar{k}_m = \frac{\sum_{i=1}^{i_m} k_c^{i_m}}{i_m} \qquad \forall \qquad m = 1, 2, 3, ..., 2453 \tag{5}$$

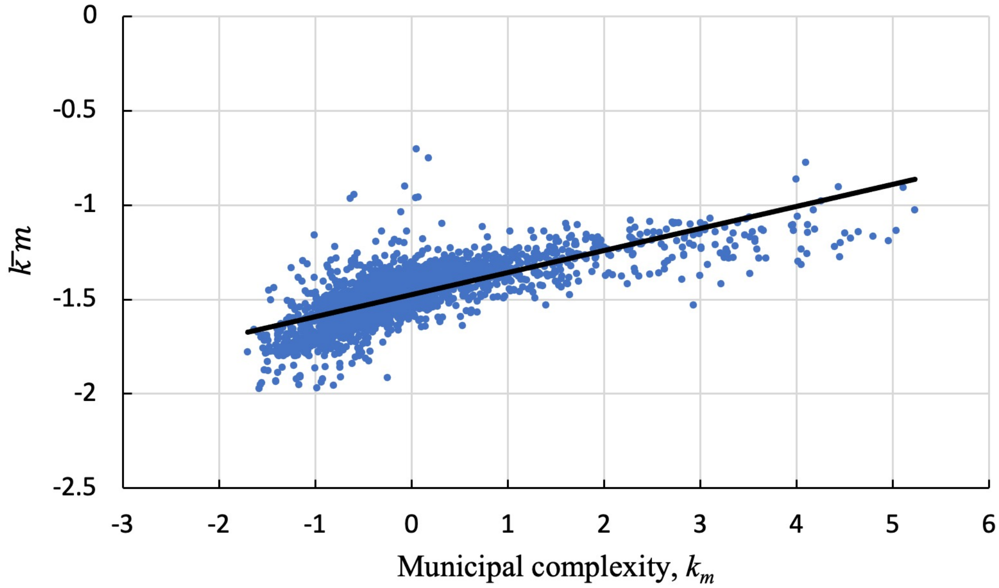
where $\bar{k}_m$ is the average complexity of the economic activities of the firms in municipality m, $k_c^{i_m}$ the level of complexity of the economic activity in which firm i is engaged in municipality m, and i_m the number of firms in municipality m.

Before we show the relationship between these two variables for all the municipalities in the country, in Figure 4 we provide an example comprising two states by way of illustration. Figure 4 shows the relationship between the complexity of municipalities and the average complexity of the economic activities of the new firms located in them in the country's most complex state (NL) and least complex state (Oaxaca). It is evident that there is a positive relationship between the variables in both states. As the municipalities of NL are, on average, more complex than those of Oaxaca, the observations corresponding to the former are further to the right and higher in the graph.

An analysis of the other 30 states reveals that the general pattern shown in Figure 4 holds for the rest of the states. The municipalities of the most complex states, which generally have more complex municipalities, tend to be located to the right of and higher up in the scatterplot because these municipalities also tend to have firms which, on average, carry out

Mexico. We consulted the first edition of 2020 (the fifteenth produced since 2010), at which time there were slightly over 5 million active firms. This directory contains detailed information on economic units across the country, in particular their location, size, and the economic activity in which they engage.

Figure 5: Relationship between k_m and $\bar{k}_m$, all municipalities in the country



economic activities that are more complex. Therefore, if we combine all the information on all the municipalities in the scatter diagram, we find there to be a positive relationship between these two variables.

Figure 5 shows that the positive correlation between the two variables holds when we consider all the municipalities in the country, thus providing evidence to support the argument of Hidalgo et al. (2007). This implies that economies move gradually through the "product space," i.e., they start with economic activities with a low level of complexity and, over time, acquire new productive capabilities, that eventually allow them to develop more complex ones.

4. CONCLUDING REMARKS

The literature on complexity and evolutionary economic geography provides a robust framework for understanding how economic growth is generated in different countries and regions. This process requires economies to acquire new skills, capabilities, and knowledge over time in order to gain comparative advantages, with the aim of becoming more diverse and producing higher-value-added goods.

