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FULL ARTICLE

Growth and inequality in the Mexican states: Regimes, thresholds, and traps

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Abstract

Using the inter-regional economic inequality index and the gross state product *per capita* for the Mexican states over the period 1940–2015, we apply regime dynamics and hierarchical cluster analysis for segmenting the sample into regimes of Mexican states with similar performance. Robust econometric models are studied showing the direction of causality between economic inequality and income *per capita*, and the existence of a U-shaped curve for the interdependence between economic growth vs economic inequality, and threshold levels. We additionally demonstrate the existence of inequality traps. The education literacy rate as a control variable indicates an inverted U-shaped curve.

KEYWORDS

economic growth, hierarchical trees, interregional inequality, Mexican economy, regime dynamics

JEL CLASSIFICATION

C14; I30; O15; O40; O54

1 | INTRODUCTION

Research studies on economic growth and inequality follow the seminal works by Lewis (1954) and Kuznets (1955). The Kuznets model pointed out that inequality follows a U- shaped inverse driven by economic, political and demographic factors. Kuznets argued that the rise in inequality is due to the tendency of the wealthy to both save and invest more of their income in the early stages of economic industrialization when the modern sector comprised a small but growing share of the economy. He further suggested that the subsequent decrease in inequality is caused by the expansion of the modern sector throughout the economy, and political reactions against the growing inequality of wealth.

The research literature on economic inequality in Latin America (LA) is so extensive because it is one of the most important and intriguing issues in LA economies. For instance, Engerman and Sokoloff (1997) argue that high levels of inequality have their roots in institutions and power structures that date back to the colonial period. Reygadas (2010) highlighted that the cultural and social mechanisms in LA give rise to the origin of economic inequality. These studies aim to explain the persistence of inequality. Other research aims to explain the dynamics of inequality.[1]

On the other side, spatial inequalities (regional or state) have been established in different ways within the regions of the countries. Since the 1990s, a large body of empirical papers have analysed the beta convergence, although only later contributions, namely the New Economic Geography models, have introduced the notion of spatial dimension into the formulation of convergence or divergence and inequality between regions (Baumont et al., 2003). The seminal model that explains the underlying mechanisms is that of Krugman (1991), on the origin of new economic geography (NEG). For LA economies, the issue about the interplay between regional inequality and national growth, has been analysed by Mendoza-Velázquez et al. (2020). The convergence of Mexican states (MS) has also been studied by several researchers (for instance, Carrion-i-Silvestre & German-Soto, 2009; Cabral & Mollick, 2012).

In this vein, the present research paper aims to relate the NEG approach to the Mexican economy. Our goal is to establish whether there is a connection and/or formation of economic regimes at the regional level corresponding to economic concentration (interregional inequality), and regional economic growth. In this research work we consider the database built by German-Soto (2016, 2019). Such data represent regional economic growth, and levels of multidimensional economic inequality for the 32 Mexican states (MS) in Mexico. Two important series are generated in such a database: (i) the regional real gross state product (GSP) *per capita* as a proxy for income *per capita* or regional economic growth; and (ii) the inter-regional distribution of income. This latter is multidimensional in the sense that it is based on four socio-economic variables, namely: product *per capita*, education, health and agglomeration, which measure the distance between the Mexican states during a specific period. That is, it provides a database of interregional economic distance and its evolution over time. Although the heterogeneity of the sample is an essential aspect for the quantitative analysis, it is convenient to find homogeneous groups of states that adequately respond to the inquiry. To this end and following Brida et al. (2013) and Brida et al. (2020), the study applies the notion of economic regime from which symbolic sequences are constructed and a metric is defined to compare the dynamic behaviour between the different states. This allows for a hierarchical analysis of clusters, thus determining the existence of homogeneous groups of MS. Once the groups are defined, an econometric model is specified for each group using a panel data structure and the results are compared.

The remainder of the paper is organized as follows. Section 2 presents a brief review of the main empirical works that analyse the relationship between economic growth and inequality in the Mexican context. Section 3 presents the data to be used in the notion of regimes, and applies the symbolic analysis of time series, and the grouping/clustering methodology by considering the minimum spanning tree, all aiming at obtaining homogeneous groups of MS in terms of inequality and growth. Once the clusters are obtained, in section 4 an econometric exercise is developed, thus making an inference of causality and effect (in term of elasticities) on the variables analysed. Finally, a concluding section is presented with the final comments, reflections, work limitations and possible future developments.

2 | LITERATURE REVIEW: THE MEXICAN CONTEXT

Mexico is one of the most unequal countries in the world, characterized by a high and persistent income-distribution inequality (see for instance, Reyes et al., 2017; Risso et al., 2013). The Mexican economy has experienced domestic macroeconomic crisis (1982, 1986, 1995) and foreign origin crisis (2001, 2008) damaging its wealth and income distribution to the extent that those crises have influenced the inequality currently existing in Mexico. As pointed out by Esquivel (2011), the Mexican Gini coefficient during the period 1984 to 2006 is represented by an inverted U-shape that peaks in the 1994 Mexican economic crisis, and steadily declines thereafter. However, Risso et al. (2013) show that there is a long-term negative relationship throughout 1968–2010 between income inequality, measured by the Gini coefficient, and *per capita* GDP (Mexican economic growth). Moreover, unidirectional causality goes from economic growth to income inequality in Mexico since the domestic crisis and reform period includes the major economic crises of 1982 and 1994. Mexico went through a critical period in 1982 (namely a debt crisis) and 1994. Following devaluations in 1982, the Mexican government declared it could not pay part of the debt, thus triggering the debt crisis, which was preceded by an increase in the primary deficit followed by an increase in inflation and the monetary base. Subsequently the 1994 crisis hit the economy. While this crisis was not preceded by large fiscal deficits, it took place after a large increase in one type of dollar-denominated debt, that is, the dollar-indexed tesobono debt. In fact, except for the transitory impact of the 1994 crisis, inflation had a downward trend from 1988 until 2006. Between 2007 and 2016, inflation remained stable, having an average value of 4% per year. Finally, the Mexican economy experienced a period of slow growth and macroeconomic stability, interrupted by the global recession of 2008–2010. Faced with the international financial crisis of 2008, the Mexican economy aimed at implementing a deficit in 2009 to bring about a change in Mexico's fiscal response to such an economic crisis. Hence, the Mexican response was to switch from surplus to deficit in 2009 as a result of countercyclical fiscal policies aimed at responding to the 2008 financial crisis in the United States (Meza, 2021).

Thus, Mexico offers a very interesting setting to investigate such an income inequality at a regional or state level. Important research works have already done so. For instance, Aguilar-Retureta (2016) describes various dimensions of regional income disparities in Mexico from 1895 to 2010 showing that, despite a persistent north–south divide (reflected in indicators of very low mobility), regional income inequality has followed an N-shaped trend (increasing-decreasing-increasing) in the long-run. This has been closely related to the different developmental models adopted in Mexico. Therefore, regional disparity grew during periods of increased international integration (the growth model led by primary exports from 1895 to the 1930s, and the most recent period of economic opening that began in the 1980s), to then decline during the state-led industrialization period that took place between 1930 and 1970. In contrast to the experience of high-income countries, regional convergence in Mexico was accompanied by a process of spatial concentration of industrial activity. On the other hand, the results of a spatial correlation analysis of income levels suggest a statistically significant grouping of the poor southern states, while the richest regions (Mexico City and the northern states) develop a group of high income (Campos-Vázquez, Lustig, & Scott, 2018). This reflects the close connections between the growth of the northern states and the United States market, as well as the powerful capital effect associated with the growth of Mexico City.

German-Soto (2016, 2019) is a pioneer who has studied the evolution of Mexican interregional income inequality extensively from the 1940s until 2010. This author shows that states in the northern and central regions of Mexico have the highest levels of *per capita* income, along with the oil-rich states of Tabasco and Campeche in the south. He also pointed out that the regional distribution of income is heterogeneous and varies over time. He revealed that the Mexican states with the highest and lowest income levels are also the most unequal, while states with income levels close to the average tend to have smaller inequality values, as would be expected from the theory. The author points out that since the 1940s, Mexican states have been highly heterogeneous, and this heterogeneity is somewhat linked to geographic location: inequalities are observable in the north, centre, and south of the country. Moreover, until the early 1980s, inequalities in those geographic areas gradually decreased, mainly in the northern and central areas. However, recently since the 2010s, regional differences have become marked once again and are very similar to those of the 1940s. Therefore, in the last three decades Mexico has underperformed in terms of growth, inclusion and poverty reduction compared to similar countries.

