Center for International Development
at Harvard University

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This research was led by Ricardo Hausmann and developed in collaboration with the Inter-American Development Bank (IDB) Emerging and Sustainable Cities Program. All opinions expressed are solely those of the authors and should not be considered a reflection of the opinions of the IDB.

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I Executive Summary

For 30 years, Hermosillo has been wondering whether it has a future after Ford. Until the early 1980s, the city relied mainly on agricultural activity. When the multinational motor company arrived in this northwestern Mexican city in 1986, it changed the history of a region that up until that point had relied heavily on agriculture. The assembly plant was established and many auto parts suppliers sprang up, triggering industrialization and increasing the complexity of its economy, its productivity, and wages. Intensive manufacturing development turned Hermosillo into the fifth richest metropolitan area in Mexico in 1998.

Broadly speaking, this growth trajectory was maintained. In 2015, Hermosillo was in the top 5% of wealthiest municipalities, with poverty levels and informal employment rates significantly lower than in the rest of the country. But the economy of this city in Sonora State has clearly lost its dynamism over the past few years. Even in Mexico's low-growth context during the period 2005-2015, growth in per capita gross domestic product in Hermosillo (1.3%) fell below the federal average (1.4%). Hermosillo's relative performance during this decade was not uniform. Between 2005 and 2010, it grew at a rate of 1.3%, placing it in the 66th percentile (among the top 34% for growth rate) of all municipalities in Mexico. In the second half of the decade, Hermosillo barely reached 1.2% growth, falling to the 47th percentile (53% of Mexican municipalities grew more). The situation worsened in the years 2013-2015, when output per worker fell by 7.2%.

What happened in Hermosillo? Can the current economic structure sustain the municipality's high wages and guarantee future growth? What policy interventions are needed?

Seeking answers to these questions, the Center for International Development (CID) at Harvard University joined forces with the Inter-American Development Bank or IDB, in particular with its Emerging and Sustainable Cities Program (ESC). This program is a technical assistance initiative that provides support to regional governments to develop and execute urban sustainability projects. ESC's goal is to contribute to priority urban interventions to provide the sustainable, harmonious growth of cities. This part of its vision is aligned with the idea of promoting inclusive growth and prosperity that guides CID's research.

Specifically, in our work in Hermosillo we employed two methods we developed at CID to help us discover the main limitations and opportunities for productive diversification specific to the location. The first method, Growth Diagnostics, is an exhaustive analysis that identifies the main constraints to private investment and growth in the location. The second is the Economic Complexity Analysis, which detects the productive capabilities of a location and the set of implicit and explicit factors that enable development of certain economic activities. These capabilities are revealed by the products each location is already able to produce and export competitively. Opportunities for

diversification require similar productive capabilities to those already found on site so that they have a higher probability of success.

Our methodologies complement each other. They demonstrate, among other things, how investment in the sectors and products with the greatest potential may have been inhibited by the lack of any productive capability or by inadequate supply of some key public goods, which can be detected in the Growth Diagnostics. Making this connection explicit is precisely one of the most innovative components of our work in Hermosillo. It was the first time we adapted these methods specifically to the municipal level.

This paper summarizes the main findings from the series of research efforts and articulates the resulting policy recommendations. It helps to understand the recent growth trajectory in Hermosillo, and sheds light on the factors the municipality should focus its actions on to sustain the prosperity it has known up until now.

Hermosillo's economy continues to rely on a set of sectors that were fairly advanced three decades ago, but that have become more common worldwide over time. Authorities fostered these sectors in the '80s to accelerate the process of industrialization and growth. But today, as could be expected, they play a major role in the recent slowdown. The most obvious of these, which certainly includes the Ford plant, is manufacturing, which represented 79% of total production in 2013 and 79% of exports in 2014. It has undergone a cumulative drop in both number of jobs (7.3%) and median wages (5.9%) over the past five years (2012-2017).

This trend did not occur in a group of 10 municipalities we've chosen that are comparable to Hermosillo in terms of workforce size, exports, export products, geographic location, and high economic complexity. Hermosillo has an unusual combination of a fall both in wages and employment suggesting that there has been a decline in job demand in the city's manufacturing sector.

Let's take the most illustrative example: automobiles. When automobile production reached the city in 1986 it was one of the most complex activities in the world. Only 13% of countries in the world showed a comparative advantage in automobile exports. But by 2010 the figure was approaching 50%. Hermosillo still depends on a sector that accounts for more than half of its production, value added, and exports, but that does not offer the growth potential it did decades ago.

Currently, 60% of products in which Hermosillo has a comparative advantage entered its export basket prior to 2004. Meanwhile, other comparable cities began from a point very similar to Hermosillo, and today, their results are quite different. The reason is that those places were able to leverage their productive capabilities to diversify exports into other products that were more complex and less ubiquitous.

Hermosillo's constraints when adding new products to its export matrix stand out even more starkly when we consider the future of the automobile industry. Hermosillo's share of total vehicle

imports in the US has gone from 5.5% in 2006 to 3.7% in 2014. In June 2017, Ford canceled its plans to invest in a new line at its plant in Hermosillo, and sent production of the new Focus model to China. If we add the risks of renegotiating the North American Free Trade Agreement, we have to wonder about Hermosillo's ability to react if the automobile industry declines at a faster rate.

What can the authorities do to add variety to the city's productive structure? To answer this question, we must first understand why Hermosillo was not able to diversify its production based on its inventory of productive capabilities acquired in those initial activities that began to take root in the '80s.

Our work has led us to identify three sets of complementary reasons. Firstly, there are coordination failures in Hermosillo that prevent an adequate supply of the enabling factors to develop industries with high potential. We know that these capacities are missing when, for example, there is a lack of infrastructure (access to ports and airports, etc.), or limits to making investments (judicial insecurity, macroeconomic instability, etc.). But the municipality lacks the necessary institutional mechanisms to identify the necessary productive capabilities that would lead to sectors and products with potential, and that should be revealed through a process of productive dialog. While this dialog is being organized, our Growth Diagnostics offers a starting point, by identifying three deficiencies in public services that tend to inhibit the appearance of new sectors: electricity, water, and logistics infrastructure. When selecting recommendations for this paper, we quantified the extent to which the sectors with greatest potential in Hermosillo depend on the quality of supply of these services.

Secondly, the higher level of public employment may be causing wage distortions in Hermosillo. Wages are 35.7% higher than in the rest of Mexico, and 16.7% higher than the average for the comparison group. In the case of the export sector, the gaps are 38.7% and 16.7%, respectively. These differences cannot be explained by any of the individual worker factors (education, experience, gender, indigenous person), nor by the sophistication or productivity of the productive structure (which is lower in Hermosillo). One possible hypothesis is that public employment, where wages are determined by level of education and experience rather than productivity, could be pushing wages upward.

This suspicion is based on the fact that the public sector in Hermosillo is the fifth largest employer and the proportion of public employment is 1.8 times greater than the average for the comparison group. Between 2012 and 2017, Hermosillo was the only municipality in the comparison group where both wages and the amount of government employment grew (1.5% and 3.8%), while the trend in the rest of Mexico was for wage increases accompanied by a drop in the number of employees. These dynamics may be making it too costly to develop some occupational vectors in the city that could normally grow because the other productive capacities they require already exist.

Lastly, Hermosillo would appear to have a lack of innovation catalysts. Cities and regions learn to do new things through various mechanisms. Two of the most important are attracting firms and individuals that have the necessary know-how, that is, direct investment and immigration. Hermosillo

does not stand out in either of these areas. Based on FDI Markets[1] statistics, between 2003 and 2016, Hermosillo received approximately US$3.2 billion in direct foreign investment. Of this, 91% can be accounted for by just one company: Ford. This is notable not only as an enormous concentration in just one firm, but also because most of the investment went to expansion of pre-existing activities. Automobile assembly can be a decisive contributor to growth–Hermosillo is a good example of this–but it brings with it much less know-how than installing corporate headquarters or research and development. It is estimated that since 2003, Hermosillo has not received any investment in this type of activity, which represents 3% of investment in the rest of Mexico and 2% in the comparison municipalities. The findings are no more encouraging on the immigration front. In 2005, barely 0.6% of workers in Hermosillo were foreign immigrants, one third of the figure for the comparison group. The internal migration rate is in fact more in line with the comparisons, but in Hermosillo, 62% of this rate are migrants who come to the city from other municipalities in Sonora, so they may not be adding new productive knowledge. The low impact in Hermosillo of these two highly important catalysts, direct investment and immigration, may be influencing the lack of new economic activities.

What can be done to reverse this situation? In this paper we include a packet of inputs for designing public policy, in three key areas: identification of sectors with potential, mechanisms to resolve coordination problems, and urban planning.

The complexity profile for Hermosillo has enabled us to identify sectors and products with high viability potential that require a knowledge base similar to the one that already exists in the municipality. In addition to considering technological proximity (how close the technical capacity of those sectors is to the city's pre-existing industrial activity), we have designed a preliminary sorting mechanism that weighs other conditions affecting the profitability of those sectors. These conditions are both external (evolution of product demand on world market, strength of product in Mexico, and labor impacts), and internal (dependence on electricity, water, and logistics). This gave us a list of sectors where the majority are in some way associated with the automobile production ecosystem and the aerospace sector, such as machinery (parts for spark-ignition engines, drive shafts, pumps, compressors and fans; densimeters, thermometers and other gauges; liquid pumps), and electronics (for example, devices for automobile lighting and electric ignition devices). Other products with potential in Hermosillo are electrical transformers and electrical control or distribution panels, plus chemicals and plastics (for example, vulcanized rubber tubes and downstream manufacturing). Altogether, the sectors that could be included in local production have an average dependency on electricity, water, and logistics that is greater than the dependency for those sectors already in

[1]For Direct Foreign Investment statistics, we used FDI Markets, which reflects investment announcements taken from the media. This database shows a bias toward large projects with greater visibility, so it is not exhaustive. Also, the database does not follow up to confirm whether these investments were in fact made according to the preliminary announcement.

Hermosillo, which indicates that supply deficiencies will have to be resolved if we want to maximize the likelihood that the new sectors will appear.

This list of sectors and products, and the factors resulting from the Growth Diagnostics, should be considered merely as a road map to guide the start of an iterative, dynamic process of public-private dialog to solve the coordination problems that have inhibited productive diversification.

Our second recommendation is to provide the city with an institutional mechanism allowing it to gather information on the potential sectors and their requirements, evaluate solutions to resolve restrictions, and learn from its own successes and failures. In our experience, this requires a set of fundamental functional elements. Firstly, it must have active participation from the private sector, whose role must go beyond generating requests to ideally beginning to take part in the design, co-financing, and implementation of solutions. Secondly, it should be able to collect information from the perspective of potential investors. We do not mean simply "selling" the city, but on understanding what is missing via interactions with stakeholders that so far have not been found in the city. Thirdly, this institutional mechanism must be well-supplied technically, and be able to validate the results of the public-private process in terms of potential sectors and major restrictions, as well as propose and implement solutions. Fourthly, it should help the city to understand its own productive potential. Lastly, it should make use of instruments other than tax exemptions and focus on providing public goods. While the former affects all areas equally and horizontally, the latter have a greater capacity to resolve restrictions to the entrance of specific sectors.

While this paper was being written, the new State Competition and Economic Development Act was being approved—a unique opportunity to formalize some of these changes.

Hermosillo's success in attracting investment and promoting catalysts that will help it diversify its economy will depend critically on urban planning. Ultimately, the decision to settle in an area is determined not only by its geographic location, market potential, and institutional capability, but also by its quality of life: restaurants, cultural spaces, shopping centers, the public space, parks, historic center, pedestrian zones, availability of high-quality public and private services (for example, education, health, and citizen safety), and facilities for getting around and connecting with work hubs (for example, public transportation). These factors lie outside our field of specialization, but they are common elements in investment promotion brochures because they represent the cornerstone for attracting and retaining talent and knowledge.

Unlike the period when Ford arrived, today the municipality is in a favorable position. It has high income levels, low poverty and informal sector, and it is one of the cities in Mexico with the greatest competitive potential.[2] But it cannot rest on its laurels. Its per capita income is higher than what would be expected given its economic structure, a situation which, according to many studies, generally

[2] http://imco.org.mx/competitividad/indice-de-competitividad-urbana-2016/

foreshadows lower growth rates.[3] The economic slowdown of the past few years is an alarm bell that should be encouraging authorities to rethink the local growth strategy. The key to overcoming these challenges lies in the city's own successful experience at attracting more complex industries, in the comparable towns that have managed to diversify, and in the specific factors that are affecting growth in Hermosillo today.

We can compile a set of policy recommendations from these three currents that are tailored to the city's opportunities and constraints, and that will help Hermosillo have greater economic sustainability and make growth more inclusive. This report provides inputs for this process of evaluation and rediscovery.

II Methodology

We used two main methodological approximations when analyzing economic performance in Hermosillo: Growth Diagnostics and Economic Complexity Analysis.

Growth Diagnostics

This methodology to identify the main restrictions on growth faced by a country, region, or town is based on the premise that economic reforms will be successful only if those aspects that prevent economic growth in the area being analyzed are correctly identified. In this sense, a policy based on the Growth Diagnostics strategy considers the following:

- Economic Growth Is Central: Improving people's standards of living is the main goal that economic and social reforms proposed by governments should have. Economic growth plays a central role in attaining this goal. This is why reforms should aim to improve growth rates, i.e., they should be economic growth strategies.
- Prioritizing: A long list of structural reforms is not much use for governments, particularly with the administrative, political, and budgetary restrictions they face. The economic Growth Diagnostics method signals those aspects of the economy that are more critical to resolve, giving some recommendations a greater sense of urgency than others.
- Answers to Local Problems: Reforms based on universal formulas or on best practices available at the time have a high probability of failing. The focus of the economic Growth Diagnostics considers the local context, concentrating on the problems and/or opportunities afforded by each region, while it follows some overarching guidelines, such as property rights and proper operation of markets, to name but two.

This methodology seeks to identify how dominant a role potential restrictions may have: credit market problems, low levels of complementary factors of production (such as human capital or infrastructure), or appropriability of returns, whether due to government shortcomings (e.g., excess

[3] See Hausmann, Hidalgo, et al (2011).

taxation, fiscal instability, public insecurity), or market failures (e.g., coordination problems between private agents or negative externalities to innovation).

After identifying active limits on growth, the methodology encourages suggesting a common syndrome to all the bottlenecks faced by the economy in question. In this way, it sees beyond the symptoms of the problem. Describing the syndrome leads to creating inputs for designing public policies specially focused on the true causes behind the economic performance in question.

Economic Complexity Analysis

The theory of Economic Complexity is based on the premise of Hausmann, Hidalgo, et al. (2011) that products are made with knowledge. For example, toothpaste is not only paste in a tube. Its real value lies in the fact that it shows a knowledge of chemicals that aid with brushing and removal of germs. In their opinion, the amount of knowledge rooted in a society does not depend mainly on what each individual knows. On the contrary, it depends on the diversity of knowledge spread among individuals and their ability to combine this knowledge and make use of it via networks of interaction.

Complex economies are those that can combine vast amounts of knowledge over large networks of people to generate a wide diversity of knowledge-intensive products. However, simpler economies have a narrow base of knowledge and therefore produce fewer, simpler products that require smaller networks of interaction.

Knowing how to make a product requires one type of knowledge and a combination of knowledge, when a location makes that product it is revealing that it already has some knowledge. Using this observation, Hausmann, Hidalgo, et al. (2011) derived the two principles that led them to build a measure of economic complexity for locations (Economic Complexity Index, ECI) and products (Product Complexity Index, PCI). These principles are as follows:

1. Locations whose residents and organizations have more knowledge have what they need to produce a more diverse set of products;
2. Products that require large volumes of knowledge are feasible only in the few areas where all the necessary knowledge is available.

Diversity and ubiquity are approximations of the variety of capabilities available in one location, or the variety of capabilities required for a product, respectively. Locations are more complex if they can produce a wider variety of products, while products are more complex when they can be produced only by a small number of locations.

Since economic complexity reflects the amount of knowledge built into the productive structure of an economy, it is not surprising to find a strong correlation between indicators of complexity and incomes. Hausmann, Hwang, and Rodrik (2007) document the positive relationship between GDP per capita of a country and the sophistication of its exports. Additionally, Hausmann, Hidalgo, et al. (2011) find that countries whose economic complexity is greater than expected given their level of

income tend to grow more quickly than those that are "too wealthy" for their current complexity level. In this sense, they argue, economic complexity is not only a symptom or an expression of prosperity, it is a driver of it.

To sum up, economic complexity is relevant because it helps explain the differences in countries' income levels and, even more importantly, because it predicts economic growth.

We can infer from the above that the economic development process implies moving from producing simple goods to producing more sophisticated goods. This process is often called structural transformation. Hausmann and Klinger (2006) argue that inputs and the necessary capabilities to produce a good are imperfect substitutes for those needed to produce others, and the degree of substitution varies. Therefore, the probability that a location will develop the capability to produce a good is related to its installed capacity to produce other, similar goods. In this context, Hausmann, Hidalgo, et al. (2011) assert that new capabilities will accumulate more easily if they can be combined with other pre-existing capabilities. This reduces the need to accumulate various new capabilities simultaneously. One consequence of this, they maintain, is that a country will diversify by going from the products that it already produces to others that require a similar host of assets and built-in knowledge.

The Economic Complexity Analysis aims to put this theory into practice by identifying the current productive knowledge base that a specific location offers, understanding how it is comprehended and how it has evolved over time, and then, indicate the potential path to structural transformation. For more detail on the terminology of Economic Complexity, see Appendix 1.

Main Sources of Information

We used over 30 different sources of data in preparing this work, including specific instruments (e.g., National Regulatory Quality and Government Impact on Companies Survey), administrative databases (e.g., National Economic Units Statistical Directory), statistical reports (e.g., State Statistics Annual Directories), interactive information systems (Mappir Mexico), and other information aggregator sources (e.g., State and Municipal Database System).

The data used most frequently in this analysis come from economic censuses, population censuses, intercensal estimates, the national occupation and employment survey (Spanish initials, ENOE), and the Mexican Atlas of Economic Complexity. A more in-depth description of the information sources used for each type of analysis can be found in Appendix 2.[4]

III Main Findings of the Analysis

In this section we present only the main findings of the Growth Diagnostics and Economic Complexity Analysis for Hermosillo. We will duly describe economic performance in the city, detail

[4] If you need more specifics on the information source used in a particular analysis, please contact the CID at Harvard research team.

the role that the manufacturing sector may be having, and identify the top restrictions that could be affecting its ability to incorporate new products into its export basket. At the time we were applying the aforementioned methodologies, we carried out a major series of analyses that are not detailed in this paper because they were not central to an understanding of recent economic performance in Hermosillo.[5]

Economic Performance in Hermosillo

Hermosillo experienced moderate growth rate at the municipal level between 2005 and 2015. According to our estimates,[6] its 1.25% compound annual growth posted during those ten years places it in the 56th percentile of all municipalities in the country. Although during the past two decades the main engines of growth and employment have been manufacturing, professional and financial services, and trade, but these three sectors display different trajectories. This is interesting in order to understand the growth dynamic in Hermosillo and the challenges that lie ahead. For example, over the period 2000-2017, manufacturing jobs dropped from 17% to 13% of total employment, jobs in trade dropped from 21% to 19%, both yielding space to the professional and financial services sector. This sector's percentage of the labor market grew by 50%, climbing from 8% to12%.