In applying the economic complexity methodology followed in this study, we used the most disaggregated economic and geographic information available for Mexico. This enabled us to corroborate that the main findings of country-level and state-level studies also hold true at the municipal level in Mexico; specifically, the positive relationship that exists between the level of complexity of a municipality, its level of wealth, and its economic growth, as well as between the level of complexity of economic activities and the average earnings of the workers employed in them. Moreover, our findings confirm that the average level of complexity of the economic activities undertaken by the municipalities' new economic units is positively correlated to the municipalities' economic complexity. This result is in line with previous studies; it is uncommon to find a large number of firms carrying out highly complex economic activities located in regions with low levels of complexity. Firms generally begin by carrying out less complex economic activities and slowly acquire more productive capabilities that allow them to develop more complex ones. This process generates economic growth and, in general, economic benefits for the population.

Lastly, future research opportunities in this literature include: i) gaining a deeper understanding of the specific features of the process of increasing local productive sophistication (i.e., geographic, institutional, and business aspects, and so on); ii) analyzing the economic and industrial impact that the most complex municipalities have had on their neighbors, and iii) identifying the specific productive knowledge that needs to be developed at a local level in order to attract or generate new industries that will help transform current economic structures.

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APPENDIX 1

To construct the binary matrices, $M^b_{m,c}$, we use the definition of Location Quotient (LQ) commonly employed in regional science literature:

$$LQ_{m,c} = \frac{\frac{PE_{m,c}}{\sum_{c=1}^{n_c} PE_{m,c}}}{\frac{\sum_{m=1}^{n_m} PE_{m,c}}{\sum_{m=1}^{n_m}\sum_{c=1}^{n_c} PE_{m,c}}}$$

where $PE_{m,c}$ is the number of people employed by municipality m in economic activity c; $\sum_{c=1}^{n_c} PE_{m,c}$ is the total number of people employed by municipality m (the sum of PE in all economic activities); $\sum_{m=1}^{m_n} PE_{m,c}$ is the total number of people employed in economic activity c throughout the country, and $\sum_{c=1}^{n_c}\sum_{m=1}^{m_n} PE_{m,c}$ the total number of people employed in the entire country. Each entry of the matrix is defined as follows:

$$m^b_{m,c} = \begin{cases} 1 & if \quad LQ_{m,c} \geqslant R^* = 1 \\ 0 & otherwise \end{cases}$$

The value of the threshold R^* is not determined but instead set by the researcher depending on how the researcher wishes to define specialization. Using the threshold $R^* = 1$ implies that a municipality m is considered to be specialized in an economic activity c if the proportion of people employed in that activity with respect to the total number of people employed in the municipality is equal to or greater than the equivalent proportion nationwide.

Our calculations of the ECIs are robust to different values of R^*. We used $R^* = 0.7$, 0.8, 0.9, 1.1, 1.2, 1.3 and the results are very similar.

APPENDIX 2

A. Average diversity and ubiquity of municipalities

The table below shows the correlation between the average diversity and ubiquity of municipalities for the ECI calculated with the three different variables for the three years in the sample.

Table A1: Correlations between average diversity and ubiquity of municipalities*

Year	PE	GPW	VAW
2009	-0.812	-0.861	-0.865
2014	-0.801	-0.858	-0.867
2019	-0.758	-0.786	-0.796

*All correlations are statistically different from zero.

B. Level of wealth and ECI of municipalities

The table below shows the correlation between the level of wealth of municipalities (measured as gross product per capita per municipality) and their ECI calculated with the three different variables for the three years in the sample.

Table A2: Correlations between the level of wealth of municipalities and their ECI*

Year	PE	GPW	VAW
2009	0.793	0.821	0.831
2014	0.801	0.856	0.865
2019	0.835	0.874	0.883

*All correlations are statistically different from zero.

C. Growth rates and ECI of municipalities

The table below shows the correlations between the ECI of municipalities in 2009 and their growth rates during the period 2009–2019 for all the variables used to calculate the ECIs.

Table A3: Correlations between growth rates of municipalities and their ECI*

PE	GPW	VAW
0.782	0.768	0.779

*All correlations are statistically different from zero.

D. Earnings per worker and ECI of economic activities

The table below shows the correlations between earnings per worker and the ECI of economic activities for all the variables used to calculate the ECIs and the three years in the sample.

Table A4: Correlations between average earnings by economic activity and the complexity of economic activities*

Year	PE	GPW	VAW
2009	0.735	0.834	0.845
2014	0.742	0.821	0.834
2019	0.757	0.796	0.798

*All correlations are statistically different from zero.