Campos-Vázquez et al. (2018) summarized the Mexican evolution of income inequality during the period 1989–2014 as follows: between 1989 and 1994, there was an increase of inequality; inequality decreased between 1994 and 2006, and between 2006 and 2014 inequality rose once again. The key component underlying the "increase–decrease–increase" pattern was the evolution of labour income inequality. By contrast, Mexico's economic growth averaged just over 2% per year between 1980 and 2018, limiting progress in convergence in relation to high-income economies. On a *per capita* basis, average growth was close to 1.0%. The country's GDP *per capita* today represents 34% of the US GDP *per capita*, compared to 49% in 1980. In this context, progress towards poverty reduction has been lost. The total proportion of the population living below the monetary poverty threshold in 2018 was 48.8%, close to the level observed in 2008. The average *per capita* income (APCI) has recently recovered after several years of decline. After a decrease between 2010 and 2014, the annualized growth rate of APCI in Mexico was 1.8% between 2016 and 2018, still well below the average for the LA region. Low growth rates and significant inequalities continued to raise the question of how Mexico could grow faster and be more inclusive. These are the central themes covered in the recent systematic country diagnostic of Mexico (World Bank Group, 2018).

After the introduction of economic liberalization and trade promotion policies in the late 1980s, the Mexican economy experienced major structural changes. These changes have had different spatial dimensions, characterized by increasing regional inequality (Rodríguez-Pose & Villareal, 2015). Studies examining the factors that have acted as important drivers of regional growth during this period have concentrated on identifying the effects of growth on regional endowments of physical and human capital (Chiquiar, 2005; Rodríguez-Oreggia, 2005). However, since 1989, inequality in Mexico has increased, decreased and increased again. Where the evolution of labour income inequality is at the core of this pattern (Cabral & Mollick, 2017). To reverse the current trend of increasing inequality, access to secondary and tertiary education must continue to expand, minimum wages must be increased, and the tax and cash transfer system must be redesigned (see, for instance, the proposals developed by Campos-Vázquez et al., 2018; Esquivel & Rodriguez-Lopez, 2003).

Recently, Mendoza-Velázquez et al. (2019) and Mendoza-Velázquez et al. (2020) have studied the club convergence hypothesis for the real regional gross domestic product (GDPR) *per capita*, as an indicator of income, and the ENI index as a measure of the interregional distribution of income. They examine the possibility that some Mexican states may have slow economic growth, limiting their ability to reach other states which are achieving a higher stable state, so not converge to the same steady state. The authors introduce four factors that make Mexico a natural experiment to analyse inequality: (i) Mexico is one of the most unequal countries in the OECD;(ii) its economy has undergone political, economic, demographic and institutional changes that affect regional inequality and income; (iii) the inequality trends have been substantially different from those observed in other developing countries; and (iv) the internationalization of the economy could have had heterogeneous effects at the regional level. The economic inequality data in Mexico indicate that a significant percentage of the states have an asymmetric income distribution, which negatively affects the level of economic growth (Ayvar-Campos et al., 2019; Quiroz & Salgado, 2016).

Therefore, our research question asks how the regimes that are formed for the 32 states of the Mexican Republic are dynamically influenced by their economic growth and their performance in terms of economic inequalities between 1940 and 2015. The empirical results allow us to quantify the dynamic regimes during the period examined, hence this study contributes to the design of strategies and policies that stimulate the behaviour of the dimension of *per capita* income and economic inequalities at the regional level in Mexico. In addition, once the dynamic regimes or clusters have been identified, we can make robust statistical inference and show either the causality and the impact of one variable on the other (inequality versus economic growth). Moreover, we claim that inequality traps may exist in the Mexican states.

Let us now move onto the next part of our work.

3 | DATA, REGIMES METHODOLOGY, AND EMPIRICAL RESULTS

The dataset is the one built by German-Soto (2005, 2016, 2019). The measure of interregional inequality in Mexico developed by German-Soto (2019) is based on homogeneous and comparable information about the GDP *per capita* constructed by German-Soto (2005), and on the concept of economic distance derived from the Euclidean norm index (ENI) and proposed by German-Soto (2016, 2019) for the Mexican states. Using the regional GDP as input, the ENI is a measure of the economic distance of a region with respect to all the other regions that make up the regional system. Therefore, it provides a measure of the interregional distribution of income and its evolution over time. Note that this index is different from the traditional inequality indices available in the literature (Gini, Theil or Atkinson, among other measures). Taking into account the idea that inequality is multifaceted and responds to a process of multiple factors, German-Soto constructs a multidimensional index (by applying ENI) that considers different socio-economic variables: agglomeration, education, *per capita* income and health. Therefore, it is possible to establish a measure of interregional inequality not exclusively referred to income, but which includes other relevant aspects. It is also important to note that in the construction of the index no weight is assumed for the four variables considered, thus avoiding the use of arbitrary assumptions regarding the weight of each of the variables. In particular, note that in Mexico's national accounts data, Campeche and Tabasco's GDP tends to be overestimated due to offshore oil and gas production accounting as part of the states' total production, but the data constructed by German-Soto (2005) does not have this problem.

The construction of the index is as follows. If x is one of the variables used (i.e., agglomeration, education, *per capita* income and health) to measure the performance of the regions, then for a system of n regions (i.e., 32 in this case), the relative distance of the region i with respect to the remaining j regions at each moment of time, in terms of the variable x is:

$$d_t(i) = \sqrt{\sum_{j=1}^{n} \left(x_{it} - x_{j,t}\right)^2} \text{with } t = 1, \ldots, T. \tag{1}$$

To obtain the multidimensional index, the interregional distances (d_t) are calculated independently for each variable considered. To avoid the possible problem of the difference in the units of measurement, it is relativized using the average. And finally, all these weighted expressions are added, as many as the variables which are considered, thus generating the multidimensional interregional inequality index (with k dimensions):

$$ENI_{i,t} = \sum_{k=1}^{K} {d_t(i)_t^k}/{\overline{d_t(i)_t^k}}, \tag{2}$$

where $\overline{d_t(i)_t^k}$ is the average of $d_t(i)_t^k$. A detailed description of the procedure is in German-Soto (2016, 2019).

A novel feature of the use of the ENI in the analysis of regional inequality is that it allows an evaluation of the change in the distribution of income of a given region over time. Therefore, it is particularly suitable for convergence analysis. The regional gross state product *per capita* (or economic growth) measurements used in our analysis are also those developed by German-Soto (2019) as a proxy for income *per capita*. Our time series covers the time period from 1940 to 2015 for all the 32 states of Mexico.

3.1 | Regime methodology and data symbolization

The dynamic performance of growth and inequality observed in the Mexican states for the period of time isconsidered in the sample studied. Specifically, given two states i and j, a notion of distance $d(i,j)$ is introduced for quantifying the similarity in its dynamics to compare its performance. Indicators of inequality and economic growth are considered in order to locate the states in different regions where a qualitatively different economic dynamic is observed. Next, data is encoded and a symbolic sequence is obtained that represents the dynamics of each state in the two variables. This symbolization of the data allows us to define a metric to compare the dynamics. From this, a cluster analysis is carried out to see if there are homogeneous groups. Although the heterogeneity of the sample is a fundamental aspect for the quantitative analysis, it is convenient to find a group that adequately responds to the analysis, so that the groups obtained are more homogeneous within it.

To capture the qualitatively relevant properties, the concept of regime and the dynamics of regimes are introduced as suggested in Brida et al. (2013, 2020). Each regime corresponds to a performance model in the inequality and economic growth variables which is qualitatively different from the others. The partition chosen for this exercise is determined by the annual averages of both, the ENI Index (μ_x) and the growth rate of the regional Gross State Product (income) *per capita* (μ_y) for all the Mexican states. Through the chosen partition, four regions are obtained according to the quadrant, and segmented according to the annual averages:

$$R_1 = \left\{(x_t, y_t) : x_t > \mu_{x_t},\ y_t < \mu_{y_t}\right\} \quad (\text{high inequality, low growth rate}),$$

$$R_2 = \left\{(x_t, y_t) : x_t > \mu_{x_t},\ y_t \geq \mu_{y_t}\right\} \quad (\text{high inequality, high growth rate}),$$

$$R_3 = \left\{(x_t, y_t) : x_t \leq \mu_{x_t},\ y_t \geq \mu_{y_t}\right\} \quad (\text{low inequality, high growth rate}),$$

$$R_4 = \left\{(x_t, y_t) : x_t \leq \mu_{x_t},\ y_t < \mu_{y_t}\right\} \quad (\text{low inequality, low growth rate}).$$

As an example, Figure 1 shows the values of the ENI and the growth rate of the GDP for the 32 Mexican states. The lines indicated in the values show the division in the four performance regimes.