This history of growth is part of the municipality's success story, although we do not have statistics with the same level of detail beyond the last decade.[7] We know that one of the main milestones of this trajectory was the construction in 1984 and inauguration in 1986 of Ford's plant.[8] Ford and the auto parts suppliers that began to develop over the same period of time sparked the industrialization process in Hermosillo. In 1980 manufacturing accounted for barely 10% of jobs in the city. By the end of the decade, this figure hovered around 16%. Also, the advent of this industry allowed the city to develop relatively more complex products, not just in relative terms, but in absolute terms as well. The farm sector was replaced: In 1970 it represented 23% of jobs, in the early '90s it was only 10%.

Ford's arrival was undoubtedly an exceptional event, which allowed the municipality to make a huge leap forward in terms of complexity. To give an anecdotal example,[9] for 1986 the Economic Complexity Index (see Appendix 1) for a traditional product from Hermosillo such as oranges was -0.57, while the index for motor vehicles was 3.86. The difference can be partially explained by the fact

[5] For information on analyses traditionally included in the Growth Diagnostics or Economic Complexity Analysis that are not contained in this paper, please contact the CID at Harvard research team.

[6] See Appendix 3 for the details on methods to estimate municipal GDP.

[7] The sources we used to estimate municipal gross domestic product were available only for the period 2003-2015.

[8] Formally registered as Hermosillo Stamping and Assembly.

[9] Information on complexity in Hermosillo is available only from 2004, but overall complexity information for specific products is available from 1960.

that during that time, only eight countries in the world were exporting autos intensively, while oranges were a much more common export.

The intensive development of these industrial activities at the Ford plant caused the average wage level in Hermosillo to become one of the highest in the country in 1998. With an average monthly wage of MXP3,061 in 1998, Hermosillo was the metropolitan area with the fifth highest wages. Broadly speaking, this growth path continued, and in 2015 estimated GDP per capita in Hermosillo placed it among the top 5% of wealthiest municipalities in Mexico. The municipality also had low levels of poverty (25.4% versus 46.3% in Mexico) and informal jobs (36.6% versus 56.5%),[10] a relatively advantaged position in development terms.

Hermosillo's trajectory did not follow a linear path. The 1.33% growth posted in the five-year term from 2005 to 2010 contrasts slightly with the 1.15% for the period 2010-2015. Nevertheless, between 2013 and 2015, the municipality saw a very significant drop in GDP per worker of 7.2%. This was an exceptional event that is seen in only 10% of all growth periods for Mexican municipalities for the period 2010 – 2015.[11] With the setback in economic activity came an increase in the unemployment rate, exceeding 6% in 2015.[12] From 2014 the average wage fell 5.5% annually (in real terms). This drop was especially marked in extractive industries (-35%), but there were also decreases in real terms in wages for services, manufacturing, and trade. As a result, although unemployment has gone down, it is unlikely to have recovered to levels of well-being.

The slowdown over the period 2010-2015, aggravated by the steep decline in GDP per worker in 2014-2015 and the consequent drops in real wages, tell us that the Hermosillo economy has lost its dynamism.

To provide a more accurate contrast between Hermosillo's performance and the more heterogeneous traits of other Mexican municipalities, we have identified a group of 11 comparable municipalities with similar characteristics (see Appendix 4). In essence, we sought similar cities in terms of size of the labor market, exports, export products, geographic location (mainly border municipalities), and high economic complexity. Even within this group of comparable municipalities,

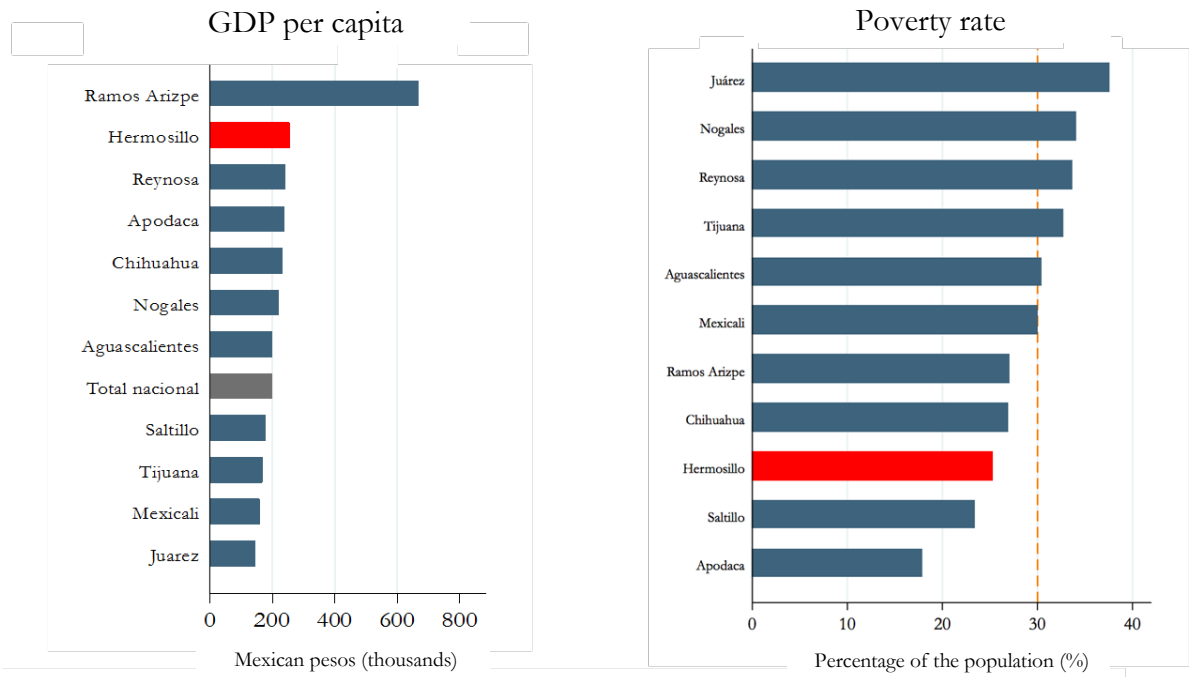
[10] Source: Encuesta Nacional de Ocupación y Empleo [National Occupational and Employment Survey], 2016 (INEGI) and Coneval, 2010. Informal market rate as per definition from TIL1 (https://datos.gob.mx/busca/dataset/objetivos-de-desarrollo-sostenible-tasa-de-informalidad-laboral-til--1/resource/1441a0a6-1264-44a3-a37c-c77bead8b070)

[11] All episodes of biannual growth were taken into account for Mexican municipalities with more than 50,000 workers, and a GDP higher than 50 billion pesos.

[12] Of note is that between 2015 and 2017, the unemployment rate fell significantly to reach the current level of 3.9%, suggesting that it is making a recovery during this period.

Hermosillo stands out for its high levels of development because it has the second highest GDP per capita in the group for 2015 and the third lowest poverty rate. (Figure 1).

Figure 1: Estimated GDP per capita (2015) and poverty rates (2010), Hermosillo and comparison municipalities



Note: Only persons of working age (15 years or more) are considered
GDP calculations based on own estimates
Population calculations based on Population Census 2000 and 2010 and the Intercensal Survey of 2015, INEGI

Curiously, Hermosillo's economic structure is different from that of the comparison municipalities. It is less focused on activities that are traditionally considered to be more productive. In the other municipalities, manufacturing accounts for 33% of employment, more than twice that in Hermosillo. In terms of GDP, manufacturing in these municipalities accounts for 31% while in Hermosillo it is barely 13%. However, activities like the government sector account for 6.3% of jobs in the city, 1.8 times higher than is seen in the other comparison municipalities.

We can also see even more dramatic contrasts here in economic development. Between 2005 and 2010, the per capita growth rate in Hermosillo (1.33%) was the second highest in the comparison group. This position changed significantly between 2010 and 2015, when Hermosillo, at 1.15%, was below the group's average, and far from the municipalities with greatest output (Chihuahua and Ramos

Arizpe were growing at 4% annually.). Also, while GDP per worker fell sharply in Hermosillo between 2014 and 2015 (by 7.2%), the comparison group grew by 1.1% on average.

Based on recent performance in Hermosillo, and the large differences with presumably comparable municipalities, we might ask what happened to the economy in Hermosillo. Why has its performance lagged behind that of the comparison group and the rest of Mexico? Will it be able to sustain its strong performance in development indicators over the long term?

Role of Manufacturing

Manufacturing has been the cornerstone of the development process in Hermosillo, accounting for 79% of total production in 2013, 65% of value added generated in the city, and 79%[13] of exports in 2014. Activities in this sector also account for 151%[14] of the municipality's economic complexity. This is undoubtedly where we should start looking for causes of the loss of economic dynamism.

It is important to point out that manufacturing has been the only sector in the city that has seen decreases, both in terms of employment (-1.5 % annually), and in real median wages (-1.2% annually), for the period 2012-2017 (Figure 2). This behavior contrasts with that in the comparison municipalities and even with the rest of Mexico. In the comparison municipalities for which we have information,[15] both employment (6.6%) and wages (1.3%) in the manufacturing sector increased over the same period, while in the rest of Mexico they grew by 3% and 0.9%, respectively. This unusual combination of a fall in both wages and employment indicates that there has been a decline in job demand in Hermosillo's manufacturing sector.

This observation is in keeping with a loss of competitiveness in the city's manufacturing sector. Between 2005 and 2015, GDP per manufacturing worker barely grew at an annual rate of 0.4% in aggregate terms. In addition, relative productivity in the manufacturing sector was significantly reduced, and is now among the lowest within the comparison group (Figure 3).

It is also true that Manufacturing Economic Units in Hermosillo tend to have, on average, barely one-fourth of the employees that these units have in the comparison municipalities. Within the sector, Economic Units for "machinery, autos, and electronics" have an average of one-fifth of the employees that are found in other municipalities. These significant differences of scale could be indicative of differences in sophistication and productivity.

A similar tendency is seen in the development of complexity for the main manufacturing activities. Over the past decade, exports of "Transport Vehicles," "Machinery," and "Electronics" for

[13] For the purposes of exports and for economic complexity, manufacturing is considered to be the sum of the categories "Transportation Vehicles," "Machinery," and "Electronics."

[14] This percentage is greater than 100% because there are product categories, particularly "Vegetables, Foodstuffs, and Wood," that have a negative complexity index.

[15] Chihuahua, Saltillo, Aguascalientes, and Tijuana

Hermosillo have undergone a sustained loss in complexity. Manufacturing in Hermosillo went from second place in the complexity ranking of comparison municipalities in 2004 (ECI: 3.18) to seventh place in 2014 (ECI: 2.42.)

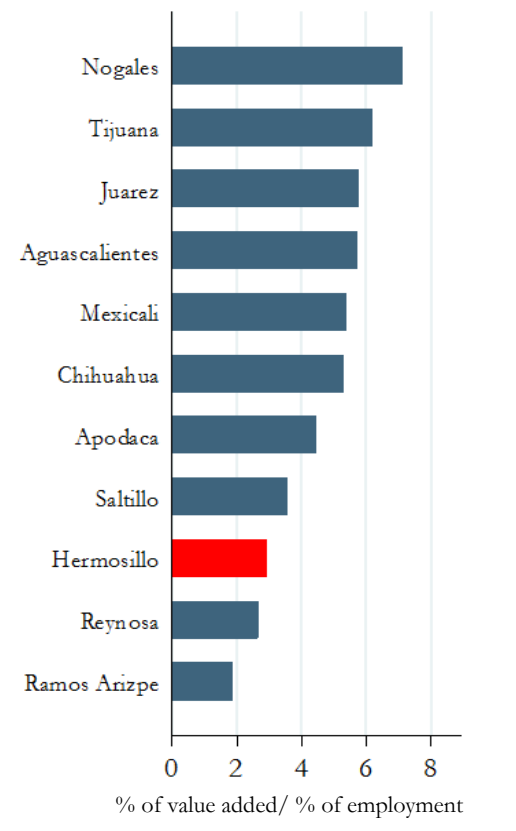
Figure 2: Job and wage trend by economic sector (2012-2017), Hermosillo

The size of the bubble represents the number of workers in each sector in 2017.

Source: Own calculations based on 2012-2017 Economic Census

This development can be explained in part by the fact that existing activities, which at the time were fairly complex and fostered the city's development, have become increasingly ubiquitous. Let's take the most relevant example of manufacturing in Hermosillo: motor vehicles. As we have stated, automobile production represents 64% of total production, 50% of the value added generated in the city, and 51% of exports. In 1986, when the Ford plant was established, barely 13% of countries had comparative advantages in exporting vehicles. In 2010 that figure was 50%, and it has now stabilized at approximately 35%. As activities become more ubiquitous, they lose their complexity (by definition), and they tend to contribute less to growth. In 1986, vehicles were in the 10th percentile (top 10%) of the most complex products in the world. By 2014, 30% of global products already had more complexity than automobile manufacturing.

Figure 3: Relative productivity of manufacturing sector (2014), Hermosillo and comparison municipalities



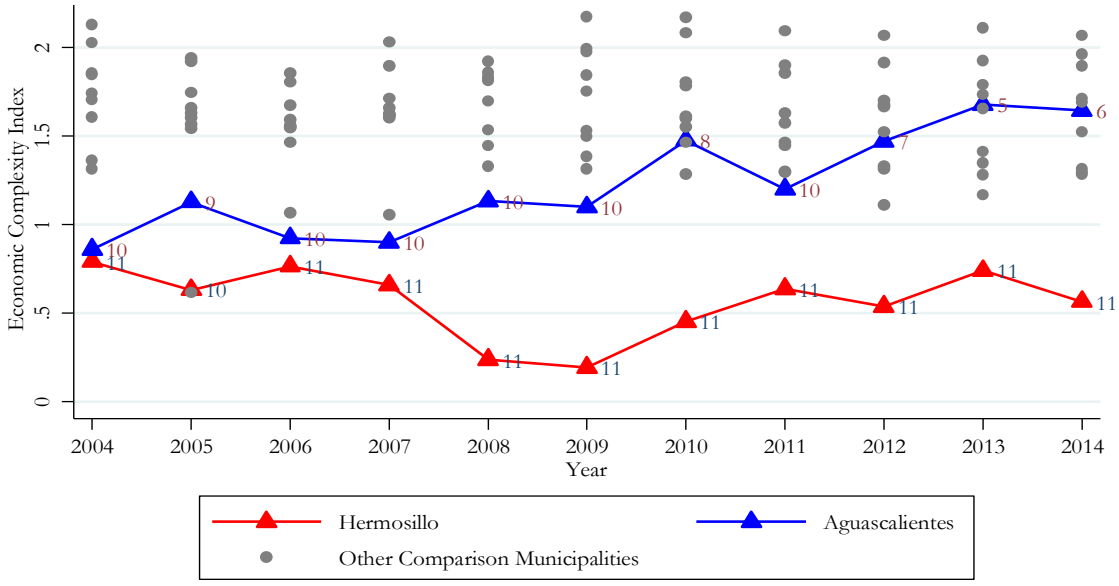
Source: Own calculations based on 2014 Economic Census

However, the changes in ubiquity in Hermosillo's export basket were not the only factors that caused the city to lose complexity. Other comparable cities began from a similar point, and today, their results are quite different.

Let's take the example of Aguascalientes, a city that shares the focus on automobile production with Hermosillo (57% of total production, 31% of value added, and 49% of exports). In 2004, Aguascalientes had an Economic Complexity Index of 0.86 and a Complexity Outlook of 43.98, which were comparable to the figures for Hermosillo (0.79 and 62.00, respectively). In addition, it intensively exported 16 products in which Hermosillo also had a comparative advantage. It was one of the municipalities with the greatest number of exports in the same categories. That year, the products composing the exports of both locations lost complexity. But then they began to differ in their ability to leverage available knowledge to develop more-complex products. In the decade from 2004 to 2014, while Hermosillo continued to export the same products, Aguascalientes began moving toward other,

more complex products. By 2014, it had already tripled the Economic Complexity Index (ECI) of Hermosillo (Figure 4). Another way of looking at the same phenomenon is to consider how long the products have been exported from both places: 60% of exports in which Hermosillo showed a revealed comparative advantage in 2014 already existed before 2004, whereas in Aguascalientes, this figure is half of that, at 30%.

Figure 4: Evolution of Economic Complexity Index (2004-2014), Hermosillo, Aguascalientes, and comparison municipalities



Source: Own calculations based on the Atlas of Economic Complexity

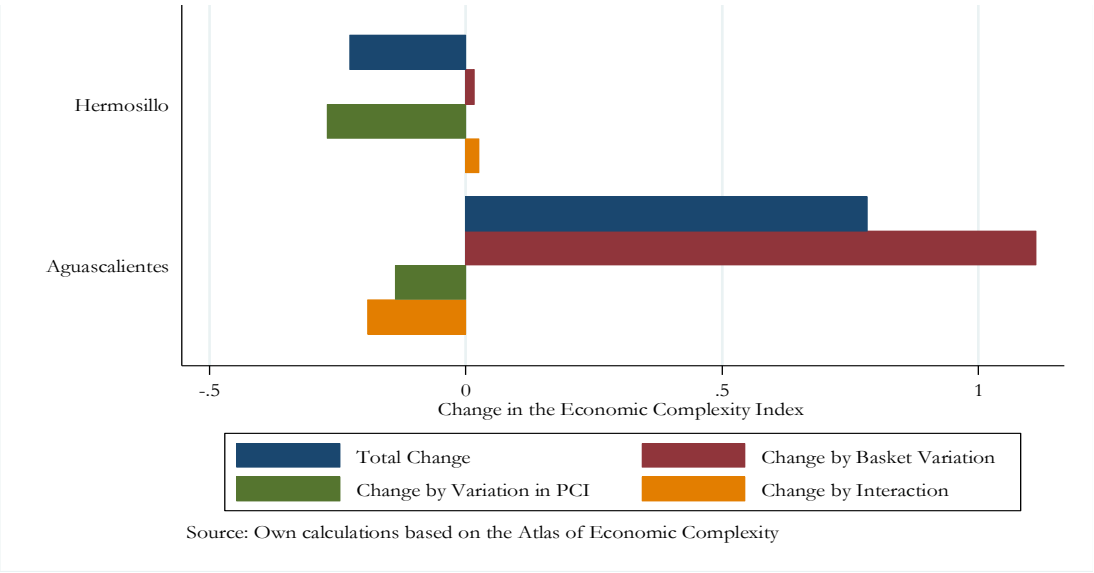
Over these past 10 years, although the diversity of Aguascalientes exports hasn't increased, the composition of its exports has moved significantly toward more complex products. The share of low-complexity products in the export basket, such as Textiles and Furniture (average ECI of -0,03 in 2014) went from 34.04% to 16.22%, while the share of other products of high complexity like Machinery (average ECI of 2.60 in 2014) grew from 23.40% to 37.84%.

In Hermosillo, export diversity dropped in absolute terms, going from 68 products in 2004 to 54 products in 2014. No substantial changes in composition can be seen here, which led to a gradual yet sustained reduction in its ECI.

To summarize: Despite the fact that Aguascalientes was also affected by the loss of complexity in its initial export basket, it was able to develop other products that significantly increased the city's economic complexity (Figure 5). By 2014, Aguascalientes was showing GDP per capita levels lower than would be expected from its complexity level. This is normally associated with greater rates of

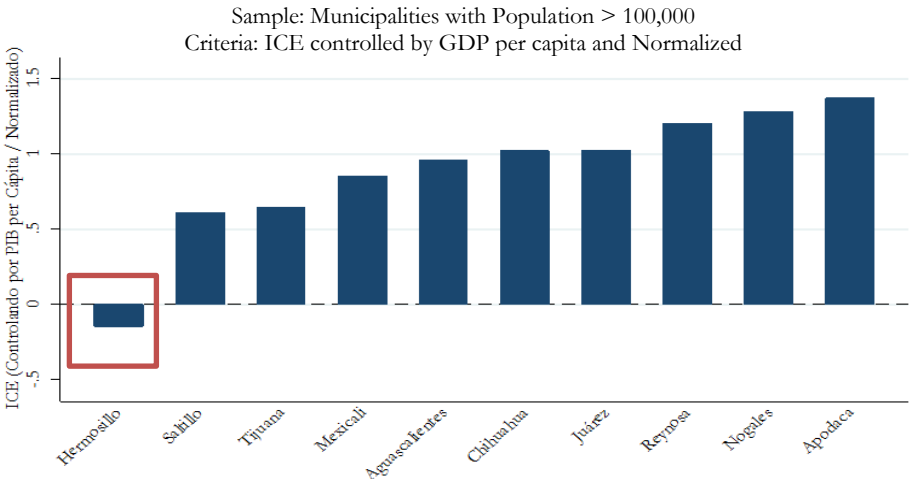
future growth. Hermosillo, however, has not shown the same dynamism, and continues to export a more stable basket of goods, which have been losing complexity. As a result, Hermosillo's current GDP per capita is greater than would be expected, considering its economic complexity level. This situation, in addition to being associated with a slowing of future growth, did not occur in any of the comparison municipalities (Figure 6).

Figure 4: Breakdown of change in Economic Complexity Index between 2004 and 2014, Hermosillo and Aguascalientes



Source: Own calculations based on the Atlas of Economic Complexity

Figure 5: Economic Complexity Index adjusted for income (2014), Hermosillo and comparison municipalities



Source: Own calculations based on the Mexican Atlas of Economic Complexity

Why Has Hermosillo Been Unable to Add New Products to its Export Basket?

Our work has allowed us to identify three possible factors—not mutually exclusive—that may explain Hermosillo's inability to move toward industries and products of greater complexity: coordination failures, wage distortions, and insufficient innovation catalysts.

Coordination Failures

Developing any product is similar to creating a word. To create a word, you need a series of letters or syllables set out in the right order. Since the letters are complementary, if one is missing it is impossible to create the word, even if you have all the other letters. In the same way, a new product requires the accumulation of a very specific set of productive capabilities, including knowledge associated with the productive process, adequate supply of public goods, regulatory framework, and access to labor with experience and appropriate skills. A lack, or inadequate supply, of any of these productive inputs is reason enough for the process to fail.

There is no exhaustive list of all productive inputs needed to develop each of the products, so that in practice, identifying "missing letters" and options for finding them should result from a public-private dialog, as we suggest in the recommendations in this paper. However, our team has developed a complete Growth Diagnostics for Hermosillo, applying the methodology of Hausmann, Rodrik, and Velasco (2005). It has led us to identify three insufficiencies in the supply of public services that may have restricted the appearance of new sectors and products. These three areas can serve as a starting point for dialog.

In each case—electricity, water, and logistics infrastructure—we gather information and develop analyses for quantifying the impact they may have had on the city's diversification.

Electricity

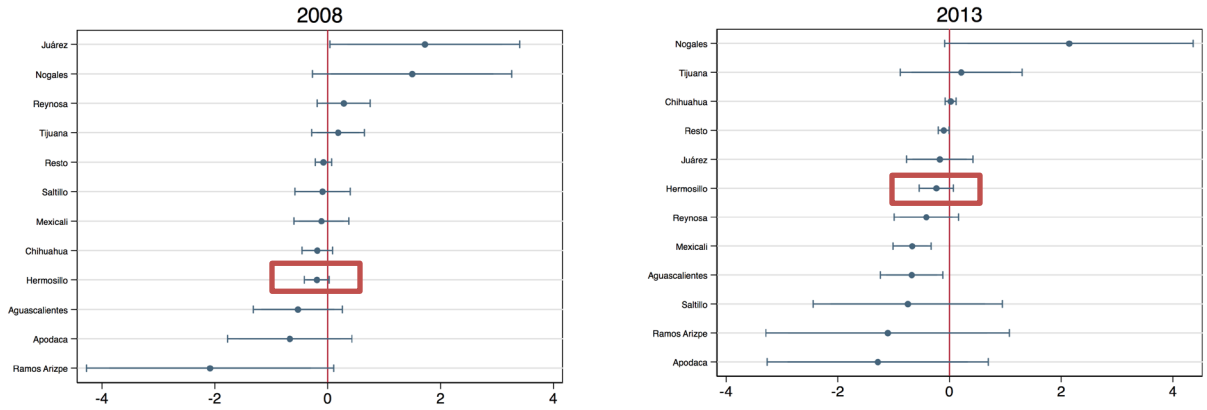
In 2016, barely 41% of Hermosillo's Economic Units were satisfied with the electric power service. This figure is the lowest in the comparison group and even lower than the satisfaction average for service nationally (46%). In our quantitative and qualitative research in the municipality, we found no evidence of restrictions to access or stability of service. Since rates are set regionally by a federal agency, it is difficult to imagine that they are a special restriction in Hermosillo. However, per capita energy consumption in Hermosillo is practically double that of cities like Aguascalientes and Tijuana. In our interviews with the major players in the city, we noted that the need for air conditioning in work spaces (plants and offices) over the summer requires Economic Units to consume more energy in Hermosillo than in other locations in Mexico. This last point suggests that, even with similar rates, the high temperatures in Hermosillo cause the same activities to be more energy-intensive here than anywhere else.

If the lack of alternatives that would allow for more efficient and economic energy consumption were a limit on the appearance of new industries and products, we would see a relative abundance of

low-energy-intensive industries within Hermosillo's productive structure. This seems to be the case. The Economic Units in the city's industrial sector are substantially less intensive in their use of electricity. Barely 0.4% of their intermediate consumption is for electricity, a percentage significantly less than the average for the comparison group (4%). Even in the second least energy-intensive municipality (Saltillo), the share of electricity in the intermediate consumption of Economic Units, at 0.7%, is nearly double that of Hermosillo.

Another sign that suggests energy costs are a significant restriction is the fact that, controlling for production patterns and discrepancies in development levels, a greater share of the city's value added is concentrated on economic activities that do not make intensive use of electricity.[16] (Figure 7).

Figure 6: Relative concentration of value added according to intensity of electricity use (2008 and 2013), Hermosillo and comparison municipalities



Source: Own calculations based on 2009 and 2014 Economic Census

Lastly, among the products close to Hermosillo's current productive ecosystem that would contribute to the city's complexity,[17] 60% show an intensity of electricity use greater than the average for the city. This means that the fact that electricity has not been a limiting factor for firms established in the city does not actually indicate sufficient supply of the service. On the contrary, these firms may

[16] According to Hausmann, Kingler, and Wagner (2008), and based on the work of Rajan and Zingales (1998), one alternative way to determine whether a factor restricts growth is to examine the relative performance of each sector in relation to its dependence on that factor. This can be evaluated empirically using an econometric specification where the dependent variable is the share of each economic sector in the GDP of each municipality, and the control variables are sector dummy variables, interactions between municipal dummies and the total municipal GDP, and interactions between municipal dummies and a measure of intensity of use of the factor in question, in this case the total electricity expense as a percentage of intermediate consumption. The latter are the variables of interest, and they indicate whether a certain municipality has a higher percentage (if the coefficient is positive and statistically significant) or lower percentage (in the opposite case) of its value added in industries that are more (or less) intensive in use of the factor. For Hermosillo, the estimated coefficients of interest are negative for both years, statistically significant in 2008, and not significant in 2013 at conventional significance levels of 0.1 (the p-value is equal to 11%), indicating that a greater share of the city's value added is concentrated in economic activities that do not use the factor intensively.

[17] The 50 products with a lower distance value and whose PCI is greater than the ECI for Hermosillo

well have made the decision to set up in the city precisely because they do not need too much energy. According to the evidence, the lack of a more efficient and economic supply of power does seem to be a significant break on attracting new businesses and diversifying Hermosillo's productive ecosystem.

Water

Most of the Economic Units are satisfied with the majority of supply metrics for water, except for leaks and cost of service. Only 48% of the Economic Units are satisfied with the prevention of leaks, 10% less than the national average. This finding is consistent with the fact that between 2005 and 2015, the percentage of water produced but not consumed went from 24.6% to 41.2%. While it is possible that the recent measurements are affected by improvements in measuring and monitoring capability, the difference is sufficiently large to deserve special attention. In the case of costs, only 35% feel that water is affordable, while the national average is above 50%. Nevertheless, this situation could be responding more to a dynamic of trend (recent changes) than of level. Water rates in Hermosillo increased 50% between 2013 and 2015, but at the end of this period they were still almost one-third lower than the national average. In fact, the ratio of rates to operating costs was nearly 1:1, which left little room for investment in ensuring, expanding, or improving the service using own resources.

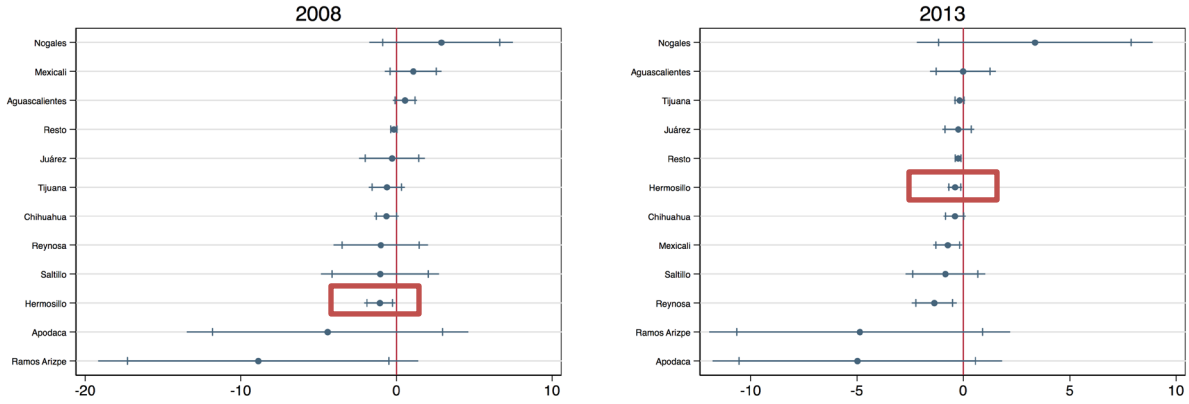
This fact, coupled with the increase in leaks, the decline in availability of the main aquifers in the Hermosillo area,[18] and the legal disputes over the Independencia Aqueduct[19] may have caused uncertainty among the Economic Units concerning the long-term supply of water. These expectations may have discouraged investment decisions in the past and may be continuing to do so in the present. If this hypothesis is true, we would expect to find a lesser representation of water-intensive activities within the city's productive structure. This also appears to be the case in Hermosillo.

The Economic Units in the industrial sector use less water. On average, water accounted for barely 0.09% of intermediate consumption in 2014, approximately one-fifth the average for the comparison group. As we saw with electricity, once we control for production patterns and differences due to development levels, a disproportionate amount of the value added for the municipality is concentrated in activities that do not use water intensively as a factor of production (Figure 8). These findings indicate that water supply may be another constraint on Hermosillo's productive diversification process.

[18] Of the eight aquifers within the Hermosillo area, seven are depleted or have availability close to zero, seven are closed from future water concession rights, two have saltwater intrusion, and five are overexploited. Aquifers are considered "shut down" when they have no average annual water availability, which means new water concessions are not authorized, due to possible deterioration of water quantity or quality (CONAGUA).

[19] The Yaqui ethnic group and other users in the southern part of the state have opposed the Independencia Aqueduct, which affects delivery of this resource via the aqueduct to Hermosillo (Nájar, 2015).
http://www.bbc.com/mundo/noticias/2015/08/150828_yaquis_mexico_guerra_agua_an

Figure 7: Relative concentration of value added according to water use intensity (2008 and 2013), Hermosillo and comparison municipalities[20]



Source: Own calculations based on 2009 and 2014 Economic Censuses

Logistics Infrastructure

When we think about logistics infrastructure, it is important to consider two complementary dimensions: the infrastructure connecting Hermosillo with the rest of the world, and the infrastructure connecting different areas within Hermosillo. The first consists mainly of ports, airports, buses and trucks, and trains. The second involves facilities for moving within the municipality—roadways and public transit alternatives.

In terms of overall connectivity, Hermosillo has excellent access to a variety of options. The port of Guaymas is approximately 117 km from the city. It is served by the General Ignacio Pesqueira García Airport, and connects directly to the Nogales border station via the Ferromex railway and Federal Highway 15.

Yet each of these options has some serious logistical limitations. The port of Guaymas has very low capacity to move container cargo, which substantially reduces the variety of products that can be shipped over this route. As for the airport, it only has one international route to Phoenix, which is also one of the costliest routes per mile traveled (Hermosillo Development Committee, 2017). In addition, unlike airports such as the one in Tijuana or Monterrey, Hermosillo's does not have a logistics consolidation center, which limits its ability to move cargo, as with Guaymas.

The result of these limitations is a strong dependency on land transportation. This phenomenon was apparent in the second half of 2013, when protestors blocked traffic on Federal Highway 15, causing a 3.6% increase in Hermosillo's inflation in April, and a 10.3% increase in May. The price hike

[20] Using the same methodology used for electricity, we find evidence that the industries operating in Hermosillo are mostly less intensive in the use of water (the estimated coefficient of interest is negative and statistically significant) for the years we looked at.

held throughout the protests, and it was 3.5 times higher than the average inflation rate for the period 2011-2017 (if we exclude the protest period). The percentage of cargo moved by truck and train is estimated at nearly 90%, much higher than the national average of 70%, and more aligned with cities like Mexicali, Tijuana, and Nogales (93%, 92%, and 91%, respectively).[21] The major difference is that these three cities are on the border, while Hermosillo is a 3.6-hour drive from the closest border station with the US.

These conditions make cargo costs relatively high. This situation accentuates the natural dependency on the US market and limits development opportunities for logistics-intensive industries. It is likely also for this reason that we see the Economic Units in Hermosillo's industrial sector tend to be less intensive than those in the comparison group in their shipping costs to sell products.[22] They devote 0.44% of intermediate consumption to it, which is one-third of the average percentage in the comparison group. Among the products close to Hermosillo's current productive ecosystem that would contribute to the city's economic complexity,[23] 68% spend more on shipping than the average for the city.

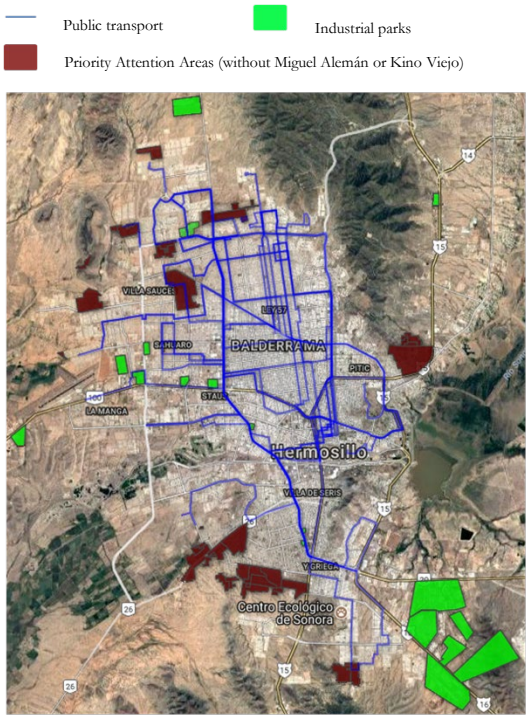
Regarding internal connectivity, barely 28% of Economic Units report satisfaction with the city's streets and roads. The interviews we had with the municipality's main stakeholders also reflected concern with the condition of roadways in the municipality. In addition, in terms of public transport in 2015, only 21% of travel to the workplace occurred on public transportation, and half of these trips lasted 30 minutes or more. In contrast, 92% of travel in private vehicles lasted 30 minutes or less. Current public transport offerings are not able to connect the most vulnerable populations to the main sources of employment (Figure 9). This is why several local firms are forced to hire private transportation to ensure workers can reach the plants on time. In 2015, 13% of travel to the workplace occurred in this employer-financed transport, a figure exceeded only in Ramos Arizpe (36%) and Saltillo (24%) among the comparison cities. While we do not have statistics for determining the impact that a lack of internal connectivity has had on the economic structure in Hermosillo, the fact that a large group of companies have decided to overcome these limitations by providing private transport tells us of their potential relevance.

[21] These percentages are approximate and derived from a methodology that assigns the cargo transported by each means of transport in each municipality according to the following criteria. First, truck cargo was assigned based on the cargo transportation fleet registered in each municipality. (This variable is assumed to be a proxy for the cargo capacity in each geographic area). The cargo transported at each seaport was assigned to the municipalities in their zone of influence based on their GDP. And finally, for cargo on trains, total transported cargo in each state was assigned based on the GDP of each of its municipalities. The underlying assumption of these last two distributions is that the cargo intensity in each municipality is strongly correlated with its level of economic activity.

[22] Information from the census variable "Shipping Costs of Products Sold" from the 2014 Economic Census. This variable includes payments to third parties for the services of transporting sold products, related only to handling, receipt, delivery, or distribution of products, merchandise, and goods sold by the Economic Unit, whether by local or outside land transport, by air (national or international), or by sea.

[23] The 50 products with a lower distance value and whose PCI is greater than the ECI for Hermosillo

Figure 8: Connectivity between priority attention areas and industrial parks via public transit (2017), Hermosillo[24]



Source: PIEDHMO

Relative Wage Distortions

One of the most important productive capabilities is labor, especially if it is labor with a set of knowledge and experience. A collection of skills can be represented with a vector of occupations, specific to each product. These occupational vectors tell us whether a product is likely to be developed in a location, because the more likely that workers can access these vectors at acceptable wages, the more likely it is that the product can be developed.