As expected, the points are distributed in the four regions showing that qualitatively the Mexican states describe different performances. Each of these regions defines a performance regime that can be interpreted (Banerjee & Duflo, 2003; Policardo et al., 2016). In particular:

1. Regime 1 of high inequality and low growth rate could be associated with economies that are in a poverty trap (such as the example of Haiti in a country context). Oaxaca could be used as an example among Mexican states. We can call it the "poverty trap regime."
2. Regime 2 of high inequality and high growth rate could be associated with emerging economies (such as the example of China in a context of countries). Nuevo León could be considered an example among Mexican states. We can call it the "wealth concentration regime."
3. Regime 3 of low inequality and high growth rate could be associated with economies that redistribute as they grow (such as the example of Uruguay or South Korea in a country context). Guanajuato could be considered an example among Mexican states. We can call it the "emerging wealth distribution regime."

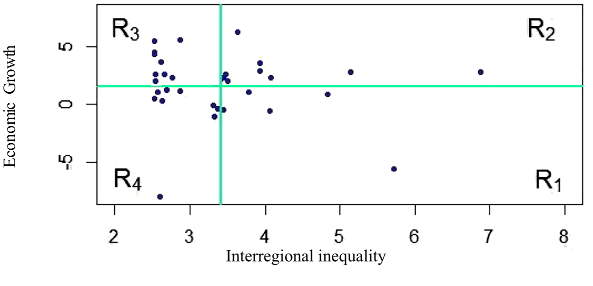


FIGURE 1 Point cloud and regime division for the 32 states, 2015
Notes: Own elaboration. The partition is determined by the values μ_x and μ_y. The point cloud is defined by all the states in 2015

4. Regime 4 of low inequality and low growth rate could be associated with mature economies that practice social welfare policies (such as the example of EU countries, and Sweden in a country context). Tamaulipas can be taken as an example among Mexican states. We can call it the "advanced wealth and social redistribution regime."

Table 1 shows the time proportion of permanence in each of the regimes over all the analysed period for each of the Mexican states.

From Table 1 different behaviours are observed as there are Mexican states that have passed through all regions. On the one hand, there are those Mexican states that are located in regions 1 and 2 for most of the period.

TABLE 1 Proportion of permanence in each regime (1941–2015) of the federal entities

Mexican state	R_1	R_2	R_3	R_4	Total
Aguas calientes	4%	8%	48%	40%	100%
Baja California	45%	15%	17%	23%	100%
Baja California S.	16%	23%	27%	34%	100%
Campeche	24%	12%	25%	39%	100%
Coahuila	32%	33%	20%	15%	100%
Colima	0%	0%	47%	53%	100%
Chiapas	40%	45%	7%	8%	100%
Chihuahua	17%	27%	29%	27%	100%
Mexico City	56%	44%	0%	0%	100%
Durango	0%	0%	43%	57%	100%
Guanajuato	1%	1%	72%	26%	100%
Guerrero	41%	51%	4%	4%	100%
Hidalgo	36%	32%	16%	16%	100%
Jalisco	0%	0%	59%	41%	100%
México	0%	0%	53%	47%	100%
Michoacán	45%	47%	5%	3%	100%
Morelos	0%	0%	56%	44%	100%
Nayarit	7%	5%	41%	47%	100%
Nuevo León	39%	61%	0%	0%	100%
Oaxaca	49%	51%	0%	0%	100%
Puebla	1%	1%	56%	42%	100%
Querétaro	5%	11%	59%	25%	100%
Quintana Roo	28%	28%	23%	21%	100%
San Luis Potosí	8%	7%	57%	28%	100%
Sinaloa	0%	0%	51%	49%	100%
Sonora	25%	25%	28%	22%	100%
Tabasco	11%	12%	23%	54%	100%
Tamaulipas	1%	1%	27%	71%	100%
Tlaxcala	44%	45%	4%	7%	100%
Veracruz	4%	4%	32%	60%	100%
Yucatán	0%	0%	45%	55%	100%
Zacatecas	24%	33%	27%	16%	100%

Note: Own elaboration. In cases where a state only passes in regimes 1 and 2 (or 3 and 4), it is inequality that governs the behaviour.

Their inequality is above the mean while the growth rate presents moments where it is above the mean and moments below. An example is Nuevo Leon, which throughout the period is in these two regimes, with a slight predominance of regime 1 (high inequality and low economic growth). On the other hand, there are those states that are located mainly in regions 3 and 4, being states that have a level of inequality below the average for most of the period considered, while its growth rate is above the average in some periods and below the average in others. An example is Yucatan, with a slight predominance of regime 4 (low inequality and low economic growth). From this Table it could be deduced that it is inequality that defines the pattern of behaviour of the states, and this may respond to the fact that the variation in time of inequality is slight compared to the variation in the growth rate that tends to fluctuate over time.

As Brida et al. (2013, 2020) pointed out, the dynamics of regime change can be represented as follows: each economy is assigned a symbol (1, 2, 3 or 4) at each moment of time, depending on the region in which it is located. Each region is labelled with a symbol (in this case the chosen label is the regime number) and then the two-dimensional time series of the ENI Index and GDP *per capita* growth is (x_t, y_t) where t takes the integer values between 1941 and 2015, in the symbolic time series $s = \{s_1, s_2, \ldots, s_T\}$ so that $s_t = j$ if and only if (x_t, y_t) is in the regime R_j. The symbolic sequence $s = \{s_1, s_2, \ldots, s_T\}$ contains all the relevant information about the dynamics of regimes and the symbolic successions that represent each of the economies reveal different types of performance.

3.1.1 | Cluster analysis

For the analysis of clusters, a concept of distance between Mexican states dynamics is defined as follows:

$$d(s_i, s_j) = \sum\nolimits_{t=1}^{75} f(s_{it}, s_{jt}) \quad with \quad f(s_{it}, s_{jt}) = \begin{cases} 0 \ if \ s_{it} = s_{jt} \\ 1 \ if \ s_{it} \neq s_{jt} \end{cases}. \tag{3}$$

This metric considers for each moment of time the function f that takes the value 0 if they coincide with the regime in the year in question, and 1 if they do not coincide. Thus, the defined distance takes values between 0 and 75 (0 if the states coincided for the 75 years considered, and at the other extreme 75 if they did not coincide in any of the 75 years considered). This distance makes it possible to compare the dynamic behaviour of two states: the smaller the distance between the two symbolic series representing two economies, the closer the dynamics of the economies' regimes.

In order to classify the Mexican states represented by the two-dimensional time series of ENI indices and growth rates of real GDP *per capita* in different groups, a qualitative closeness criterion is used. For this purpose, a minimum spanning tree (MST) and a hierarchical tree (HT) are built (Figures 2 and 3). Based on the defined distance, the cluster analysis is performed, which allows us to see if there are groups of states that have had homogeneous dynamic behaviour. In the construction of the HT, the nearest neighbour method is used, following the techniques developed in Mantegna (1999) and Mantegna and Stanley (2000). It is an aggregative method, so in the first step the initial partition is formed considering each individual as a cluster: $P = \{P_1, P_2, \ldots, P_n\}$. The two closest (smallest distance) clusters are determined: P_i, P_j (with $i = 1,\ldots,n$; $j = 1, \ldots, n$; $i \neq j$), and are grouped into a single cluster, forming the partition: $P = \{P_1, P_2, \ldots, P_i \cup P_j, \ldots, P_n\}$. In the following stages, grouping is continued based on the minimum distances, considering the distance between clusters as the minimum distance between the individuals of each one. That is the distance between the clusters C_i (with n_i elements) and C_j (with n_j elements), is defined as:

$$d(C_i, C_j) = Min\{d(x_k, x_l)\}, \tag{4}$$

with $x_k \in C_i$, $x_l \in C_j$ ($k = 1, \ldots, n_i$; $l = 1, \ldots, n_j$).

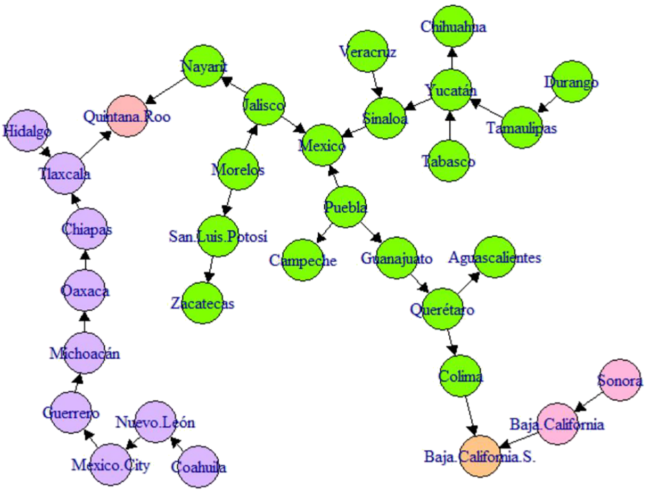


FIGURE 2 MST of the federal entities of Mexico (1941–2015)

Notes: Own elaboration. Each state is represented by a vertex. The green corners represent the economies with low inequality, that is economies that have been in regimes 3 and 4 most of the time. Note the central role of Yucatan in this conglomerate. The purple corners define another conglomerate that is characterized by having engaged regimes 1 and 2 for the most part (high inequality). In addition to these two conglomerates, there is the one made up by Sonora and Baja California (coloured with pink) and two states, Quintana Roo and Baja California Sur, that do not fall into any of the three groups identified

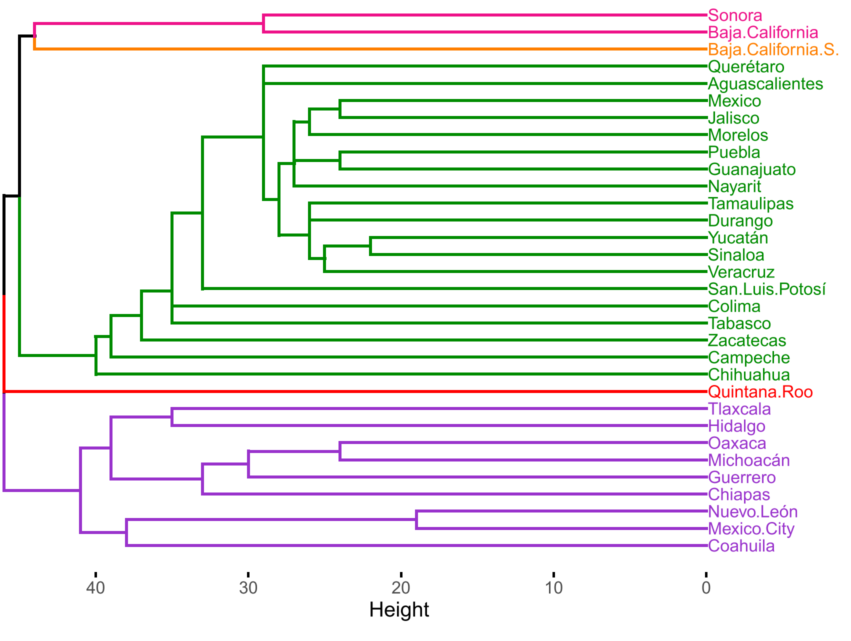


FIGURE 3 HT of the federal entities of Mexico (1941–2015)

Notes: Own elaboration. Each state is represented by a vertical line. Two states are connected when a horizontal line joins the two vertical lines. The height of the horizontal line indicates the ultrametric distance between the two economies. The lower they merge indicates that the groups are more similar to each other. The presence of three well-differentiated conglomerates and two non-classifiable economies is clearly appreciated in the graph

The MST (Kruskal, 1956), is progressively built by joining all the Mexican states by the minimum distance. In this case, there is a graph of 32 vertices corresponding to each Mexican state. Figures 2 and 3 depict the MST and HT. A set of indicators were calculated to determine the optimal number of groups, using the Pseudo-F (Caliński & Harabasz, 1974) and the Pseudo-t^2 (Duda & Hart, 1973). Both tests indicate that the optimal number of groups is three, plus two states that are not grouped. Note that Mexico City presents a central position in the MST, showing the relevance of the dynamical connections of this state with the rest of the country. In addition, note that the rest of the MST shows an almost linear picture, revealing that the role of Mexico is remarkable.

Figures 2 and 3 show the emergence of two groups well confirmed by several Mexican states. Group 1 is characterized by being in regime 3 and 4 with low inequality, and group 2 by being in regime 1 and 2 of high inequality. That is to say:

1. Group 1 (green colour) conformed by Querétaro, Aguascalientes, Mexico, Jalisco, Morelos, Puebla, Guanajuato, Nayarit, Tamaulipas, Durango, Yucatan, Sinaloa, Veracruz, San Luis Potosí, Colima, Tabasco, Zacatecas, Campeche and Chihuahua. This group is characterized by being a group of low inequality (inequality below the average). Countries that are located most of the time in regions 3 and 4, present inequality below the average and a growth rate that oscillates between high and low.
2. Group 2 (purple colour) conformed by Tlaxcala, Hidalgo, Oaxaca, Michoacán, Guerrero, Chiapas, Nuevo León, Mexico City and Coahuila. These states are generally in regions 1 and 2, they have above average inequality and their growth rate presents periods where it is above and below the average.

In addition, two other minor groups emerge containing only a couple of Mexican states:

3. Group 3 (pink colour) conformed just by Sonora and Baja California. This group is characterized by beginning the period in a state of high inequality (oscillating growth) and changing the pattern towards the 1980s, when they started to have low inequality most of the time. Some details which emerge are the following. Since 1970, Sonora, as well as Baja California and Baja California Sur, have registered a GDP *per capita* higher than the national level, explained by the low levels of population. Sonora corresponds to a case in which the product per worker evolved favourably, but the relationship between the employed population and the total population advanced slowly. Until 1985, Sonora contributed mainly to the national agricultural GDP. However, since 1988 it has contributed less to this sector, and its contribution to industrial GDP has been greater compared to the GDP of the service sector.
4. Finally, Baja California Sur and Quintana Roo do not form any group and remain isolated. Some details could help us to understand this atypical conglomerate of Baja California Sur and Quintana Roo. For instance, Baja California Sur was a "territorial unit" for a long time, because until the 1970s it was practically an unsettled state, while at the time of our study it averages a small number of habitants. Population density is barely 5 or 6 persons by squared kilometre. Quintana Roo, in the meantime, has been a state with a small population, but with an economy of virtually no industrial activity which, since the 1970s, has registered a huge number of investments mainly in the services sector. This specific state boasts a large infrastructure in hotels and tourism. Therefore, these special economic dynamics make them different to other Mexican states.

In Brida et al.'s (2013) study the performance of Mexican states for the period 1970–2006 and three groups emerge (depending on the GDP and growth rate of the GDP): groups of high, medium and low performance. The low inequality group contains all the states in the medium performance group, and ends up exclusively conforming to states that belong to the low performance group. Thus, we could say that the low inequality group is of medium-low performance. The high inequality group is made up of both, high and low performing states, while Sonora and Baja California, which together formed one group in our analysis, are high-performing states. In relation to the educational level observed in the country, the low inequality group (group 1), on average, presents higher levels of education compared to the high inequality group (group 2).

Figure 4 shows the map of Mexico that group 1 (green) with low inequality is not only the most numerous, but also the one that occupies the largest portion of the territory. It is important to notice that group 2 (purple) has two isolated regions, one in the southwest and the other in the northeast.

A brief comment on the descriptive statistics is that the high inequality group on average presents more stable growth rates throughout the entire period (average rates ranging from approximately −2% to 2.5%). By contrast, in the low inequality group the average growth rate has greater variability (close to 8 negative points in 1941 and 14 points in 2015). Regarding inequality, a variable that has a greater incidence in the conformation of the groups, a considerable difference between the two main groups is immediately evident. In the low inequality group, the average ENI varies between approximately 2.5 and 4.3, while the mean for the high inequality group ranges from 3.4 to 6.4. In both cases, the trend decreases, although it is slightly more marked in the high inequality group. It is important to highlight a degree of heterogeneity in that states classified as advanced or rich are either in group 1 or in group 2. For example, Coahuila and Nuevo León are states that are in group 2 of high inequality but in all probability most of the time they move to regime 2 which is characterized by high inequality with high economic growth. Hence, inequality is the engine of the attained clustering.