When the necessary labor is scarce, the costs of obtaining it—whether through competing with wages, providing training, or attracting talent from other parts of the country or the world[25]—end up

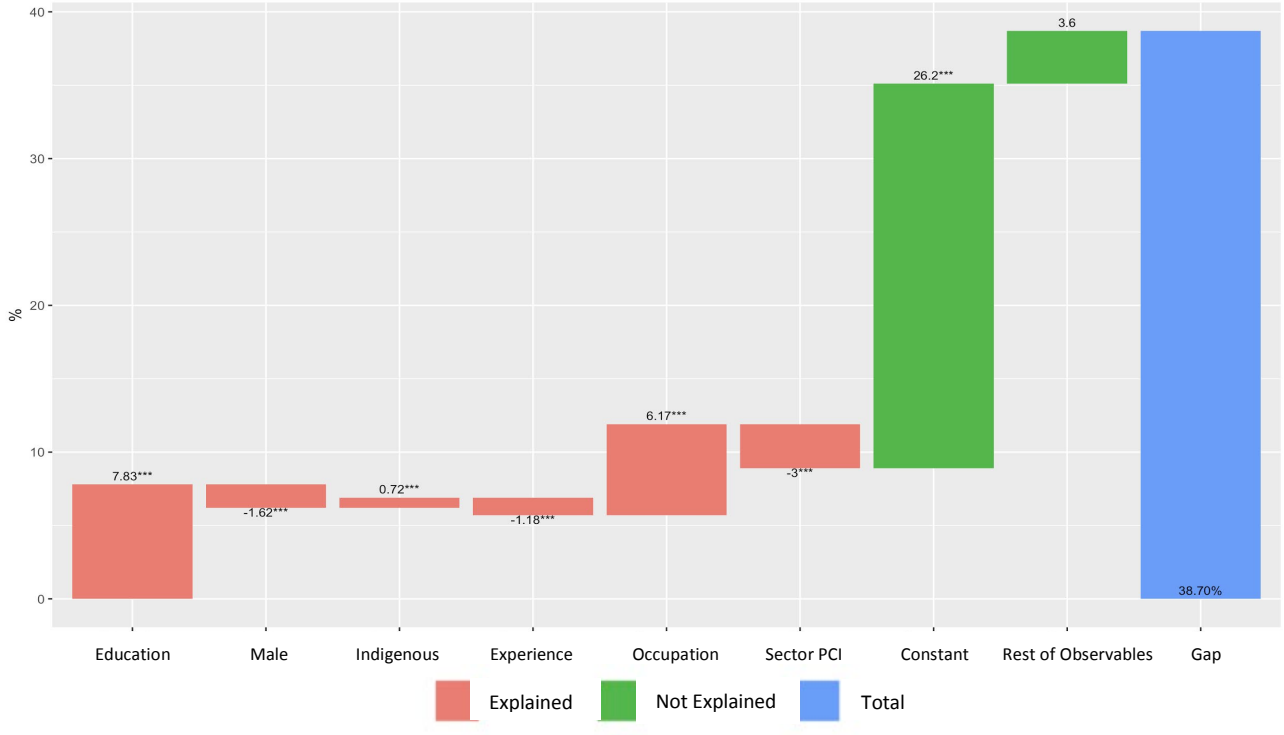
[24] This information was collected from the PIEDHMO information system created by the Economic Development Committee of Hermosillo Municipality. The system displays the geographic location of the industrial parks where the main manufacturing plants are found, the Priority Attention Areas (PAA), and transportation routes. The image shows the relative isolation of these two types of geographic areas. We should point out that the PAAs are areas whose population has poverty indexes indicative of significant insufficiencies and a lag in exercise of basic rights. They are determined using the poverty and social backwardness indicators from CONEVAL [Spanish initials for National Social Development Policy Evaluation Council] and INEGI.

[25] In cases where labor is scarce due to low levels of training or to barriers to migration, the problem can essentially be one of coordination, such as the problems described in the above section. It should be addressed in a similar way.

hindering the rise of an industry. And if labor is scarce because the wage equilibrium level is greater than would be expected, given the productivity of the work, a distortion is created that discourages the arrival of new industries that could diversify an area's economy.

The most common analogy is the *Dutch disease*, a condition that tends to affect manufacturing in countries with abundant natural resources. The disease is spread through two main channels (Neary, 1982). On the one hand, surges in natural resource prices increase the profitability of industries using them, which in turn increase their demand for labor and equilibrium wages in the economy. On the other hand, the same boom that raises revenues in the area and its internal consumption, hikes the price of non-tradable goods (services) as compared to the tradable manufacturing sector (those whose prices are set by international markets). Although the services sector can raise prices in response to the boom in demand, it must pay higher equilibrium wages, which reduces profitability in the tradable sector. In fact, the Dutch disease is characterized by the manufacturing sector having to pay wages that are higher than would be expected by labor's productivity.

Figure 9: Blinder-Oaxaca decomposition of employee wage gap in export sector (2015), Hermosillo vs. all other municipalities in Mexico



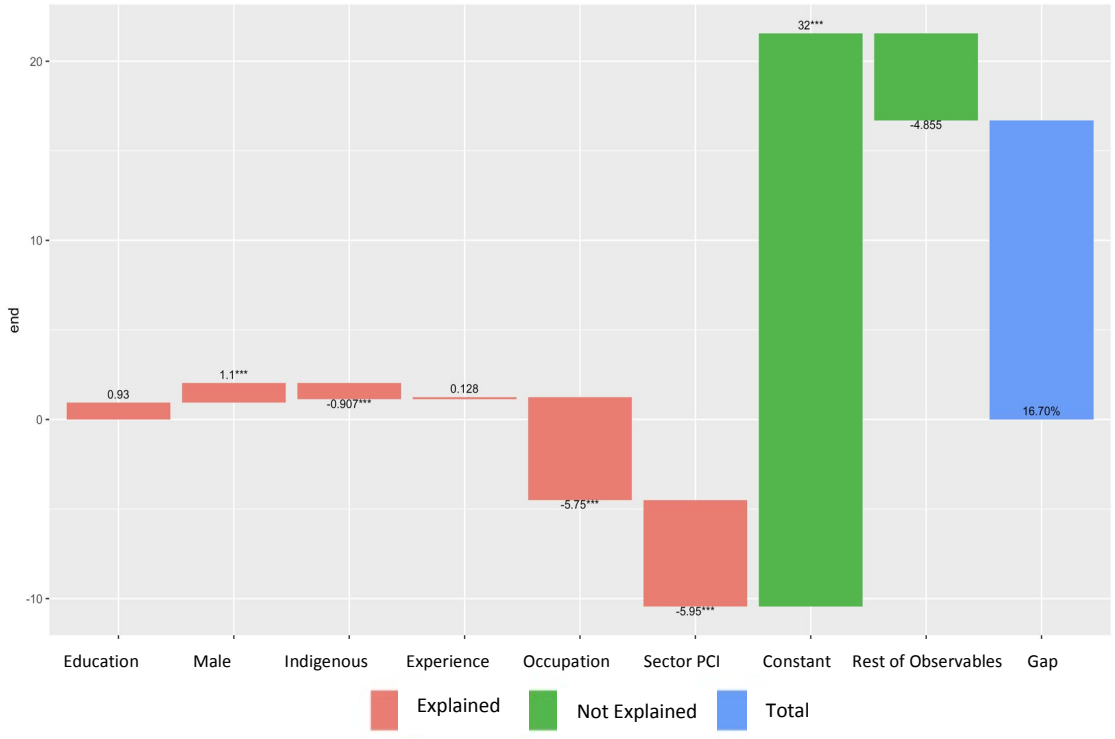
Source: Own calculations based on the 2015 Intercensal Survey and the Atlas of Economic Complexity

Our analyses of the evolution of wages and productivity by sector suggest that a similar dynamic may be taking place in Hermosillo. In Hermosillo, wages are 35.7% higher than in the rest of Mexico,

and 16.7% higher than in the comparison group. In the specific case of the export sector, the differences are 38.7% and 16.7%, respectively. Using the Blinder-Oaxaca decomposition methodology, we tried to identify the main factors explaining the differences in average wages, considering education, gender, ethnicity, occupation, experience, and sector/sectoral complexity. For the rest of Mexico, these factors explain less than 10 percentage points of the gap, while the constant for Hermosillo, which reflects endogenous factors not associated with these variables, explains 26.2 percentage points of the gap (Figure 10).

For the comparison group, the results are quite significant. If these municipalities were to receive the allocation of the observable categories that Hermosillo has, wages would be 10.5 percentage points lower than they are today. In other words, more than explaining the gap, they widen it. The constant for Hermosillo explains 32 percentage points of the gap, i.e., nearly double the original gap (Figure 11). Stated another way, there is something in Hermosillo not related to the traditional variables of human capital, productivity, complexity, or discrimination that is causing wages in the city to be much higher.

Figure 10: Blinder-Oaxaca decomposition of employee wage gap in export sector (2015), Hermosillo vs. comparison municipalities



Source: Own calculations based on the 2015 Intercensal Survey and the Atlas of Economic Complexity

One hypothesis notes the fact that the government sector is the fifth largest employer in the city, which is why Hermosillo has 1.8 times more workers than the reference municipalities (measured as a percentage of total employment). In 2016, the average salary of these workers was nearly double the average salary in manufacturing and professional and financial services. In fact, during the period 2012-2017, Hermosillo was the only municipality in the comparison group where both real incomes and employment in the government sector showed positive compound annual growth rates (1.5% and 3.8%, respectively). The trend in the rest of Mexico was for wage increases and a drop in the number of employees.

It's true that the government sector is critical for promoting a society's well-being. It is also valid that having well-paid public officials attracts the best talent and reduces incentives for corruption. However, we should remember that public sector wages are set differently from wages in the rest of the economy, not necessarily according to productivity. This reality, together with the fact that public employment in Hermosillo represents a much greater segment of employment than in the comparison municipalities, could be behind the higher equilibrium wage observed, and could also be operating like a sort of Dutch disease on the manufacturing sector.[26]

Insufficient Innovation Catalysts

A third hypothesis to explain the lack of productive diversification in Hermosillo is the lack of factors that would jump-start innovation. To continue with the metaphor of creating words, it's not enough to have all the letters in a word. We also need to know how to place them in the correct order, in other words, we need in-depth knowledge of the process behind the making of a product, literally the "know-how" of the product.

Inventing the way to make a product is a process that generally is reserved for locations on the frontier of knowledge, while developing cities must overcome the slightly different but equally complex challenge of learning how to make a product for the first time and adapting it to the local context. The advantage that developing cities have is that they can import part of the know-how by collaborating with firms and actors where the know-how exists in order to learn by doing, and in the process, develop undertakings and innovations specific to that city. This is why external investment and migrants are catalysts of innovation processes. These are two of the very factors that Hermosillo has had difficulty in attracting.

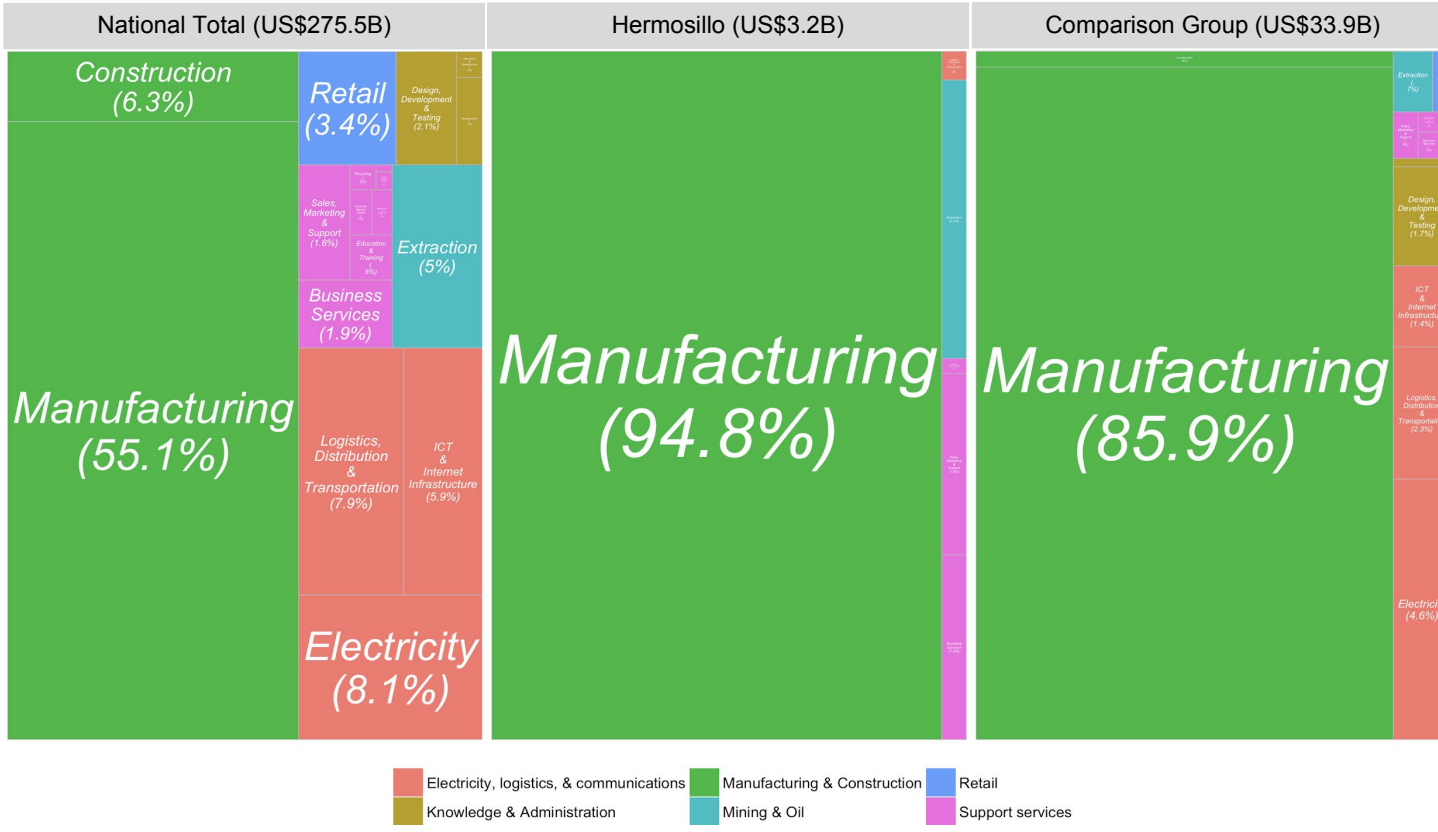
Between 2003 and 2016, Hermosillo received approximately US$3.2 billion in direct foreign investment.[27] This figure places it within the average of municipalities in the comparison group. Nevertheless, 91% of this investment was received by just one company, Ford, in just one sector, and

[26] This hypothesis could be assessed with a Oaxaca-Blinder decomposition. It would explain the wage differences between municipalities using a host of factors, including the influence of public employees at the location (measured by number of employees or total wages). This analysis is part of the CID's research, but it goes beyond the scope of this report.
[27] According to FDI Markets.

it was in order to expand an activity that already existed in the city, which significantly restricts the opportunities for learning by doing. In the other municipalities in the group, no one company accounts for more than 60% of investment during this period. In addition, 95% of investment in the city went to manufacturing activities, and not necessarily to the manufacturing sector, but to the activity of assembling products.

While assembly activities have great value, they do not contain the largest share of productive know-how. Know-how is not usually concentrated in locations where the products are physically made. It is found in places where people are thinking (i.e., corporate headquarter, research and development centers, testing and design centers). It is estimated that since 2003, Hermosillo has not received any investment in knowledge-intensive activity, which represents barely 3% of investment in the rest of Mexico and 2% in the comparison municipalities (Figure 12). In fact, 10% of all investment made in these activities in Mexico that year took place in the comparison municipalities. Not being able to attract intensive knowledge-based activity or to diversify the sectoral focus of investment may have delayed, or at least substantially decreased, the speed of innovations in Hermosillo.

Figure 11: Composition of Direct Foreign Investment by activity (2003-2016), Hermosillo, comparison municipalities, and rest of Mexico



Source: FDI Markets Data

If we look at migrants, 4,000 workers living in Hermosillo in 2015 were foreigners. This was barely 0.6% of the city's workers. The figure is one-third of the percentage of foreign workers in the comparison municipalities, and one-sixth of what we saw in cities like Tijuana. This path to transferring knowledge is therefore almost nonexistent in Hermosillo. The migration rate from other parts of Mexico is aligned with the other comparison municipalities, but 62% of these come from other parts of the same state of Sonora. This suggests they may not be contributing to the spread of knowledge that would increase complexity in Hermosillo.

IV Inputs for the Design of Public Policies

In this section we will detail some of the inputs for the design of public policy focused on addressing the innovation problems in Hermosillo in the manufacturing sector. We hope that these inputs help identify potentially viable economic sectors and adjust institutional design to address coordination failures. We will also assess the role that urban planning may have in economic diversification processes.

Attempts at Identifying Potentially Viable Products and Sectors in Hermosillo

The evidence we presented on economic complexity in Hermosillo, especially its manufacturing sector, suggests that it will be hard for the municipality to maintain its historic strong performance with the current economic structure. Hermosillo can reverse the trend, as Aguascalientes did, once it identifies the sectors with the greatest potential and corrects the flaws that have prevented them from developing in those areas.

The structural transformation that allows locations to diversify products depends on the progressive accumulation of capabilities and knowledge. The premise of this theory, originally suggested by Hausmann and Hidalgo (2009), is that even though capabilities and knowledge are not observable, we can infer the number and nature of the goods that a location is capable of producing competitively. Locations with few productive capabilities will be able to make only a relatively small number of goods (low diversity), that many other locations on average are able to make (high ubiquity). Locations that call on large stores of knowledge are not only able to make a more varied range of goods (high diversity), they can also make goods that few other locations are able to make (low ubiquity). The structural transformation process therefore consists of a gradual expansion of productive capabilities and knowledge that will allow a location to make an increasing quantity of goods that few other locations on average are able to produce.

The diversification process poses the problem of the chicken and the egg. On the one hand, no one has incentives to acquire the required capabilities for an industry that does not exist. On the other, it is unlikely that an industry will develop in a location that does not have the required capabilities. Hidalgo and Hausmann (2009) have documented the way that locations that have managed to diversify

have resolved this dilemma. Countries do not take the same path of expansion to diversify, nor do they take a random path. Rather, they move toward "adjacent" economic activities that require capabilities similar to those of the products they already have, and can reuse.

Identifying the potential expansion path begins with an inventory of the productive knowledge a location has. Only in this way will it be possible to identify the most attractive activities that are adjacent to current ones. The identification strategy we apply in Hermosillo will weigh not only the economic complexity of products, but also their distance—in terms of knowledge—from those that are already produced intensively in the city.

There are various ways of measuring this distance. In Hermosillo, our measurement of distance between pairs of products comes from the probability of co-exporting.[28] If two products are often co-exported, we can infer that both products require a similar set of capabilities. This measurement does not necessarily imply a logic of clusters or value chains. For example, "lifting machines" are at a shorter distance from "cars" than other products that are part of or closer to the cluster of vehicles or the automotive sector (such as "vehicles for the transport of goods" or "tractors").

Methodology for Identifying Potentially Viable Products

In most locations — Hermosillo is no exception—there is a trade-off between complexity and distance. The more complex and therefore more attractive products are usually at a greater distance from the capabilities the location has in greater abundance, while the less complex ones are the closest.

This relationship can be seen as a risk/benefit hurdle. That is, the location runs greater risks if it starts producing more complex items, since it requires capabilities farther away from its initial supply in order to do so. But if the venture is successful, the rewards will be greater, because the location will have gained complexity in its know-how.

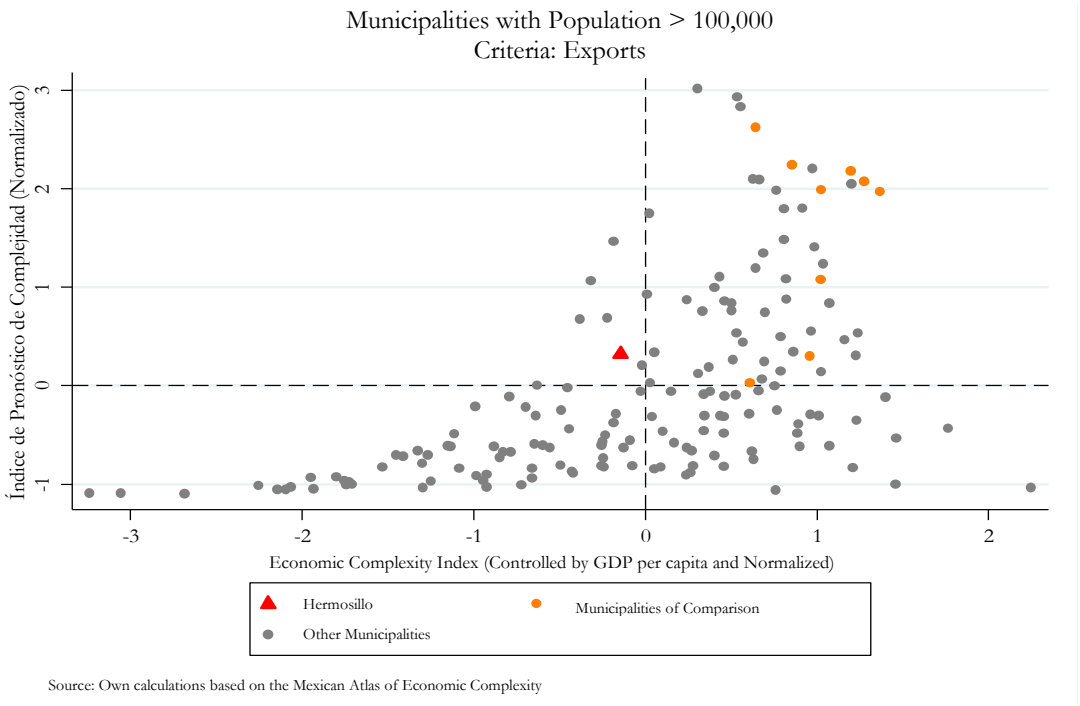
As we can see in Figure 13, Hermosillo has a complexity level slightly lower than expected given its GDP per capita and a relatively high complexity outlook nationally. (Both concepts are defined in Appendix 1). In other words, while Hermosillo is in an unfavorable position in terms of complexity level, its potential to improve it is relatively high. An unhurried industrial policy that facilitates the diversification process toward short-distance products in the product space (see definition in Appendix 1), seems the most appropriate course. For this reason, the strategy we chose for identifying sectors attempts to balance complexity and distance.

The main goal of our analysis is to offer an initial roadmap that will guide policymakers and a list of products that should not be taken as the final word, but as the result of rigorous work that includes

[28] In developing both the International Atlas of Economic Complexity and the Mexican Atlas of Economic Complexity, we verified that distance, measured as the probability of co-exporting, has the ability to predict the appearance and disappearance of products within the economic structure of countries and Mexican states, respectively.

a set of weightings subject to discussion and adjustment. Ultimately, the "target" sectors should emerge from discussions between the public and private sectors.

Figure 12: Economic complexity and Complexity Outlook controlling for GDP per capita and standardizing, Mexican municipalities with over 100,000 inhabitants



Source: Own calculations based on the Mexican Atlas of Economic Complexity

The methodology used to identify and prioritize the potential products for Hermosillo relies mainly on the economic complexity theory, which offers analytical rigor and impartiality. However, we also considered other pertinent factors that impact the viability and profitability (both private and social) of the various options. Our methodology contains various stages, which are described below and summarized in Figure 14.

1. Minimum Local Conditions Filter: Firstly, we selected those products that Hermosillo does not export intensively (and for which it does not have a revealed comparative advantage), but whose average exports over the past five years are greater than 0. This way we narrow down the identification process to products that at least one agent was able to export from Hermosillo, which indicates that the municipality meets certain minimum conditions for those products.

2. Economic Complexity Filter: This stage is the cornerstone of the methodology. As we have stated, the idea is that Hermosillo should leverage the store of capabilities and knowledge it already has to advance to new, more complex products and sectors. Considering Hermosillo's position in Figure 13, we used a balanced strategy that weights the distance factor at 50% and

distributes the other 50% over complexity factors (Economic Complexity Index and Complexity Outlook). These weightings were applied to the set of products filtered for Minimum Local Conditions to identify the 50 products with the highest scores.

3. Ranking of Market Considerations: Once we've defined the products with greater potential for Hermosillo in terms of complexity, we move on to filter them based on the different considerations that are exogenous to the city, but that are used to indicate the viability and profitability (both private and social) of producing them in the area.

The first type of consideration—which this methodology assigns the greatest weight to—is related to demand for the products. The economic complexity theory is mainly an analysis of supply, based on the overlap between the productive capabilities required to develop the product and available capability in the area. While this criterion is decisive in the sector's probability of success, it tells us nothing about the demand for the various products. This is why we found it necessary to complement our focus with an analysis of demand.

We therefore calculated the average of global imports and the annual growth rate over the past five years (2009-2014), for the 50 products on the list. This allowed us to approximate a measure of the market in terms of global volume and demand for each product. Although markets are increasingly integrated, some regions are natural markets for Hermosillo. In first place would be Mexico itself, but also the US, and, to a lesser extent, Latin America. In this way, we adjusted a set of weightings for these preferred regions.

We also included in the methodology Mexico's strength in exporting, because if the country is competitive in exporting a specific product, this indicates that, at least on the national level, there are favorable conditions for its viability and profitability. This doesn't mean all of the conditions are also in Hermosillo, but it at least suggests that the macro variables are also favorable here. Ultimately, it should be easier to attract investment to sectors that have decided to run the "Mexican risk." Therefore, the variables used are the average, growth, and RCA (relative comparative advantage) of Mexican exports.

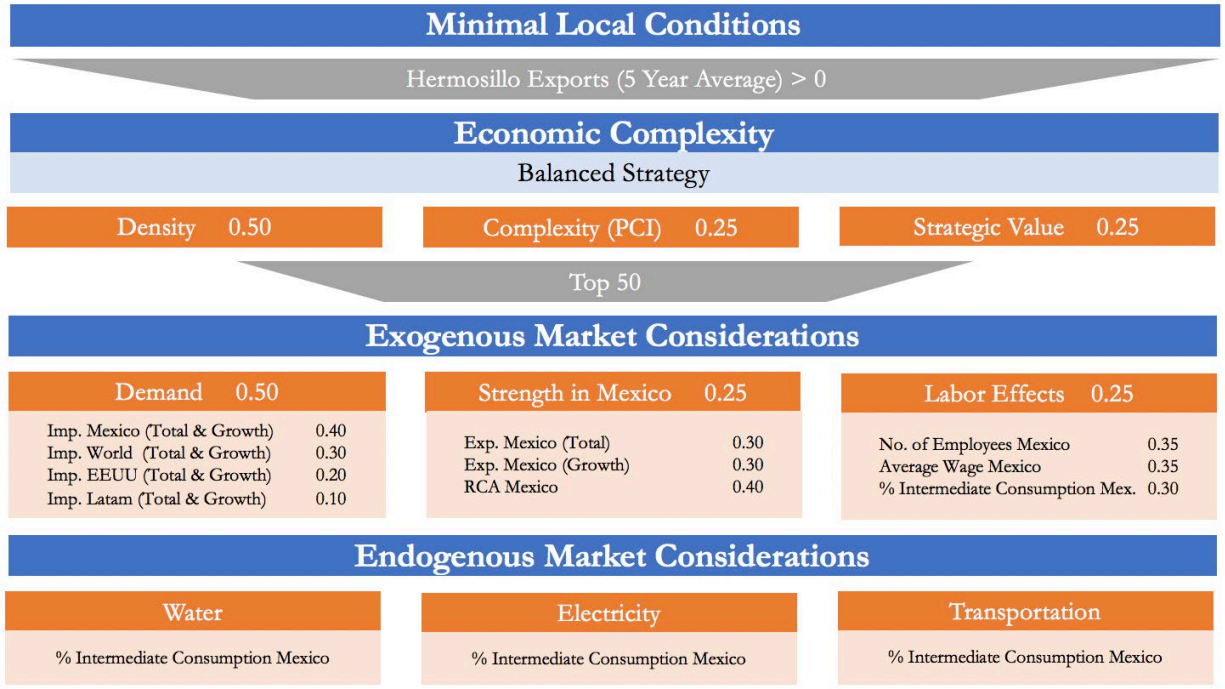
Lastly, given its economic and social importance, we decided to give special emphasis to the labor market and the social return of the various products. The economic complexity theory mainly considers these effects: producing more sophisticated goods enables a structural transformation that results in higher income levels. However, we also stress the relevance of these considerations by including variables such as number of employees, average wage, and intensity of use of the employment.

It is a valid argument that what is relevant about the labor factor is not necessarily the social return that Hermosillo would receive, but how well adapted the city's available labor force is to what industry would require. In this sense, in future exercises it would be worthwhile to identify the occupations vector that is specific to each product, and evaluate both the comparative advantage in terms of wages

that Hermosillo has in each of them, and the similarity between the occupations vector required, and the one that is available. This analysis would strengthen the other approximations in our methodology on the viability and private profitability of the various products.

The considerations discussed in the previous phase are exogenous to Hermosillo. There are other factors that can affect the viability and profitability of certain products that the municipality does have influence over, that are fundamental when determining priorities. In the economic Growth Diagnostics that informed the section on coordination failures, we identified possible restrictions on the availability of water, electricity, and transport. Consequently, in this final analysis phase, we have referenced these factors by considering how intensely the various products require them, in order to assess to what extent, the products on the list can be exported under current conditions or if, on the contrary, exporting would require solving some bottlenecks. We can prioritize the products according to progress in certain areas.

Figure 13: Process for identifying potentially viable products and sectors



Preliminary Identification of Potentially Viable Products in Hermosillo

The list of the 50 products according to the balanced identification strategy is described in Figure 15. These are the products that would allow Hermosillo to increase its complexity and improve its strategic position more quickly and efficiently.

Of the 50 products on the list, 40% belong to the machinery category, 18% are products in metals, and 14% are electronics products, representing between them nearly three-fourths of all products.

Most of them have low levels of RCA, i.e., they are currently being produced with low intensity (76% have an RCA between 0 and 0.2).

Figure 14: Top 50 products identified using a balanced strategy, in alphabetical order

Product	Category (2 digits)	Category (1 digit)
Aluminum foil < 0.2 mm	Aluminum	Metals
Aluminum tube or pipe fittings	Aluminum	Metals
Apparatus protecting electrical circuits for > 1k volts	Electrical machinery and equipment	Electronics
Appliances for thermostatically controlled valves	Boilers, machinery and mechanical appliances	Machinery
Articles of cement, of concrete or of artificial stone	Articles of stone, plaster, cement, etc.	Stone and glass
Automatic regulating instruments	Apparatuses (optical, medical, etc.)	Machinery
Bakery products	Preparations of cereals, flour, starch or milk	Vegetables, foodstuffs and wood
Calendering or other rolling machines, other than for metals or glass	Boilers, machinery and mechanical appliances	Machinery
Centrifuges	Boilers, machinery and mechanical appliances	Machinery
Corrugated paper and paperboard	Paper and paperboard	Vegetables, foodstuffs and wood
Electric signal and traffic controls	Electrical machinery and equipment	Electronics
Electrical boards for protecting electrical circuits	Electrical machinery and equipment	Electronics
Electrical ignition equipment	Electrical machinery and equipment	Electronics
Electrical lighting equipment used for motor vehicles	Electrical machinery and equipment	Electronics
Electrical transformes	Electrical machinery and equipment	Electronics
Equipment for the treatment of materials by a change of temperature	Boilers, machinery and mechanical appliances	Machinery
Grindstones	Articles of stone, plaster, cement, etc.	Stone and glass
Hydrometers, thermometers etc	Apparatuses (optical, medical, etc.)	Machinery
Instrument panel clocks for vehicles	Clocks	Machinery
Instruments for measuring flow or other variables of liquids or gases	Apparatuses (optical, medical, etc.)	Machinery
Insulating fittings for electrical machines	Electrical machinery and equipment	Electronics
Interchangeable tools for hand tools	Metal tools and tableware	Metals
Knives and blades for machines	Metal tools and tableware	Metals
Lathes for removing metal	Boilers, machinery and mechanical appliances	Machinery
Machine tools for drilling by removing metal	Boilers, machinery and mechanical appliances	Machinery
Mechanical appliances for dispersing liquids or powders	Boilers, machinery and mechanical appliances	Machinery
Meters	Apparatuses (optical, medical, etc.)	Machinery
Natural or artificial abrasive powder	Articles of stone, plaster, cement, etc.	Stone and glass
Other articles of aluminum	Aluminum	Metals
Other articles of iron and steel	Articles of iron and steel	Metals
Other articles of vulcanized rubber	Rubber	Chemicals and plastics
Other lifting machinery	Boilers, machinery and mechanical appliances	Machinery
Other plastic plates, sheets etc.	Plastics	Chemicals and plastics
Packing boxes	Wood	Vegetables, foodstuffs and wood
Paints and varnishes, nonaqueous	Dyes, paints, inks, etc.	Chemicals and plastics
Parts and accessories for metal working machines	Boilers, machinery and mechanical appliances	Machinery
Parts suitable for use with spark-ignition engines	Boilers, machinery and mechanical appliances	Machinery
Pumps for liquids	Boilers, machinery and mechanical appliances	Machinery
Pumps, compressors, fans, etc.	Boilers, machinery and mechanical appliances	Machinery
Slag wool, rock wool and similar mineral wools	Articles of stone, plaster, cement, etc.	Stone and glass
Springs of iron or steel	Articles of iron and steel	Metals
Steam turbines	Boilers, machinery and mechanical appliances	Machinery
Stoppers, caps and lids of metal	Miscellaneous articles of base metal	Metals
Stoves and similar non-electric appliances of iron or steel	Articles of iron and steel	Metals
Textile articles for technical use	Impregnated, coated, or laminated textile fabrics	Textiles and furniture
Toilet paper	Paper and paperboard	Vegetables, foodstuffs and wood
Tools for hand working, pneumatic, hydraulic motors	Boilers, machinery and mechanical appliances	Machinery
Trailers and semi-trailers	Vehicles	Transport Vehicles
Transmission shafts	Boilers, machinery and mechanical appliances	Machinery
Vulcanized rubber tubes	Rubber	Chemicals and plastics

Figure 15: Top 50 products identified using a balanced strategy, in order of total score on exogenous conditions

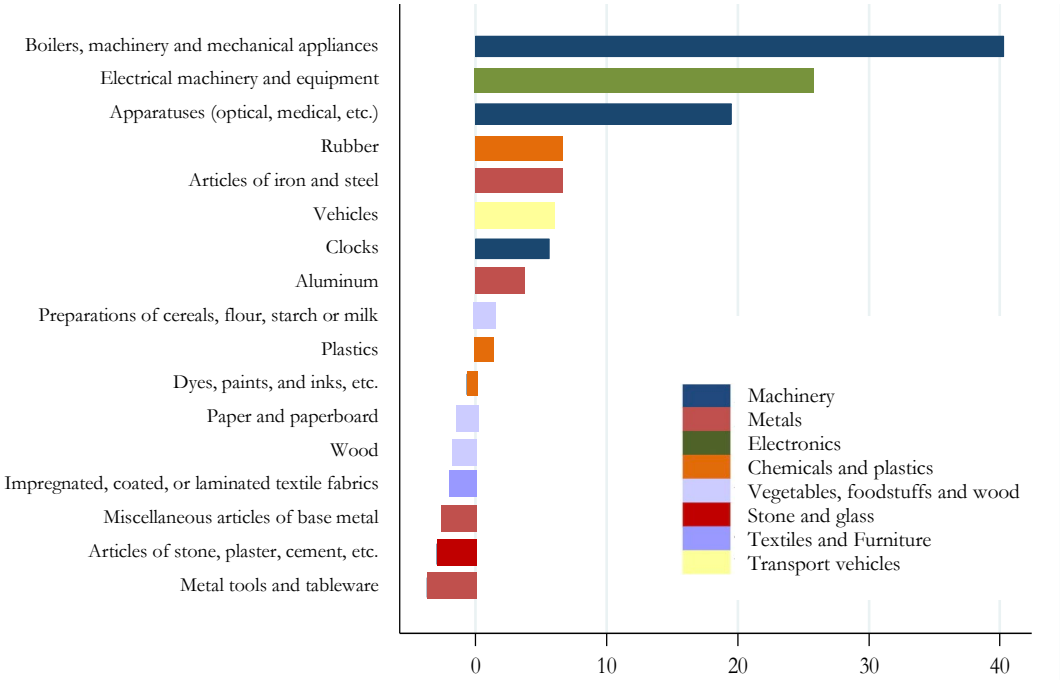
	Product	Category	Score Demand	Score Strength.	Score Employ.	Score Total
1	Parts suitable for use with spark-ignition engines	Machinery	1.02	1.13	1.46	1.16
2	Transmission shafts	Machinery	0.78	0.14	2.08	0.94
3	Pumps, compressors, fans, etc.	Machinery	0.95	0.56	1.13	0.90
4	Appliances for thermostatically controlled valves	Machinery	1.06	0.43	0.73	0.82
5	Meters	Machinery	0.63	1.30	0.72	0.82
6	Pumps for liquids	Machinery	0.84	0.46	1.11	0.81
7	Electrical lighting equipment used for motor vehicles	Electronics	0.59	0.82	1.19	0.80
8	Electrical transformes	Electronics	0.80	0.80	0.73	0.78
9	Centrifuges	Machinery	0.59	0.58	0.98	0.69
10	Trailers and semi-trailers	Transport Vehicles	0.45	0.78	1.01	0.67
11	Automatic regulating instruments	Machinery	0.29	0.76	1.34	0.67
12	Electrical boards for protecting electrical circuits	Electronics	0.76	1.11	0.01	0.66
13	Instrument panel clocks for vehicles	Machinery	-0.23	2.28	0.72	0.64
14	Other articles of iron and steel	Metals	0.46	0.24	1.31	0.62
15	Electrical ignition equipment	Electronics	0.23	0.66	0.80	0.48
16	Instruments for measuring flow or other variables of liquids or gases	Machinery	0.27	0.36	0.72	0.41
17	Vulcanized rubber tubes	Chemicals and plastics	0.18	0.33	0.89	0.39
18	Other articles of vulcanized rubber	Chemicals and plastics	0.35	0.18	0.50	0.35
19	Hydrometers, thermometers etc	Machinery	0.05	0.23	0.97	0.32
20	Springs of iron or steel	Metals	0.11	0.65	0.14	0.25
21	Aluminum tube or pipe fittings	Metals	0.10	-0.01	0.73	0.23
22	Mechanical appliances for dispersing liquids or powders	Machinery	0.02	0.05	0.72	0.20
23	Equipment for the treatment of materials by a change of temperature	Machinery	0.01	0.09	0.62	0.18
24	Other articles of aluminum	Metals	0.04	-0.09	0.64	0.16
25	Bakery products	Vegetables, foodstuffs and wood	0.01	0.13	0.46	0.15
26	Other plastic plates, sheets etc.	Chemicals and plastics	0.28	0.07	-0.08	0.14
27	Apparatus protecting electrical circuits for > 1k volts	Electronics	-0.34	0.13	0.73	0.05
28	Insulating fittings for electrical machines	Electronics	-0.04	-0.40	0.61	0.03
29	Articles of cement, of concrete or of artificial stone	Stone and glass	0.17	-0.13	-0.09	0.03
30	Other lifting machinery	Machinery	0.23	-0.08	-0.30	0.02
31	Electric signal and traffic controls	Electronics	-0.51	-0.09	1.21	0.02
32	Aluminum foil < 0.2 mm	Metals	-0.11	-0.32	0.58	0.01
33	Calendering or other rolling machines, other than for metals or glass	Machinery	-0.01	-0.15	0.14	-0.01
34	Interchangeable tools for hand tools	Metals	0.26	-0.03	-0.59	-0.02
35	Toilet paper	Vegetables, foodstuffs and wood	-0.14	0.09	0.08	-0.03
36	Parts and accessories for metal working machines	Machinery	0.17	-0.25	-0.22	-0.03
37	Paints and varnishes, nonaqueous	Chemicals and plastics	-0.03	-0.05	-0.20	-0.08
38	Slag wool, rock wool and similar mineral wools	Stone and glass	0.05	0.03	-0.51	-0.09
39	Natural or artificial abrasive powder	Stone and glass	-0.09	0.20	-0.51	-0.12
40	Stoves and similar non-electric appliances of iron or steel	Metals	-0.21	0.18	-0.30	-0.13
41	Corrugated paper and paperboard	Vegetables, foodstuffs and wood	-0.14	-0.19	-0.10	-0.14
42	Lathes for removing metal	Machinery	0.21	-0.47	-0.56	-0.15
43	Grindstones	Stone and glass	0.03	-0.19	-0.51	-0.16
44	Tools for hand working, pneumatic, hydraulic motors	Machinery	-0.20	-0.04	-0.30	-0.18
45	Packing boxes	Vegetables, foodstuffs and wood	0.01	-0.17	-0.67	-0.20
46	Textile articles for technical use	Textiles and furniture	-0.19	0.02	-0.51	-0.22
47	Stoppers, caps and lids of metal	Metals	-0.25	0.07	-0.73	-0.29
48	Machine tools for drilling by removing metal	Machinery	-0.25	-0.28	-0.56	-0.34
49	Knives and blades for machines	Metals	-0.39	-0.28	-0.55	-0.40
50	Steam turbines	Machinery	-0.92	-0.17	0.29	-0.43