4 | ECONOMETRIC ESTIMATION

In the following part, we perform panel data econometric analysis. We analyse the two main groups (group 1 and group 2) that we obtained in the previous analysis. Our aim is to understand how inter-regional inequality, measured by the ENI index, and income *per capita*, measured also as regional GDP *per capita*, YL, are statistically related for the 32 Mexican states during the period 1940–2015. For the purposes of control variables, the education literacy rate (LR) was also considered as an indicator. This education indicator helps us to control possible effects on *per capita* income and levels of inequality.

The estimating equations will be the following, although they may have some variants depending on the type of panel data econometric model estimated:

FIGURE 4 Map of the inequality and growth conglomerates of the federal entities of Mexico (1941–2015)
Notes: Own elaboration. The map seems to show that geographical proximity is important when integrating a conglomerate

$$\ln(ENI_t) = \alpha_0 + \alpha_1 \ln(YL_t) + \alpha_2\, ln\left(YL_t^2\right) + \alpha_3 \ln(LR_t) + \alpha_4\, ln\left(LR_t^2\right) + u_{i,t}, \tag{5}$$

$$\ln(YL_t) = \beta_0 + \beta_1 \ln(ENI_t) + \beta_2\, ln\left(ENI_t^2\right) + \beta_3 \ln(LR_t) + \beta_4\, ln\left(LR_t^2\right) + v_{i,t}. \tag{6}$$

Equation 5 indicates that that inequality is determined by *per capita* income (YL_t) and by literacy education (*LRt*). Equation 6 tells us that *per capita* income is determined by inequality (ENI_t) and levels of literacy education (*LRt*). Note that the variables allow for the possibility that the square of these variables has an impact on inequality and growth, since the existence of a Kuznets' curve (as an inverted U or U) has been widely studied (see for instance, Chen, 2003; Risso & Sánchez Carrera, 2019; Ille et al., 2017).

The following panel data econometric models will be studied for these regressions, namely:

1. the well-known fixed effects (FE) and random effects (RE) models are applied;
2. we apply the dynamic model based on those proposed by Arellano and Bover (1995) and Blundell and Bond (1998). These are the only models that have the lagged component. This is a dynamic estimator that overcomes the potential weakness presented by the Arellano and Bond (1991) as it not only considers the lagged levels as instruments for the first differences of the variables, but also includes lagged differences. In this way, the Arellano and Bover (1995) and Blundell and Bond (1998) model would estimate the following equations:

$$\Delta\ln(ENI)_{i,t} = \alpha_1 \Delta ln(ENI)_{i,t-1} + \alpha_2 \Delta ln(YL)_{i,t-1} + \alpha_3 \Delta ln(YL)^2_{i,t} + \alpha_4 \Delta ln(LR)_{i,t-1} + \alpha_5 \Delta ln(LR)^2_{i,t} + \Delta\varepsilon_{i,t}, \tag{7}$$

$$\Delta\ln(YL)_{i,t} = \beta_1 \Delta ln(YL)_{i,t-1} + \beta_2 \Delta ln(ENI)_{i,t-1} + \beta_3 \Delta ln(ENI)^2_{i,t} + \beta_4 \Delta ln(LR)_{i,t-1} + \beta_5 \Delta ln(LR)^2_{i,t} + \Delta\eta_{i,t.} \tag{8}$$

For the Mexican state i = 1, 2, …, 32 over the year t = 1940, 1941, …, 2015 and all the variables are expressed in its first difference. Since the variables are still in logarithms, the parameters α and β can be interpreted as elasticities. The parameters α_1 and β_1 indicate the degree to which inequality or *per capita* income is determined by its previous value. In this way we can measure both short-term and long-term effects. In the latter case, it is only necessary to divide the elasticities by (1- α_1) or (1- β_1) to obtain the long-term elasticities. On the other hand, non-stationarity problems can be avoided by taking the data in differences. Considering that endogeneity in Equations 5, 6, 7 and 8 may arise, the GMM method with instrumental variables (IV) is applied, limiting the number of IV given that T is large.

Taking into account the divide between those who believe Achen's theory (Achen, 2000) that the inclusion of lagging dependent variables (LDV) will produce negatively biased coefficient estimates, and those who support the inclusion of LVD (Keele & Kelly, 2006), we apply the panel data model with corrected standard errors (PCSE) proposed by Beck and Katz (1995). This model is within the framework of the cross-section models with time series (TSCS). Beck (2001) indicates that at least 10 years are needed for each individual cross-section to justify its application. In our study T = 76.[2] As T is very large and to rule out the possibility of applying non-stationary methodology such as cointegrated panel models, a unit root analysis will be performed on panel data. Table 2 shows the unit root tests of panel data by applying four tests (Levin, Lin, and Chu t test; Im, Pesaran, and Shin W-stat; ADF Fisher chi-square; PP Fisher chi-square) for the YL, ENI and LR series, both for the total of the 32 Mexican states, and for the two groups separately. As can be seen, in all cases the existence of a unit root can be rejected in the context of panel data, and therefore the aforementioned techniques can be applied.

Next, the causality in panel data is studied to understand the causal direction between YL and ENI. Two versions of the causality test are applied. On the one hand, the Granger causality test is applied in its standard way. This method assumes that all coefficients are equal among the Mexican states. The second approach is that suggested by Dumitrescu and Hurlin (2012), which adopts the opposite assumption in which all the coefficients are different

TABLE 2 Panel unit root tests

Ln (YL)	Mexico				Group 1				Group 2			
Method	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**
H0: Unit root (assumes common unit root process)												
Levin, Lin & Chu t	−8.485	0.000***	32	2,294	−5.958	0.000***	19	1,367	−5.958	0.000***	9	647
H0: Unit root (assumes individual unit root process)												
IM, Pesaran and Shin W-stat	−1.344	0.090*	32	2,294	−0.736	0.231	19	1,367	−1.194	0.1160	9	647
ADF-Fisher Chi-square	94.504	0.008***	32	2,294	51.311	0.073*	19	1,367	35.751	0.001***	9	647
PP-Fisher Chi-square	119.483	0.000***	32	2,400	70.910	0.001***	19	1,425	36.301	0.01**	9	675
Ln (ENI)												
Method	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**
H0: Unit root (assumes common unit root process)												
Levin, Lin & Chu t	−5.529	0.000***	32	2,237	−3.639	0.000***	19	1,319	−3.155	0.001***	9	642
H0: Unit root (assumes individual unit root process)												
IM, Pesaran and Shin W-stat	−3.978	0.000***	32	2,237	−3.537	0.000***	19	1,319	−2.032	0.021**	9	642
ADF-Fisher Chi-square	107.095	0.001***	32	2,237	66.929	0.003***	19	1,319	26.925	0.080*	9	642
PP-Fisher Chi-square	124.103	0.000***	32	2,400	72.637	0.001***	19	1,425	30.262	0.035**	9	675
Ln (LR)												
Method	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**	**Statistic**	**Prob. (a)**	**Cross-section**	**Obs.**
H0: Unit root (assumes common unit root process)												
Levin, Lin & Chu t	−23.816	0.000***	32	2,327	−17.406	0.000***	19	1,395	−15.624	0.000***	9	642
H0: Unit root (assumes individual unit root process)												
IM, Pesaran and Shin W-stat	−18.257	0.000***	32	2,327	−13.877	0.000***	19	1,395	−11.444	0.000***	9	642
ADF-Fisher Chi-square	456.439	0.000***	32	2,327	273.439	0.000***	19	1,395	142.835	0.000***	9	642
PP-Fisher Chi-square	664.029	0.000***	32	2,400	410.854	0.000***	19	1,425	201.177	0.000***	9	675

Notes: Own elaboration.
*** rejection of the unit root hypothesis at 1%;
** rejection of the unit root hypothesis at 5%;
* rejection of the unit root hypothesis at 10%.

TABLE 3 Granger causality test in panel data (standard)

Null Hypothesis:	México		Group 1		Group 2	
	F-Statistic	Prob.	F-Statistic	Prob.	F-Statistic	Prob.
L (YL) does not homogeneously cause L (ENI)	4.802	0.008***	4.618	0.010**	9.272	0.000***
L (ENI) does not homogeneously cause L (YL)	5.388	0.005**	10.670	0.000***	3.800	0.023**
L (LR) does not homogeneously cause L (YL)	11.308	0.000***	10.725	0.000***	1.327	0.266
L (YL) does not homogeneously cause L (LR)	4.411	0.012**	1.709	0.182	4.904	0.008***
L (LR) does not homogeneously cause L (ENI)	0.497	0.608	3.667	0.026**	2.091	0.124
L (ENI) does not homogeneously cause L (LR)	2.411	0.090*	0.974	0.378	0.204	0.815

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10%.

TABLE 4 Dumitrescu and Hurlin (2012) causality test

Null Hypothesis:	México			Group 1			Group 2		
	W-Stat.	Zbar-Stat.	Prob.	W-Stat.	Zbar-Stat.	Prob.	W-Stat.	Zbar-Stat.	Prob.
L (YL) does not homogeneously cause L (ENI)	5.515	9.210	0.000***	4.502	5.016	0.000***	5.836	5.338	0.000***
L (ENI) does not homogeneously cause L (YL)	3.982	5.124	0.000***	3.262	2.469	0.014**	3.188	1.595	0.111
L (LR) does not homogeneously cause L (YL)	6.959	13.061	0.000***	7.105	10.364	0.000***	4.581	3.564	0.000***
L (YL) does not homogeneously cause L (LR)	2.539	1.279	0.201	2.761	1.440	0.150	2.123	0.090	0.928
L (LR) does not homogeneously cause L (ENI)	5.036	7.934	0.000***	5.039	6.120	0.000***	3.999	2.742	0.006***
L (ENI) does not homogeneously cause L (LR)	1.856	−0.543	0.587	1.439	−1.274	0.203	1.490	−0.805	0.421

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10%.

TABLE 5 Estimates of the equality of inequality for the total of Mexico, as well as for Group 1 and Group 2

	Mexico			Grupo 1	
ln (ENI)$_{i,t}$	Fixed Effect	Arellano-Bover/Blundell-Bond	Regression PCSE	Random Effect	Arellano-Bover/Blundell-Bond
ln (ENI)$_{i,t-1}$		0.44 (4.72)***			0.59 (14.38)***
ln (YL)$_{i,t}$	−2.66 (−3.42)***	−6.87 (−5.41)**	−6.18 (−21.15)***	−4.45 (−6.16)***	−4.41 (−6.51)***
ln (YL)$^2_{i,t}$	0.15 (3.37)***	0.37 (5.42)***	0.34 (21.35)***	0.25 (5.89)***	0.23 (6.67)***
ln (LR)$_{i,t}$	4.48 (2.69)**	5.38 (2.37)**	5.17 (7.25)***	3.50 (−1.59)	0.38 (2.36)**
ln (LR)$^2_{i,t}$	−0.59 (−2.65)**	−0.61 (−2.28)**	−0.62 (−6.96)***	−0.46 (−1.68)*	
c	4.89 (1.25)	20.38 (6.09)***	18.58 (12.80)***	14.63 (2.98)***	19.43 (7.16)***
Specification	71.32 (0.00)	242.30 (0.00)	609.48 (0.00)	182.23 (0.00)	1254.06 (0.00)
R-squared	0.4194		0.5364	0.5720	
autocorrelation:					
order 1		−2.5687 (0.01)			−3.80 (0.00)
order 2		−1.42 (0.16)			−3.34 (0.00)
sargan test		31.87 (1.00)			18.96 (1.00)
Number of obs.	2,432	2,400	2,432	1,444	1,425

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10%.

TABLE 5 (Continued)

	Grupo 1	Grupo 2		
ln (ENI)$_{i,t}$	**Regression PCSE**	**Fixed Effect**	**Arellano-Bover/Blundell-Bond**	**Regression PCSE**
ln (ENI)$_{i,t-1}$			0.75 (6.85)***	
ln (YL)$_{i,t}$	−5.26 (−15.32)***	−1.99 (−3.60)***	−2.50 (−4.46)***	−4.84 (−14.22)***
ln (YL)$^2_{i,t}$	0.28 (14.83)***	0.09 (3.27)**	0.13 (4.24)***	0.26 (13.70)***
ln (LR)$_{i,t}$	0.18 (2.55)**	0.51 (2.30)*	0.42 (4.41)***	2.26 (2.74)***
ln (LR)$^2_{i,t}$				−0.20 (−1.91)*
c	24.91 (17.21)***	10.07 (5.21)***	10.44 (4.18)**	18.26 (12.01)***
Specification	415.75 (0.00)	72.42 (0.00)	372.84 (0.00)	296.94 (0.00)
R-squared	0.5666	0.6382		0.6504
autocorrelation:				
order 1			−2.237 (0.03)	
order 2			−1.95 (0.05)	
sargan test			7.66 (1.00)	
Number of obs.	1,444	684	675	684

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10%.

among the Mexican states. Following on, Table 3 and Table 4 present the results of the causality tests for the standard cases and the one proposed by Dumitrescu and Hurlin (2012). In both cases, a bi-directional causality between inequality and income *per capita* is not rejected. An exception is made in the second case, for Group 2 in which income would appear to determine inequality. However, in the standard test there would be bi-directionality.

In the case of education literacy it can be seen that, in most cases, it is both literacy and inequality that determine income *per capita*. This is clearer in the tests in Table 4. In Table 3, the exception is presented by Group 2 in which it would appear that *per capita* income would cause education literacy levels.

Therefore, the two relationships are estimated where ENI depends on YL and YL depends on ENI. Table 5 shows the results for the case of the inequality function and Table 6 the results of the Hausman, autocorrelation and heteroskedasticity tests in the case of the FE and RE models. Since the DPD model and PCSE are valid we focus our analysis on these two models. First, it can be seen, that in all cases the estimated coefficients are significant, including the effect of the squared variables, except for the square effect of education literacy in some models for groups 1 and 2.

In general, this can be interpreted as the existence of "inequality traps." These traps can be defined as the preceding high levels of inequality and can produce a "cheat or a feedback loop" in which current economic inequality is reinforced. Inequality traps are characterized by dynamic inequality that tend to perpetuate themselves over time. A key issue related to the notion of inequality traps is how to distinguish them from the well-known notion of poverty traps (Azariadis & Stachurski, 2005). The nuance between the two notions depends on the way in which the different groups of society interact. That is, poverty traps refer to the lack of opportunities available to the poor and imply that there is both chronic and transient poverty. On the other hand, in the case of inequality traps this lack of opportunities is accompanied by stagnation in the society's income distribution structure. For more on the formal concept of an inequality trap see Bourguignon et al. Walton (2007).

Our results indicate that in Mexico, as well as in the Mexican states confirming Groups 1 and 2, a U-shaped curve can be observed for the interdependency between inequality and *per capita* income. In other words, for low income values an increase in the curve would determine a fall in inequality, until a threshold is reached. Subsequently, any increase in income would lead to increasing inequality. The Arellano-Bover/Blundell-Bond model would indicate that this threshold for Mexico as a whole would be $10,056.12, while in Group 1 it is $12,209.50, and in Group 2 it is $ 15,373.93 (considering that the amount represents GDP *per capita* in millions of 1993 pesos = 100). In the case of the PCSE model, these thresholds are in the amount of $9,032.49 in the case of Mexico, $12,103.10 in the case of Group 1, and $13,206.89 in the case of Group 2. Therefore, Group 2 has a threshold higher than Group 1 and in both cases the thresholds are higher than those of Mexico.

Figure 5 shows that, if the inter-regional inequality functions are plotted depending only on *per capita* income (i.e., regional GDP), maintaining the level of the literacy rate constant, Group 1 presents a U-curve above Group 2's U-curve with both being above the Mexico's curve. The span of the curves can also indicate the effort in terms of the increase in *per capita* income that each Group needs to reach for attaining lower or higher levels of inequality. Considering the same level of the literacy rate, a particular value of *per capita* GDP is associated with larger levels of inequality

TABLE 6 Hausman tests, autocorrelation and heteroscedasticity (inequality models)

	Mexico	Group 1	Group 2
Hausman	H0: Fixed Effects		
Chi2 (Prob>Chi2)	66.89 (0.00)*	2.28 (0.68)	252.75 (0.00)*
Wooldridge	H0: Autocorrelation		
F	54.10 (0.00)*	807.12 (0.00)*	99.97 (0.00)*
Wald	H0: Heteroskedasticity		
Chi2 (Prob>Chi2)	3632.27 (0.00)*	1152.51 (0.00)*	1205.28 (0.00)*

Notes: Own elaboration.
* rejection of the null hypothesis at 1%.