Better — Worse

As previously explained, once the list of the top 50 products is defined, the methodology assigns to each of them a partial score linked to the exogenous factors considered. Then these scores are weighed to obtain a total score for each product. Figure 16 shows the individual results of this process. One option for assessing how the scores are distributed among the product categories is to add the total scores for the 50 products, and then calculate what percentage of this represents each category. For products in the two-digit category, the main opportunities are concentrated in "boilers, machines, and mechanical devices," "machinery and electrical systems," and "optical, medical, etc. devices," as shown in Figure 17.

According to our endogenous factors analysis, we can conclude that each of these categories has products that depend on variables that are potentially limited in Hermosillo. Figure 18 summarizes the degree of intensity of use for the various products on the list, while Figure 19 shows the share of products of medium-low intensity by category. In the short term, the focus should be on categories that have a high share (like "boilers, machines, and mechanical devices"), and the city should hold off on efforts in categories with low share (particularly "optical, medical, etc. devices") until progress is made in the availability of these resources.

Figure 16: Percentage of total score for factors by product category



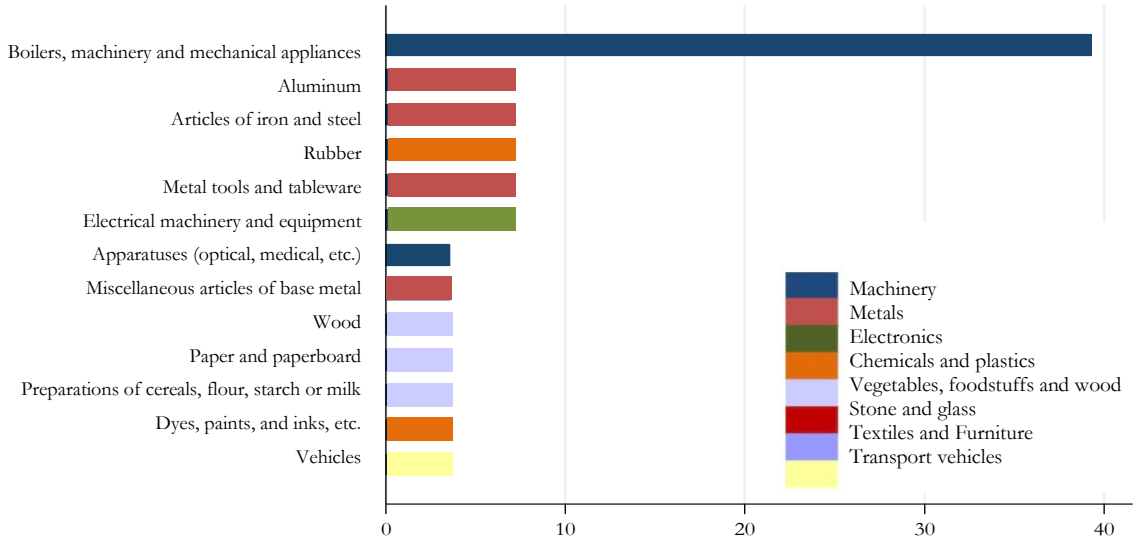
Source: Own calculations based on the Mexican Atlas of Economic Complexity

Figure 17: Top 50 products identified with balanced strategy, in order of intensity of use of potentially restrictive factors

Product	Category	Electric. Int.	Water Int.	Freight Int.	Total Int.	Total % IC
Paints and varnishes, nonaqueous	Chemicals and plastics	M/L	M/L	M/L	M/L	3.2%
Stoppers, caps and lids of metal	Metals	M/L	L	M/L	M/L	3.7%
Lathes for removing metal	Machinery	M/L	M/L	M/L	M/L	3.9%
Machine tools for drilling by removing metal	Machinery	M/L	M/L	M/L	M/L	3.9%
Other lifting machinery	Machinery	M/L	M/L	M/L	M/L	4.0%
Tools for hand working, pneumatic, hydraulic motors	Machinery	M/L	M/L	M/L	M/L	4.0%
Bakery products	Vegetables, foodstuffs and wood	M/L	M/L	M/L	M/L	4.1%
Stoves and similar non-electric appliances of iron or steel	Metals	M/L	M/L	M/H	M/L	4.4%
Parts and accessories for metal working machines	Machinery	M/L	M/L	M/L	M/L	4.4%
Interchangeable tools for hand tools	Metals	M/L	M/L	M/L	M/L	4.4%
Trailers and semi-trailers	Transport Vehicles	M/L	M/L	M/L	M/L	4.5%
Centrifuges	Machinery	M/L	M/L	M/L	M/L	4.6%
Pumps, compressors, fans, etc.	Machinery	M/L	M/L	M/H	M/L	4.7%
Packing boxes	Vegetables, foodstuffs and wood	M/L	M/L	M/H	M/L	4.8%
Mechanical appliances for dispersing liquids or powders	Machinery	M/L	M/L	M/L	M/L	4.8%
Toilet paper	Vegetables, foodstuffs and wood	M/L	M/L	M/L	M/L	4.9%
Calendering or other rolling machines, other than for metals or glass	Machinery	M/L	M/L	M/L	M/L	4.9%
Electrical lighting equipment used for motor vehicles	Electronics	M/L	M/L	M/L	M/L	5.0%
Knives and blades for machines	Metals	M/L	M/L	M/L	M/L	5.1%
Electrical ignition equipment	Electronics	M/L	M/L	M/L	M/L	5.3%
Pumps for liquids	Machinery	M/L	M/L	M/H	M/L	5.3%
Equipment for the treatment of materials by a change of temperature	Machinery	M/L	M/L	M/H	M/L	5.5%
Vulcanized rubber tubes	Chemicals and plastics	M/L	M/L	M/L	M/L	5.6%
Other articles of aluminum	Metals	M/L	M/H	M/L	M/L	5.8%
Aluminum foil < 0.2 mm	Metals	M/L	M/H	M/L	M/L	6.0%
Other articles of iron and steel	Metals	M/L	M/H	M/L	M/L	6.0%
Other articles of vulcanized rubber	Chemicals and plastics	M/L	M/H	M/L	M/L	6.2%
Automatic regulating instruments	Machinery	M/H	M/L	M/L	M/L	6.6%
Transmission shafts	Machinery	M/L	M/H	M/H	M/H	6.8%
Aluminum tube or pipe fittings	Metals	M/H	H	M/L	M/H	7.0%
Appliances for thermostatically controlled valves	Machinery	M/H	H	M/L	M/H	7.0%
Articles of cement, of concrete or of artificial stone	Stone and glass	M/H	M/L	M/L	M/H	7.1%
Springs of iron or steel	Metals	M/H	M/L	M/L	M/H	7.5%
Electrical boards for protecting electrical circuits	Electronics	M/L	H	M/H	M/H	7.6%
Instruments for measuring flow or other variables of liquids or gases	Machinery	M/H	M/L	M/L	M/H	8.0%
Meters	Machinery	M/H	M/L	M/L	M/H	8.0%
Instrument panel clocks for vehicles	Machinery	M/H	M/L	M/L	M/H	8.0%
Steam turbines	Machinery	L	M/H	H	M/H	8.0%
Other plastic plates, sheets etc.	Chemicals and plastics	M/H	M/L	M/H	M/H	8.1%
Textile articles for technical use	Textiles and furniture	M/H	M/H	M/L	M/H	8.2%
Grindstones	Stone and glass	M/L	M/L	H	M/H	8.2%
Natural or artificial abrasive powder	Stone and glass	M/L	M/L	H	M/H	8.2%
Slag wool, rock wool and similar mineral wools	Stone and glass	M/L	M/L	H	M/H	8.2%
Corrugated paper and paperboard	Vegetables, foodstuffs and wood	M/H	M/H	M/H	M/H	8.3%
Insulating fittings for electrical machines	Electronics	M/H	M/L	M/H	M/H	8.4%
Parts suitable for use with spark-ignition engines	Machinery	M/H	M/H	M/H	M/H	9.3%
Electric signal and traffic controls	Electronics	M/H	H	M/H	M/H	9.8%
Electrical transformes	Electronics	M/H	H	M/H	M/H	10.6%
Apparatus protecting electrical circuits for > 1k volts	Electronics	M/H	H	M/H	M/H	10.6%
Hydrometers, thermometers etc	Machinery	H	H	M/L	M/H	10.7%

L: Low, M/L: Medium Low, M/H: Medium High, H: High

Figure 18: Share of medium-low intensity products under endogenous conditions, by product category



Source: Own calculations based on the Mexican Atlas of Economic Complexity

Adjustments to Institutional Design to Address Coordination Failures and Promote Self-Discovery

This section introduces a host of inputs intended to optimize institutional design and solve potential coordination problems, while promoting strategic dialog with the private sector. We also synthesize our proposals on the interventions that could arise from this dialog, which we believe should focus on the supply of public goods and stimulation of entrepreneurial activities and self-discovery. Our analysis does not attempt to recommend one particular institutional structure or a set of specific policies. Rather, the aim is to emphasize the key principles that may provide timely, accurate identification of elements restricting the development of certain industries, and the capabilities to address them swiftly and efficiently. Our recommendations are inspired by the work of Hausmann, Rodrik, and Sabel (2008), and Crespi, Fernández-Arias, and Stein (2014).

1. Promoting Public-Private Coordination and Self-Organization within the Private Sector

The institutional structure should mainly guarantee spaces for strategic dialog between state and local government and the private sector, in order to minimize coordination failures and facilitate identification of restrictions on development of industries.

In Sonora State, the Economic Development Act of 2002 sets out the parameters for participation, outreach, and collaboration between government agencies, public and private institutions, academia, and other relevant stakeholders, both at the state government level and at the municipal government level. At the time of writing, the new State Competitiveness and Economic Development Act was being approved. This would replace the current law. It seeks, among other things, to simplify state functions in the area of stimulating competition and investment. Simplification implies consolidating functions within a centralized department that would be in charge of ruling on and settling requests for incentives.

From a technical standpoint, a centralized department can avoid bureaucratic inefficiencies, but this institutional change must be coupled with better organization regarding dialog with other players in the public and private sectors.

If the proposed changes in the new Competitiveness Act are approved, it would be necessary to promote active coordination between this centralized department and municipal governments. Municipal governments should not lose their discretion or ability to leverage assets to promote productive initiatives—particularly those with high institutional capability, like Hermosillo—which can generate more resources for incentives, and attract and identify potentially successful projects. For the municipalities, interaction with the centralized department should mean less bureaucracy and more opportunity to focus resources on their productive initiatives and improved coordination in order to resolve distortions in productive processes.

We also recommend the creation of flexible mechanisms so that the private sector can self-organize. Companies must have the freedom to organize themselves according to their shared needs and knowledge, and their capacity to overcome obstacles, and not just based on their geographic location or the specific economic sector they are in. The private sector should also have channels for offering the most efficient supply of public services affecting economic activity (for example, design of solutions, co-financing), and for creating the conditions for the autonomous, continuous appearance of new productive initiatives.

This institutional setup will be able to accomplish its goals only if the state and municipal public sectors are guaranteed to have the advanced technical ability to manage industrial policy, incentives, and discussions with the private sector. It would be advisable to have the active participation of relevant ministry heads. It would also be beneficial to create a consultative agency that included high-level sector experts to provide specialized technical assistance and make suggestions on the design of strategies.

2. Directing Promotion Efforts toward Information-Gathering

Hermosillo needs policies that will allow it to find out what is preventing other industrial sectors from arriving. We learned from our analysis of potential restrictions to economic growth that there is a close relationship between the loss of competitiveness in the manufacturing sector, the inability to

offset the sustained decrease in complexity of its export basket, and the economic slowdown in recent years. The spaces for dialog serve as a mechanism for collecting some of this information. However, these spaces are skewed in favor of the stakeholders already in the city, so that they tend not to know the inputs that have prevented the appearance of others.

In concrete terms, we propose including in the institutional solution for executing productive development policies a promotion mechanism that not only focuses on attracting investment initiatives, but also identifies those aspects that discourage potential investors. The municipality must systematically and continually track investment flows to strategic sectors that don't exist in Hermosillo, know where those investments are going, who is behind them, which activities are receiving them, etc. Otherwise, it will not be able to understand what it can do to appear on the radar of those investors. In other words, Hermosillo needs to learn from itself, its successes and its failures, in order to move forward.

This information will enable the city to optimize the design of pitch books for each sector and activity found to be strategic. The books would specify Hermosillo's advantages and opportunities, and stimulate discussion between potential investors and the municipality about key variables.

3. Implementing Strategies to Assess Performance

The institutional structure should be able to evaluate what it does to promote both coordination between the public and private sectors, and self-organization in the private sector. But the metrics it uses for this evaluation should not only focus on quantifying final results such as number of tax incentives and nontax incentives granted, investments brought in, or trainings taking place, but also document the process itself: quantity and frequency of spaces created to expose problems and seek solutions between the public and private sectors, number of strategic associations promoted, implementation of planned solutions, and number of interactions with potential investors. This would enable authorities to determine whether coordination between stakeholders is being adequately promoted, and whether the coordination is speeding up the timely supply of factors that enable and/or spur development of high-potential industries.

4. Shifting Focus of Interventions to Provide Public Goods

Most policy instruments for promoting economic development in Hermosillo, and in Sonora, are characterized by a traditional focus on subsidies and tax relief. Sonora's Economic Development Act (2002) gives it a fundamental role in market interventions such as tax incentives (tax exemptions and reductions) and nontax incentives (subsidies and financial support for R&D, feasibility and pre-investment studies, access to goods and services at subsidized prices). However, the productive development policies from the viewpoint of strategic, coordinated dialog with the private sector that we are supporting in this document should focus firstly on supplying public goods and services that enable the growth of competition and facilitate the appearance and development of activities with

greater productive complexity. These interventions may, in turn, favor economic activity in general, or focus on solving the needs of specific sectors with competitive potential.

We mentioned earlier that our economic Growth Diagnostics exercises for Hermosillo identified at least three areas where there seems to be an undersupply of public goods: electricity, water, and logistics infrastructure. So, for example, if this were confirmed in a dialog, municipal and state governments could improve the supply of public goods and services through these initiatives:

a. Electricity supply: Given the pressure exerted by high temperatures on total power consumption and the lack of subsidies for electricity rates for industrial consumption, the city should harness local potential for producing clean energy, particularly solar energy. This could lower industrial costs, and would help the municipality to leap toward products of greater complexity that are energy-intensive.
b. Water treatment and supply: On this front, projects could be launched to treat gray water that could be used in the productive processes of local firms.
c. Logistics infrastructure conditions: Just as there are gaps in Hermosillo's connection to its natural market, the US, the limitations at the airport and the Guaymas seaport complicate access to other potential markets. Public transport is also unable to fully match supply and demand of labor. The relevant government officials could consider these points:
    - Invest in the maintenance and updating of the state highway network;
    - Increase capacity at the Guaymas port for transporting cargo via containers;
    - Increase the airport's capacity for cargo transport and for carrying out logistics and modal integration operations by creating a Logistics Consolidation Center;
    - Enhance the public transit system to efficiently connect residential areas with the economic and commercial poles, and with industrial parks.

Instead of making recommendations on each of these areas, we aim to underline that the solutions to coordination problems cannot come from the traditional approach of subsidies and tax incentives. Rather, interventions must come specifically from policy, the context of Hermosillo, and the needs of the relevant stakeholders. As a result, the institutional setting in charge of productive dialog must address this type of demand.

The main concerns when considering this alternative approach to dialog are usually technical capacity and financing. But both things can be achieved with public-private cooperation. Since a large number of manufacturing companies have been hiring firms to transport their workers, we would recommend creating incentives for those resources to be allocated toward co-financing improvements to the public transport system, making it possible for those industries to optimize their resources while everyone who currently does not have access to this service can benefit. Similar initiatives can take

advantage of private experience in gray water treatment or the design of a Logistics Consolidation Center at the Hermosillo airport to meet the needs of high cargo-volume transportation.

In some cases, public sector participation could go beyond policy design or allocation of financial resources and focus on solving coordination problems between agents or reducing transaction costs by streamlining administrative processes. In general, the idea is to align public and private incentives in order to extend the benefits to the people, take advantage of private knowledge, and optimize allocation of public resources.

5. Promoting Self-Discovery of the Region's Productive Potential

As mechanisms are consolidated that allow the region to identify which public goods are missing and to ensure their timely supply, diversification will depend both on the private sector's ability to discover potential beyond the usual space, and on the ability of public institutions to facilitate this exploration. What would be useful here are new state agencies or new functions within the current institutional framework that facilitate private enterprise with high productive potential.

These facilitating mechanisms do not have to be limited to allocating funds, which may not be viable or sustainable; they can also address information asymmetries that limit access to resources for developing local projects. One step in this direction is the Finance Company for Economic Development in Sonora (Spanish acronym, FIDESON), which aims to provide access to risk capital for companies by means of strategic alliances with the federal government and other private organizations.

However, this initiative should be accompanied by strategies for connecting high-potential projects in Hermosillo with local and international networks that support enterprise (incubators, accelerators, venture capital), facilitate shared temporary offices for entrepreneurs in early development stages, facilitate access to consulting in key areas (marketing, acquiring business, recruiting investors), and other initiatives that can minimize the costs and losses that usually occur in innovative projects.

6. Reviewing Existing Market Interventions

Lastly, although our focus is not on traditional interventions, we must recognize that these exist in current legislation and in the institutional setting. They may work in harmony with the other suggestions we've made. Specifically, there should be guarantees that the mechanisms for allocating fiscal and non-fiscal incentives are guided by the principle of promoting increased competitiveness and solving coordination failures, rather than compensating or artificially sustaining specific activities or sectors. This would minimize inefficiencies that distort market signals and encourage rent-seeking behaviors.

In addition, allocation criteria should be set up in relation to the size and duration of the fiscal and non-fiscal incentives. This implies assessing which incentives should be maintained beyond the time required by a project to become established and which ones should be simply a one-time push to enter the local market.

Additional Considerations on the Role of Urban Planning

As we said earlier, the possibility that an economic activity will develop in a location depends largely on the existence of certain productive capabilities (for example, public goods and services, occupational vector, regulatory framework). These factors are necessary conditions, but they are not sufficient to attract and retain talent and direct investment. When firms decide where to set up they also consider those aspects that make a city attractive to live and work in (Mulligan and Carruthers, 2011). We therefore advise that a policy to promote productive development in Hermosillo include measures that would improve the city's standard of living.

Glaeser, Kolkoy, and Saiz (2001) describe four types of urban amenities that have a positive impact on the perception of quality of life in a particular area, and consequently, its capacity to attract talent and highly skilled workers, who are more likely to be concentrated in activities that generate knowledge. The first amenity is the diversity of consumer and leisure goods and services (such as restaurants, cultural meeting spaces, shopping centers). The second group is how the public space is configured, the physical and aesthetic appearance of the city (for example, revitalization of historic centers and architectural rebuilding, creation of pedestrian zones, etc.). The third group is the supply of public goods and services that directly raise quality of life, such as schools, hospitals, and public safety agencies. The last group concerns how quickly and easily people can move around and make connections. This refers not only to a good transportation system, but to physical proximity between the economic poles and people through greater urban density.

Although we have broached some of these topics only tangentially in our analysis, and we therefore are not making specific recommendations for measures in this area, we do want to stress the importance of considering planning interventions that would make Hermosillo attractive to highly skilled workers, and to the corporate headquarters, R&D centers, and testing and design centers that could employ them. We should not lose sight of equity in allocating resources and respect for the city's own identity.

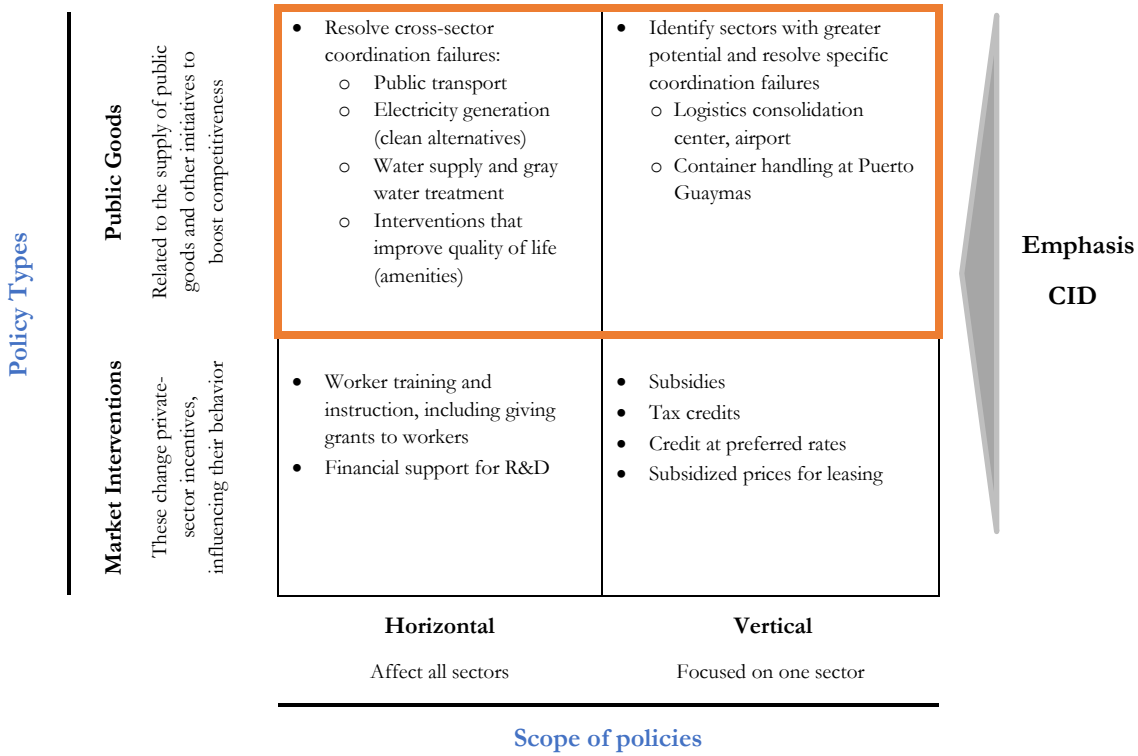
Conclusions

Today Hermosillo is one of the most highly developed municipalities in Mexico. Yet over the past few years, its economy has experienced major decreases in GDP per worker and in real incomes, due to the loss of competitiveness and complexity in the manufacturing sector that the city relies on so heavily. More specifically, the cause seems to lie with the difficulties in being able to add significant numbers of new, more sophisticated products to its export basket.

Our analysis indicates that Hermosillo has been prevented from advancing toward diversification due to coordination failures in the supply of key public goods, wage distortions not explained by the stock of human capital or sectoral complexity, and the lack of catalysts to innovation like direct, knowledge-intensive foreign investment and the ability to attract and retain talent.

Based on these conclusions, we are offering a set of inputs for the design of public policies that will relaunch innovation in the city. These inputs are centered on mechanisms to identify economic sectors with potential for Hermosillo, adjustments to institutional design, and high-level observations on the role that urban planning can play. Our proposals underscore the supply of public goods, both those that benefit all sectors in general and those that are fundamental for a specific activity. The inputs are summarized in Figure 20.

Figure 19: Chart of productive development policy types, tailored to Hermosillo



Source: Adapted from Campante and Solé (CID, 2015), based on Crespi, Fernández-Arias, and Stein (2014).

Hermosillo is still wondering whether it has a future after Ford. But in the 30 years since the company came to the city, the municipality has raised its income levels, decreased poverty and informal jobs, and become one of the cities with the greatest competitive potential[29] in Mexico.

But it cannot rest on its laurels. Its per capita income is higher than expected given its economic structure, which generally suggests a growth deceleration. The economic slowdown is an alarm bell that should be encouraging authorities to think about why they haven't seen the productive diversification observed in other cities that began from a similar point, and what can be done about it.

Our job has been to contribute to this process of evaluation and rediscovery. Curiously, what we set out to do was determine how to give back to Hermosillo the attractiveness it had, in one form or another, over 30 years ago. At that time, the city managed to draw to the desert a small group of activities whose sophistication contrasted with the basic nature of its economy, thus producing an exceptional transformation.

[29] http://imco.org.mx/competitividad/indice-de-competitividad-urbana-2016/

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VII Appendixes

Appendix 1: Data for Calculating and Defining Economic Complexity Terms

1. Data for calculating and defining economic complexity terms

The calculation of economic complexity terms is generally based on international trade data, the only set of data available that links the countries with the products they produce in a standard classification. It offers major advantages, but also has some limits. First, it includes data on exports, not on production. Countries can make things they do not export, because they may not be very competitive in their production. Countries can also export things they do not make. To avoid this problem, countries must have a revealed comparative advantage in their exports. (See definition of terms.) Secondly, since customs offices collect the data, they include only goods and not services, which are becoming an increasingly large part of international trade. Unfortunately, the statistical efforts in most countries have not kept up with this reality. For this analysis, we used the export data from Mexico's Tax Administration Service (Spanish initials, SAT), which were mined to construct the Mexican Atlas of Economic Complexity (http://complejidad.datos.gob.mx/#/?locale=en-mex).

2. Definition of economic complexity terms

Complexity

A society's roads to prosperity depend on companies being able to successfully produce and export goods and services that require diverse skills and knowledge. Complexity can be measured for a location, an export product, or a sector.

Complexity Outlook

Ranks a location's potential for increasing its economic complexity. The ranking accounts for the level of complexity of all the export products already present, and the distance in terms of skills and knowledge that separates them from other industries. Using this information, it measures the likelihood of new exports appearing and how much they would raise the location's complexity.

Distance

A measure of a location's ability to develop a specific export, determined by its current productive capabilities. Where an export product requires some of the same capabilities already present in a location, the product is considered closer. Thus, distance reflects the proportion of the productive knowledge required so that an export product can appear in a location where it does not exist.

Proximity is the reverse of the distance between two goods *i* and *j* in year *t*. It is defined as follows:

$$\varphi_{i,j,t} = \min\{P(Xj,t), P(Xi,t)\}$$

where, for any country c,

$$x_{i,c,t}\begin{cases}1 \;\; SI \;\; RCA_{i,c,t} > 10\end{cases}$$

where the conditional probability is calculated for all countries in year t, using disaggregated export data for a large sample of countries from World Trade Flows (Feenstra, 2005) and UN COMTRADE.

Economic Complexity Index (ECI)

A measure of the sophistication of a location's productive capabilities based on the diversity and exclusivity of its productive sectors or exports. A location with high complexity is able to produce or export goods and services that few other locations can produce. High-complexity locations tend to be more productive and generate higher wages and incomes. Countries with export baskets more sophisticated than expected for their income level tend to grow faster.

To calculate it, Mcp is defined as a matrix that contains 1 if country $\boldsymbol{c}$ produces good $\boldsymbol{p}$ with a revealed comparative advantage (RCA) > 1, and 0 in any other case. Diversity and ubiquity are simply the result of adding rows and columns in this matrix. Formally, we will define:

$$Diversity = k_{c,o} = \sum_{p} M_{cp}$$

$$Ubiquity = k_{p,0} = \sum_{c} M_{cp}$$

To create a more accurate measure of the number of capabilities available in a country or that are required for a product, we need to use the information in ubiquity to correct the information in diversity. For countries, this means we must calculate the average ubiquity of the products it exports, and the average diversity of countries that export these same goods, and so on. For products, we must calculate the average diversity of countries that make the goods, and the average ubiquity of the other products that these countries are able to make. This iteration can be expressed with this recursion:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} k_{p,N-1} \qquad (1)$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} k_{c,N-1} \qquad (2)$$

By inserting (2) in (1) we get:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} \frac{1}{k_{p,0}} \sum_{c'} M_{c'p} k_{c',N-2}$$

$$k_{c,N} = \sum_{c'} k_{c',N-2} \sum_{c'} \frac{M_{c'p} M_{cp}}{k_{c,0} k_{p,0}}$$

Which in turn can be rewritten as:

$$k_{c,N} = \sum_{c'} \tilde{M}_{cc'} k_{c',N-2}$$

Where:

$$\tilde{M}_{cc'} = \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}}$$

Note that (6) is satisfied when *kc,* = *kc,*−2 = 1. This is the *eigenvector* of $M \square cc'$ that is associated with the greater *eigenvalue*. Since this eigenvector is a vector of ones, it is not informative. We will look instead for the eigenvector associated with the second largest eigenvalue. This is the eigenvector that captures the greatest amount of variation in the system, and it will be our measure of economic complexity. From here, we will define the Economic Complexity Index (ECI) as follows:

$$ECI = eigenvector\ associated\ with\ the\ second\ largest\ eigenvalue\ of\ \tilde{M}_{cc'}$$

Product Complexity Index (PCI)

It ranks export products according to the diversity and ubiquity of productive capabilities they need. A location with high economic complexity is able to produce many goods and services that few people on average know how to make. Locations with greater economic complexity tend to be more productive, which translates into higher wages. Countries whose export baskets are more complex than expected for their income level tend to grow faster. We used data from the United Nations COMTRADE database of nearly 200 countries to calculate the complexity of export products.

Export Product Space

A visualization showing how similar the required knowledge and capabilities are for different products. Each color represents one sector, each point represents one export product, and each link between a pair of products indicates that they require similar productive capabilities. The Product Space also shows when a location has revealed comparative advantages (RCA) in the production and export of a good, and how close it is to other products where it does not have an RCA. The map shows potential paths to export diversification based on existing knowledge and skills. A product that has more links to others that are not exported offers greater potential for export diversification through shared capabilities. And if these capabilities are complex, the product has high potential to

raise complexity in the location. The product similarity map is based on international trade data for 192 countries over more than 50 years. See http://atlas.cid.harvard.edu/.

Strategic Value

This measures how much a location could benefit if it manages to develop a specific export product. Also known as "opportunity gain," this measure expresses the distance to all the other exports that a location does not currently produce and their respective complexity. It reflects how one new export can lead the way to other, more complex products.

Revealed Comparative Advantage (RCA)

This measures the relative size of an export sector or product in a location. RCA, which should not be considered an indicator of productive efficiency or competitiveness, is also known as the "location quotient." Following the methodology of Balassa (1964), it calculates the quotient of the product's weight in the location's export basket and compares it to the weight the product has in world trade. If this ratio is greater than 1, we say the location has a revealed comparative advantage in that sector or export. In this case, because we are dealing with a subnational study that analyzes municipalities, some of which are small and export very little, we established an additional criterion that the product export volume in one year must be greater than or equal to USD5000.

Appendix 2: Main Sources of Information by Topic

Figure 20: List of information sources by topic (database names are in Spanish)

Topic	Database
Finance	- Comisión Nacional Bancaria y de Valores - Censo Económico, INEGI - Índice de Competitividad Urbana, Instituto Mexicano para la Competitividad (IMCO) - Base de Índice de Precios del Consumidor, INEGI
Human Capital	- Encuesta Intercensal 2015, INEGI - Censo Poblacional, INEGI
Electricity	- Comisión Federal de Electricidad (CFE) - Programa de Desarrollo del Sistema Eléctrico Nacional (PRODESEN), Secretaría de Energía - Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - Anuarios Estadísticos Estatales, INEGI - Censo Económico, INEGI
Water	- Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - Programa de Indicadores de Gestión de Organismos Operadores (PIGOO) - Comisión Nacional del Agua (CONAGUA) - Agua de Hermosillo (Aguah) - Censo Económico, INEGI
Mobility	- Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - Anuarios Estadísticos Estatales, INEGI - Encuesta Intercensal 2015, INEGI - Plataforma de Información Económica Digital de Hermosillo (PIEDH), Comisión del Fomento Económico del Municipio de Hermosillo

Topic	Database
Logistics Infrastructure	- Mappir México, Secretaría de Comunicaciones y Transporte - Anuario Estadístico del Transporte Marítimo, Secretaría de Comunicaciones y Transporte - Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - Dirección General de Aeronáutica Civil, Secretaría de Comunicaciones y Transporte - Comisión de Fomento Económico de Hermosillo - Bureau of Transportation Statistics, US Department of Transportation - U.S. Customs and Border Protection
Corruption	- Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - Encuesta Nacional de Calidad e Impacto Gubernamental (ENCIG), INEGI
Regulatory Framework	- Encuesta Nacional de Calidad Regulatoria e Impacto Gubernamental en Empresas (ENCRIGE), INEGI - World Bank Doing Business Indicators
Safety	- Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública (SESNP), Secretaría de Gobernación - Encuesta Nacional de Victimización y Percepción sobre la Seguridad Pública (ENVIPE), INEGI - Encuesta Nacional de Victimización de Empresas (ENVE), INEGI - Sistema Estatal y Municipal de Bases de Datos (SIMBAD), INEGI
Labor Disputes	- Sistema Estatal y Municipal de Bases de Datos (SIMBAD), INEGI - Instituto Mexicano para la Competitividad (IMCO) - Encuesta Nacional de Ocupación y Empleo (ENOE), INEGI
Economic Complexity	- Mexican Atlas of Economic Complexity, CID Harvard - Anatomía de Clústeres, Tecnológico de Monterrey - Censo Económico, INEGI
Market Failures	- Censo Económico, INEGI - Índice de Competitividad Urbana, Instituto Mexicano para la Competitividad (IMCO) - Mexican Atlas of Economic Complexity, CID Harvard

Appendix 3: Estimate of Municipal GDP

The starting point for diagnosing growth is in fact the evolution of a variable that considers the aggregate economic activity of a country or territorial unit. In most cases, assuming information is available, this variable tends to be Gross Domestic Product (GDP). However, Mexico's national institute of statistics and geography (INEGI) does not publish official GDP statistics at the municipal level. So, we had to look for other methods to obtain an accurate idea of what economic growth has been like in Hermosillo municipality over the past few years.

This appendix details the methodology used to calculate GDP in Mexican municipalities, provides a brief description of some alternatives considered, and analyzes the main advantages and disadvantages of each estimate. We also describe the metrics and statistical and economic criteria used to compare the predictive performance of each estimate.

1. Nonparametric estimate of GDP based on structures of municipal value added and employment

The nonparametric method used to calculate municipal GDP assumes that the sectoral structure of GDP for each municipality closely follows the sectoral structures for employment and value added captured by economic censuses. Specifically, GDP for each municipality was obtained using this equation:[30]

$$PIB_{jt} = \sum_{i=1}^{n} \frac{PIBE_{it} * \left(\frac{PO_{ijt}}{POE_{it}}\right) + PIBE_{it} * \left(\frac{VA_{ijt}}{VAE_{it}}\right)}{2} \quad \forall \, t = 2003, \ldots, 2015 \quad (1)$$

Where:

PIB_{jt} is the GDP of municipality *j* in the year *t*.

$PIBE_{it}$ is the GDP of economic sector *i* in the state where the municipality is located in year *t*.

PO_{ijt} is the Working Population in economic sector *i* in municipality *j* in the year *t*.

POE_t is the Working Population in economic sector *i* in the state where the municipality is located in year *t*.

VA_{ijt} is the gross census value added in economic sector *i* in municipality *j* in the year *t*.

[30] The same method was used by Mexico's institute for geographic, statistical, and cadastral information and research (Spanish initials, IGECEM), (2013) to calculate GDP for the 125 municipalities in Mexico.

VAE_t is the gross census value added in economic sector *i* in the state where the municipality is located in year *t*.