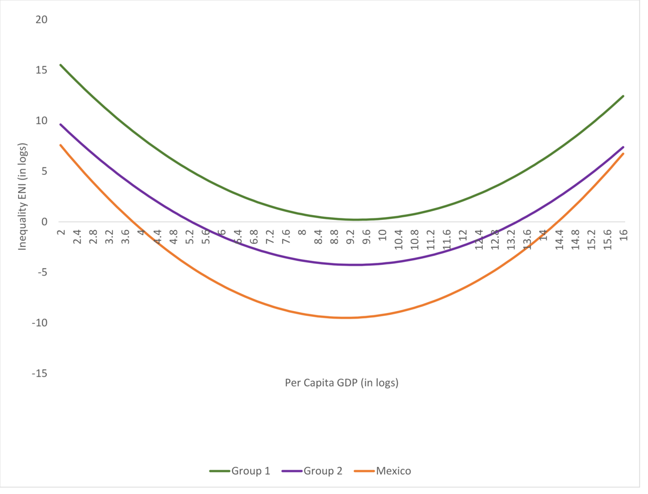


FIGURE 5 Income-inequality curves according to the PCSE model for Group 1, Group 2, and Mexico (from top to bottom)
Source: Own elaboration

FIGURE 6 Inequality-education curves according to the PCSE model for Group 1, Group 2 and Mexico (from top to bottom).
Source: Own elaboration

in Group 1 than in the rest of the Groups. Movements in the literacy rate will impact on the curve. Since there is also a U-shape curve with literacy, then depending on the part of this literacy curve, the movement will go up or down.

As can be seen in Table 5, in the Arellano-Bover/Blundell-Bond and PCSE models, the YL^2 coefficient is lower in the case of Group 1 (0.13 and 0.26), than in the case of Group 2 (0.23 and 0.28) and these than in the case of Mexico (0.37 and 0.34). Hence, this indicates that it is Group 1 which needs a greater movement of income *per capita* (regional GDP *per capita*) to move the inequality levels. However, it is group 1 where income *per capita* is more consolidated (i.e., they are more homogenous) than group 2.

Hence, our results indicate that inequality traps may exist for the Mexican states. This is due to the fact, that the dynamic model shows that the past value of inequality has a greater impact in the case of Group 2 with a coefficient of 75%, while in Group 1 the inequality of the previous period impacts at 59%, and that in Mexico as a whole, the impact is of 44%. This indicates that it is Group 2 which shows a greater persistence and reinforcement of inequality levels. However, if the slope of the second derivative is calculated, the result obtained demonstrates that in the long run this value is higher in Group 1 (0.57) than in Group 2 (0.52). This indicates that in Group 2, where the income distribution is more problematic, there is a larger persistence of past income distribution.

In the case of the literacy rate as a control variable, the results are interesting. If the case of Mexico is appreciated and partly in the case of Group 2, there is an inverted U-shaped curve (see Figure 6). That is, for low levels of

TABLE 7 Wald-test for equality of regression coefficients among the models for Group 1, Group 2 and Mexico (Inequality equations)

	Group 1 = Mexico			Group 2 = Mexico			Group 2 = Group 1		
Coefficient	**FE/RE**	**A-B/B-B**	**PCSE**	**FE/RE**	**A-B/B-B**	**PCSE**	**FE/RE**	**A-B/B-B**	**PCSE**
LENI(−1)	N/A	13.24	N/A	N/A	6.07	N/A	N/A	2.19*	N/A
LYL	90.82	13.2	6.84	1.5*	36.05	15.49	19.89	11.65	1.49*
LYL2	95.41	15.54	8.93	5.43	40.79	20.43	36.56	11.78	1.72*
LLR	4.61	947.24	866.31	314.02	3.35*	12.33	177.99	0.19*	6.34*
LLR2	5.42	N/A	N/A	N/A	N/A	15.88	N/A	N/A	3.65
_CONS	71.4	0.12*	0.1*	7.19	15.87	0.05*	5.54	12.99	19.17
All coef	165.33	3,100,000	300,000	743.65	3,000,000	600,000	247.71	88.7	165.27

Notes: Own elaboration.
* significance of the equality of coefficient at 5%.

TABLE 8 Estimates of the equation of income *per capita* for Mexico as a country, as well as for Group 1 and Group 2

	Mexico			Grupo 1	
ln (YL)$_{i,t}$	**Random Effect**	**Arellano-Bover/Blundell-Bond**	**Regression PCSE**	**Random Effect**	**Arellano-Bover/Blundell-Bond**
ln (YL)$_{i,t-1}$		0.75 (12.11)***			0.88 (50.21)***
ln (ENI)$_{i,t}$	−1.12 (−2.60)***	−1.50 (−3.76)**	−1.37 (−9.96)***	−2.82 (−5.86)***	−0.58 (−2.65)***
ln (ENI)$^2_{i,t}$	0.47 (2.65)***	0.57 (3.68)***	0.60 (10.57)***	1.24 (5.93)***	0.21 (2.07)**
ln (LR)$_{i,t}$	−7.64 (−3.89)***	0.56 (3.19)***	−3.41 (−4.12)***	−10.42 (−3.71)***	0.19 (3.47)***
ln (LR)$^2_{i,t}$	1.19(4.77)***		0.68 (6.51)***	1.52 (4.40)***	
c	20.31 (5.43)	0.75 (2.50)**	11.76 (7.24)***	27.03 (4.87)***	0.64 (3.61)***
Specification	899.96 (0.00)	4580.91 (0.00)	1360.86 (0.00)	633.09 (0.00)	13828.23 (0.00)
R-squared	0.8214		0.9165	0.8498	
autocorrelation:					
order 1		−3.48 (0.00)			−3.40 (0.00)
order 2		−1.86 (0.06)			−2.64 (0.01)
sargan test		31.65 (1.00)			18.36 (1.00)
Number of obs.	2,432	2,400	2,432	1,444	1,425

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10.

TABLE 8 (Continued)

	Grupo 1	Grupo 2		
ln $(YL)_{i,t}$	Regression PCSE	Fixed Effect	Arellano-Bover/Blundell-Bond	Regression PCSE
ln $(YL)_{i,t-1}$			0.93 (31.38)***	
ln $(ENI)_{i,t}$	−1.31 (−8.58)***	−0.78 (−3.00)**	−0.77 (−2.69)***	−1.48 (−6.84)***
ln $(ENI)^2_{i,t}$	0.51 (7.47)***		0.24 (2.54)**	0.46 (5.81)***
ln $(LR)_{i,t}$	−9.33 (−8.08)***	−5.06 (−3.41)***	0.10 (1.63)*	1.70 (21.75)***
ln $(LR)^2_{i,t}$	1.37 (9.69)***	0.82 (4.07)***		
c	24.50 (10.43)***	16.68 (6.77)***	0.81 (3.25)**	2.85 (8.60)***
Specification	1279.68 (0.00)	677.72 (0.00)	9328.67 (0.00)	587.18 (0.00)
R-squared	0.9502	0.9110		0.9126
autocorrelation:				
order 1			−2.36 (0.02)	
order 2			−1.92 (0.06)	
sargan test			8.70 (1.00)	
Number of obs.	1,444	684	675	684

Notes: Own elaboration.
*** rejection of the null hypothesis at 1%;
** rejection of the null hypothesis at 5%;
* rejection of the null hypothesis at 10.

literacy rate, an increase causes inequality to rise until a threshold is reached from which higher levels of literacy rate reduce inequality. However, in the case of Group 1, the estimate gives us a positive coefficient of 0.18 in the case of the PCSE, while in the case of the dynamic model the coefficient is 0.935 in the long-run (the long-run coefficient is obtained by dividing the long-run coefficient by the rate of convergence 1–0.59). This may indicate that Group 1 is still in the first part of the U-inverted, the dataset does not capture a threshold and therefore the estimation only produces a straight line with a positive slope, since it has not reached the literacy rate threshold necessary to start lowering the levels of inequality. Note that for a determined and constant level of *per capita* GDP, the same level of literacy rate will have a smaller impact in Group 1 than in the rest. In particular, Group 1 seems to be still in the increasing part of the curve. In order to move down the Group 1 curve, it is necessary to move the *per capita* GDP. This is more complex if we consider that the direction of this movement depends on the part of the Income curve (Figure 5).