$i = 1, 2, \ldots, 20$ economic activity sectors

$j = 1, 2, \ldots, n$ municipalities

Equation (1) implies that total GDP for municipality *j* is obtained by adding the municipal GDP for each economic sector. Then we get each municipal sectoral GDP by distributing the GDP of each economic sector in Sonora State according to the simple average of the share of each municipality in the working population and the census gross value added for the state total for that economic activity. As with the IGECEM, (2013), economic activities are classified according to the North American Industry Classification System (NAICS). We also explored two specifications where sectoral GDPs were distributed using only the working population or the value added.

To obtain the estimate for equation (1), we used the series of GDPs by state in the base year 2008 published by INEGI, and the working population and gross value-added data from the INEGI economic census for 2004, 2009, and 2014. To calculate weights for working population and gross value added in the years when no census information was collected, we considered two options:[31]

a) Maintain the 2003 weights of the 2004 Economic Census for the years 2004 to 2008; 2008 weights from the 2009 census for the years 2009 to 2012; and the 2013 weights from the 2014 census for the years 2014 and 2015.

b) Calculate the compound annual growth rates (CAGR)[32] between 2003 and 2008 and between 2008 and 2013 of the working population and gross value-added series and use them to calculate amounts for these series in the years between censuses. With this calculation we can approximate the underlying trends of the series during the period under consideration.

This methodology was used for the 32 states, obtaining the series of GDPs for the 2,446 municipalities in the country. Thus, in order to evaluate the performance of the predictions obtained, we applied a similar exercise to recreate the GDP series for the states based on the series of total Mexican GDP.

[31] We should mention that the data for economic activities classified as "sectors grouped by the confidentiality principle" were prorated. That is, they were distributed across the major economic activity sectors explicitly specified according to their proportions of the municipal total.

[32] Compound annual growth rate, or CAGR, is defined as $CAGR = \left(\frac{Final\ Value}{Initial\ Value}\right)^{\frac{1}{number\ of\ years}} - 1$.

Parametric estimate of GDP based on energy consumption and on incomes or factor payments

In addition to the nonparametric method described above, we considered two alternative parametric methods that use earned incomes and energy consumption as predictors of economic activity in regions and municipalities.

- **Estimate based on earned incomes:** Factor payments, i.e., the income earned by the working population and the value added generated by the Economic Units, is a good indicator of the evolution of economic activity in a given territorial unit. Given the above, we performed a two-stage parametric calculation to estimate municipal GDP. In the first stage, we estimated GDP in the states according to the equation (2):

$$Ln(GDP_{it}) = \alpha + \beta Ln(Income_{it}) + Ln(VA_{it}) + \varsigma_i + \varphi_t + \varepsilon_{it} \quad \forall\, t = 2005, \dots, 2014 \quad (2)$$

  where $Ln(GDP_{it})$ is the logarithm of GDP for state *i* in the year *t*; $Ln(Income_{it})$ is the logarithm of total earned income for the working population; and $Ln(VA_{it})$ represents the total gross census value in state *i* in the year *t*. In the second stage, we distributed the estimated GDP for each state among its municipalities according to their share in total earned income and/or the value added according to the specification. As with the nonparametric method, the GDP data for the states match the figures published by INEGI for 2003 to 2014. The income series were obtained from the national occupation and employment survey (Spanish initials, ENOE).

- **Estimate based on energy consumption:** Assuming energy consumption is positive and strongly correlated with economic activity, and following the method proposed by Bundervoet, Maiyo, and Sanghi (2015), we can calculate GDP for the states in three stages. In the first, we estimate total Mexican GDP based on equation (3) using aggregate series of GDP and energy consumption for all countries in the OECD:[33]

$$Ln(GDP_{it}) = \alpha + \beta Ln(CE_{it}) + \varsigma_i + \varphi_t + \varepsilon_{it} \; \forall\, t = 2003, \dots, 2014 \quad (3)$$

[33] We made estimates for different groups of countries (Latin America, middle-income countries as per World Bank criteria, and OECD countries). The last one proved the most suitable.

where $Ln(GDP_{it})$ is the logarithm of GDP for country *i* in the year *t* and $Ln(CE_{it})$ is the logarithm of total energy consumption in country *i* in the year *t*. This specification includes fixed effects at the country level, ς_i, and fixed temporary effects, φ_t. Next, the estimated GDP is divided in two according to the share of industry and services and the share of the agricultural sector in total GDP. After this, we distribute the portion of GDP corresponding to industry and services among the states based on their respective share in national energy consumption. In the third and final stage, we distribute the GDP for the agricultural sector among the states based on their respective share of rural population out of the country's total rural population. The GDP of each state will then equal the sum of the corresponding industrial and services GDP and agricultural GDP.

We should mention that we were not able to apply this methodology at the municipal level, as we do not have a series of information on energy consumption to this degree of disaggregation. However, we are consulting with the proper authorities to gain access to this information.

Comparison of Goodness-of-Fit of Methodologies Considered

As indicated above, the methods described allowed us to obtain not only estimates of the municipal GDP series (for which there are no official data), but also GDP estimates for states (which are calculated and published periodically by INEGI), and their respective annual growth rates. These rates are particularly informative, because they allow us to compare the goodness-of-fit of each of the methodologies. With the rates, we can rigorously assess the predictive power of each method, and use statistical criteria to select the one that best approximates municipal GDP growth rates.

The following criteria were used to make this comparison:

- **Symmetric mean absolute percentage error, or sMAPE**: a measure of the predictive accuracy of an estimate, regardless of whether it was obtained using a parametric or nonparametric method. It is usually defined thusly:

$$sMAPE = \frac{\sum_{t=1}^{n} |F_t - A_t|}{\sum_{t=1}^{n} |A_t| + |F_t|}$$

Where A_t is the observed value of the GDP growth rate and F_t is the predicted value. This measure, delimited by the range [0,1], is unbiased and penalizes both underestimate and overestimate errors symmetrically. So, we say that one estimate is more accurate than another if its sMAPE is lower (closer to 0).

Figure 22 shows the comparison between methodologies using the sMAPE as the criterion. Here we see that the estimates obtained from the nonparametric method where compound growth rates were used to approximate the trends of the aggregate population and census gross value-added series are generally more accurate. In particular, the specification that distributes GDP using employment exclusively gave the best results, both overall and for Sonora.

Figure 21: Symmetric mean absolute percentage error for GDP estimates

	Symmetric MAPE, sMAPE 2006-2014							
		Nonparametric			Nonparametric & CAGR			
State	Electricity Consumption	Employ. & VA	Employment	VA	Employ. & VA	Employment	VA	Income ENOE
Total	0.414	0.392	0.367	0.476	0.393	0.280	0.540	0.342
Aguascalientes	0.296	0.338	0.240	0.432	0.326	0.268	0.407	0.236
Baja California	0.377	0.343	0.292	0.405	0.457	0.226	0.656	0.359
Baja California Sur	0.358	0.679	0.663	0.695	0.567	0.499	0.623	0.360
Campeche	0.940	0.777	0.817	0.764	0.824	0.873	0.845	0.649
Coahuila de Zaragoza	0.460	0.346	0.394	0.411	0.303	0.472	0.265	0.361
Colima	0.345	0.543	0.500	0.689	0.416	0.296	0.686	0.207
Chiapas	0.483	0.741	0.388	0.851	0.699	0.374	0.854	0.447
Chihuahua	0.447	0.396	0.410	0.523	0.421	0.293	0.548	0.326
Ciudad de México	0.497	0.249	0.323	0.181	0.194	0.236	0.267	0.242
Durango	0.425	0.422	0.452	0.398	0.324	0.421	0.392	0.363
Guanajuato	0.347	0.166	0.192	0.198	0.240	0.124	0.353	0.275
Guerrero	0.366	0.489	0.435	0.576	0.505	0.373	0.768	0.540
Hidalgo	0.435	0.194	0.388	0.443	0.168	0.219	0.312	0.340
Jalisco	0.319	0.247	0.118	0.366	0.233	0.142	0.373	0.253
México	0.290	0.174	0.262	0.184	0.119	0.122	0.150	0.279
Michoacán de Ocampo	0.498	0.281	0.377	0.393	0.251	0.241	0.312	0.279
Morelos	0.518	0.216	0.412	0.370	0.285	0.465	0.274	0.353
Nayarit	0.320	0.363	0.325	0.412	0.243	0.278	0.271	0.342
Nuevo León	0.312	0.165	0.179	0.164	0.184	0.164	0.203	0.239
Oaxaca	0.438	0.464	0.388	0.641	0.892	0.372	0.965	0.531
Puebla	0.355	0.259	0.272	0.330	0.145	0.170	0.186	0.298
Querétaro	0.247	0.360	0.354	0.366	0.085	0.076	0.174	0.184
Quintana Roo	0.365	0.332	0.300	0.433	0.272	0.227	0.377	0.254
San Luis Potosí	0.287	0.244	0.161	0.322	0.117	0.168	0.175	0.297
Sinaloa	0.522	0.419	0.193	0.536	0.285	0.191	0.488	0.449
Sonora	0.518	0.476	0.483	0.481	0.316	0.165	0.503	0.379
Tabasco	0.348	0.512	0.534	0.531	0.565	0.402	0.621	0.507
Tamaulipas	0.503	0.381	0.459	0.327	0.327	0.376	0.398	0.437
Tlaxcala	0.488	0.309	0.331	0.265	0.498	0.143	0.732	0.321
Veracruz de Ignacio de la Llave	0.319	0.578	0.356	0.710	0.718	0.376	0.800	0.458
Yucatán	0.397	0.269	0.190	0.464	0.228	0.156	0.433	0.313
Zacatecas	0.488	0.513	0.479	0.531	0.409	0.379	0.465	0.514

Source: Own Calculations

- **Mean absolute error**, **MAE**: The mean absolute error is another measure of predictive accuracy. Like the sMAPE, MAE can be used regardless of the method applied to obtain estimates. This measure is defined as follows:

$$MAE = \frac{\sum_{t=1}^{n} |F_t - A_t|}{n}$$

The measure preserves the measurement units of the series evaluated (in this case, percentage points), so it is easily interpreted. We say that one estimate is more accurate than another if its MAE is lower.

Figure 23 compares the estimates obtained using MAE. The results are generally consistent with those obtained using sMAPE, and tend to favor the nonparametric methods that use CAGR, especially the one that uses employment to assign sectoral GDPs.

Based on this analysis, we decided to use the municipal GDP estimate for this study based on the nonparametric method, using CAGR and basing distribution exclusively on employment. In addition to producing the best results in terms of its goodness-of-fit, this method produces a longer series of time and a series of GDPs for each economic sector (not just total GDP).

Figure 22: Mean absolute error for GDP estimates

	Mean Absolute Error. MAE 2006-2014							
	Electricity		Nonparametric		Nonparametric & CAGR			Income ENOE
State	Consumption	Employ. & VA	Employment	VA	Employ. & VA	Employment	VA	
Total	0.032	0.033	0.028	0.048	0.035	0.021	0.061	0.022
Aguascalientes	0.030	0.036	0.023	0.050	0.030	0.025	0.036	0.023
Baja California	0.026	0.024	0.018	0.034	0.027	0.015	0.045	0.019
Baja California Sur	0.035	0.097	0.085	0.111	0.064	0.050	0.080	0.027
Campeche	0.079	0.047	0.052	0.046	0.090	0.047	0.112	0.039
Coahuila de Zaragoza	0.042	0.033	0.035	0.042	0.029	0.040	0.030	0.033
Colima	0.029	0.059	0.038	0.125	0.059	0.022	0.196	0.015
Chiapas	0.031	0.079	0.021	0.134	0.042	0.022	0.086	0.023
Chihuahua	0.037	0.039	0.030	0.065	0.027	0.021	0.040	0.022
Ciudad de México	0.027	0.021	0.031	0.014	0.015	0.017	0.022	0.014
Durango	0.026	0.036	0.039	0.034	0.025	0.032	0.035	0.018
Guanajuato	0.030	0.015	0.018	0.016	0.020	0.011	0.033	0.021
Guerrero	0.017	0.030	0.024	0.043	0.038	0.020	0.121	0.024
Hidalgo	0.029	0.014	0.024	0.049	0.013	0.015	0.028	0.020
Jalisco	0.021	0.019	0.009	0.031	0.017	0.011	0.028	0.018
México	0.019	0.012	0.018	0.013	0.008	0.008	0.011	0.017
Michoacán de Ocampo	0.052	0.023	0.027	0.039	0.017	0.017	0.019	0.017
Morelos	0.029	0.013	0.031	0.031	0.019	0.028	0.021	0.020
Nayarit	0.024	0.027	0.023	0.033	0.019	0.021	0.023	0.020
Nuevo León	0.031	0.016	0.017	0.016	0.017	0.015	0.019	0.021
Oaxaca	0.021	0.035	0.024	0.071	0.186	0.026	0.352	0.023
Puebla	0.026	0.021	0.020	0.032	0.012	0.013	0.018	0.019
Querétaro	0.025	0.038	0.036	0.040	0.009	0.008	0.020	0.018
Quintana Roo	0.041	0.034	0.025	0.052	0.023	0.020	0.031	0.023
San Luis Potosí	0.024	0.020	0.011	0.031	0.009	0.012	0.015	0.019
Sinaloa	0.038	0.029	0.013	0.047	0.020	0.013	0.037	0.025
Sonora	0.046	0.041	0.042	0.042	0.028	0.015	0.044	0.027
Tabasco	0.029	0.033	0.035	0.037	0.050	0.027	0.067	0.031
Tamaulipas	0.025	0.024	0.033	0.022	0.019	0.018	0.029	0.019
Tlaxcala	0.036	0.019	0.023	0.018	0.054	0.011	0.137	0.018
Veracruz de Ignacio de la Llave	0.018	0.053	0.022	0.098	0.062	0.017	0.109	0.021
Yucatán	0.028	0.022	0.012	0.053	0.018	0.010	0.045	0.018
Zacatecas	0.060	0.050	0.047	0.056	0.044	0.039	0.053	0.038

Source: Own calculations

Appendix 4: Comparison Group for Hermosillo

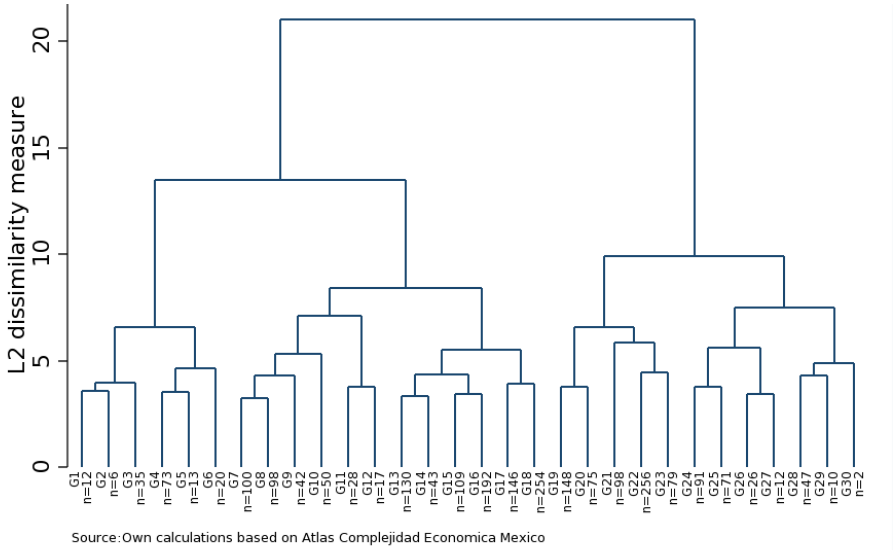
To compare Hermosillo's relative performance, we created a comparison group using the hierarchical cluster method. The cluster method is an exploratory data analysis technique where you attempt to group data according to their natural properties (Kaufman and Rousseeuw, 1990). In our analysis of Mexican municipalities, we included the following variables:

- Size of labor force as number of workers
- Size of exports
- Composition of exports: Exported products are classified by each municipality into nine categories based on the harmonized system of tariff nomenclature.
- Geographic ubiquity: We considered only the states bordering the US.

The data used include annual information between the years 2010 and 2014. There is a wide variety of options for grouping and separating the data using cluster analysis (Miligan and Cooper, 1985; Everitt et al., 2011) and, in general, the process is subject to the researcher's criteria and decisions. In this case, we used the hierarchical agglomerative method. With this approach, we begin by considering each municipality as a group. Then, the two closest groups are combined, and the process continues until all observations are considered as one single group. This is the most commonly used technique in the literature since other techniques, such as divisive hierarchical clusters, require computing capacity, and few statistical packets contain them. Figure 24 details the process of generating clusters for the Mexican municipalities based on the data described above.

Once the groups were formed, 20 clusters were generated to create the comparison group for Hermosillo, with these municipalities: Reynosa, Chihuahua, Juárez, Aguascalientes, Mexicali, Tijuana, Ramos Arizpe, and Saltillo. Lastly, to measure how far Hermosillo is from the municipalities with the highest productive capabilities in Mexico, we also included two of the municipalities with the highest economic complexity index in the country: Apodaca (Nuevo León) and Nogales (Sonora). The resulting comparison group contained the municipalities shown in Figure 25.

Figure 23: Cluster analysis using agglomerative hierarchical methodology



Source:Own calculations based on Atlas Complejidad Economica Mexico

Figure 24: Comparison group for Hermosillo

STATE	MUNICIPALITY	Size of the Labor Force (2015)	Annual Exports (2010-2014, millions)	Economic Complexity Index (2014) Index (2014)	Exports Composition (2010-2014)								
					Textiles and furniture	*Vegetables, foodstuffs and wood*	*Stone and glass*	*Minerals*	*Metals*	*Chemicals and plastics*	*Transport Vehicles*	*Machinery*	*Electronics*
Nuevo Leon	Apodaca	248,819	10,198.50	2.1	2.5	0.5	0.5	0	7	5	11	37.5	36.5
Sonora	Nogales	96,978	4,134.50	2	3	1.5	0	0	13	2.5	1.5	38	40
Tamaulipas	Reynosa	258,439	17,467.50	1.9	3	1.5	0.5	4.5	2.5	4.5	5.5	21.5	57.5
Chihuahua	Chihuahua	376,168	8,247.00	1.7	2	2	1.5	1.5	1	3	33	26.5	29.5
Chihuahua	Juarez	574,927	36,903.50	1.7	4	2.5	0.5	0	1.5	2.5	4.5	52.5	32
Aguascalientes	Aguascalientes	365,718	6,078.50	1.6	4	2	0	0	0.5	1	74.5	12.5	5.5
Baja California	Mexicali	411,304	9,060.50	1.5	5	3.5	3	0.5	6.5	3	14	25	40.5
Baja California	Tijuana	714,010	29,424.50	1.3	5	3	2	0	3	3.5	9.5	15.5	59
Coahuila	Ramos Arizpe	38,935	6,146.00	1.3	4.5	1	1	0	8	1	68	15	1.5
Coahuila	Saltillo	327,023	4,569.00	1.3	7	2	1	0.5	0.5	2	68	13	5.5
Sonora	Hermosillo	386,232	7,168.00	0.6	3	6.5	8	0.5	4	1	59	10	8.5

Source: own calculations based on INEGI y the Atlas of Economic Complexity