Table 7 shows that even if some regression coefficients are similar between Groups, the set of coefficients are significatively different among the models according to the Wald test. Table 8 estimates the models for *per capita* income in the case of Mexico, Group 1 and Group 2, while Table 9 shows the results of the Hausman, autocorrelation and heteroskedasticity tests in the FE and RE models.

The results also show the existence of a U-shaped curve if the *per capita* income is considered to depend on the levels of inequality (see Figure 7). In other words, there would be a first phase whereas inequality levels increase and *per capita* income decreases until a threshold is reached from which any increase in inequality causes *per capita* income to rise. According to the estimates, these thresholds are higher in the cases of Group 2 than in the case of Group 1 and both higher than in the case of Mexico. Thus, for Group 2 the levels would be 4.94 if the PCSE model is considered, or 4.86 in the long-term according to the dynamic model. In the case of Group 1 these values are 3.61 and 4.07 respectively, and in the case of Mexico as a whole, the coefficients are 3.11 and 3.69 respectively. Beyond these thresholds, any increase in inequality would have a positive impact on levels of *per capita* income. In this case it can be noted that for a determined level of literacy rate Group 1 always has the largest level of *per capita* GDP when all the group reaches the same levels of inequality. In this case it is observable that for the same level of inequality, Group 2 requires more effort to increase literacy in order to obtain larger levels of *per capita* GDP.

The existence of the inequality trap is illustrated as follows. The dynamic Arellano-Bover/Blundell-Bond model shows the existence of greater persistence and reinforcement in the impact of past income levels *per capita* in the case of Group 2, in which 93% of the past value persists the following year, then Group 1 at 88%, and Mexico as a whole, shows a persistence of 75% of the value of the previous year. According to the slope of the derivative of this curve, it can be seen, that in the long-run, and according to the dynamic model, the highest value is that of Group 2 (3.44) over Group 1 (1.74). Therefore, it is in Group 2 that a change in inequality levels could have a greater impact on *per capita* income.

Concerning literacy rate levels, an interesting result is found, since in the case of Mexico and Group 1 the models would indicate the existence of a U-shaped curve. This would indicate the existence of a threshold, as before this

TABLE 9 Hausman tests, autocorrelation and heteroscedasticity (income models *per capita*)

	Mexico	Grupo 1	Grupo 2
Hausman	H0: Fixed Effects		
Chi2 (Prob>Chi2)	4.75 (0.31)	1.64 (0.80)	30.41 (0.00)*
Wooldridge	H0: Autocorrelation		
F	161.70 (0.00)*	210.26 (0.00)*	78.19 (0.00)*
Wald	H0: Heteroskedasticity		
Chi2 (Prob>Chi2)	11774.89 (0.00)*	5433.05 (0.00)*	913.64 (0.00)*

Notes: Own elaboration.
* rejection of the null hypothesis at 1%.

FIGURE 7 Income-inequality curves according to the PCSE model for Group 1, Mexico and Group 2 (from top to bottom).
Source: Own elaboration

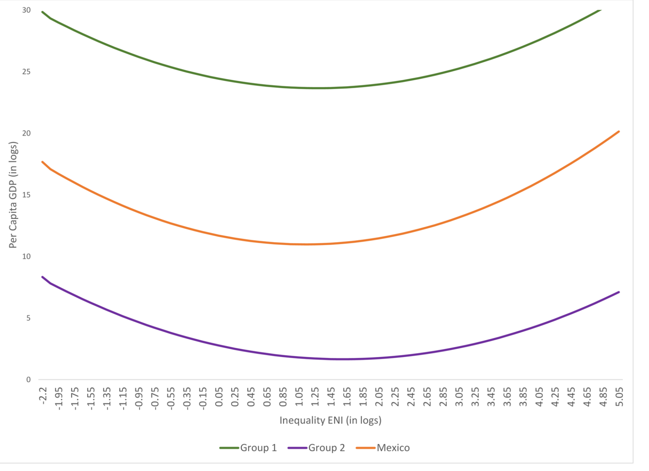
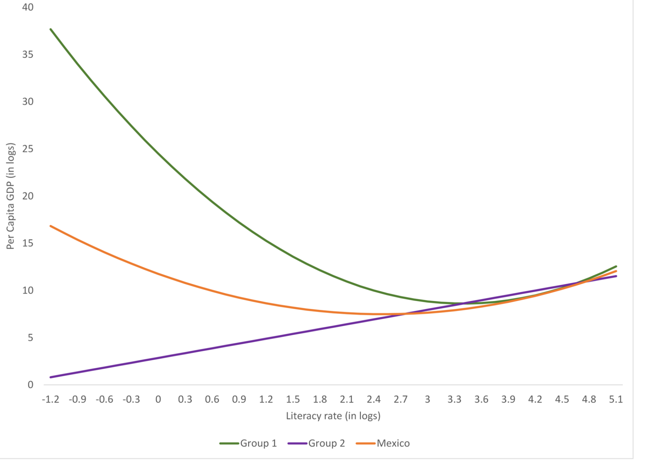


FIGURE 8 Income-education curves according to the PCSE model for Group 1, Mexico and Group 2 (from top to bottom).
Source: Own elaboration



the levels of literacy rate reduce *per capita* income levels and after that threshold the impact on income is positive. However, a deeper analysis demonstrates that these thresholds are extremely low and correspond to literacy rates of 12.33% in the case of Mexico and 30.35% in the case of Group 1. Values lower than these thresholds are particular and were only reached in the case of Group 1 in Querétaro between the years 1940 and 1944. Therefore, the states have almost always been in the zone corresponding to the positive impact of education on income. In the case of Group 2, a linear and positive relationship is found between *per capita* income and education (see Figure 8). Note that in this case the curves seem to converge in the positive part, meaning that for the same level of inequality the relation between *per capita* GDP and literacy rate is generally similar among the groups. As previously mentioned, the decreasing initial part of the curve is related to virtually no practical observed value, due to the low levels of literacy that are required in order to be in this part of the curve.

In the case of Group 2, there is a positive elasticity of 1.70 (considering the PCSE model) and an elasticity of 1.42 in the long run (according to the dynamic model). In the case of Group 1, a long-run elasticity of 1.61 can be observed. This would mean that while in Group 2 a 100% increase in the literacy rate impacts on a 1.42% increase in *per capita* income, in Group 1 this impact is greater, as it is 1.61% over income. The impact is smaller in Group 2, considering that the elasticity in the group of all the Mexican states (i.e., Mexico as a whole) is 2.27.

TABLE 10 Wald-test for equality of regression coefficients among the models for Group 1, Group 2 and Mexico (Income equation)

	Group 1 = Mexico			Group 2 = Mexico			Group 2 = Group 1		
Coefficient	FE/RE	A-B/B-B	PCSE	FE/RE	A-B/B-B	PCSE	FE/RE	A-B/B-B	PCSE
LYL(−1)	N/A	54.02	0.13*	N/A	35.89	0.28*	N/A	2.68*	N/A
LENI	90.33	15.91	1.8*	67.35	5.74	3.01*	2323.78	0.44*	0.61*
LENI2	119.55	12.07	26.27	N/A	10.45	4288.69	N/A	0.15*	0.34*
LLR	18.5	43.84	23.78	38.41	54.74	N/A	165	2.17*	19975.45
LLR2	17.84	N/A	29.41	51.18	N/A	721.72	179.1	N/A	N/A
_CONS	25.35	0.37*	63.47	19.29	0.06*	39263.97	156.55	0.47*	4262.29
ALL COEFF	208.99	121.92		7112.87	83.65		47043.05	18.23	160,000

Notes: Own elaboration.
* significance of the equality of coefficient at 5%.

Table 10 shows that even if some regression coefficients are similar between Groups, the set of coefficients are significatively different among the models according to the Wald test.

5 | CONCLUDING REMARKS

This research paper contributes to the literature by providing an exploratory analysis of the interdependency between economic growth and inequality and offers a substantial description of the economic dynamics of Mexican states. The dynamics of each Mexican state are represented by the growth rate of GDP *per capita* and the ENI of interregional inequality, becoming a one-dimensional representation of the dynamics through the symbolization of the series based on the concept of "regimes." From the series of symbols, the symbolic distance is defined and the cluster analysis is performed. For the whole period, the existence of two important groups of states is observed, a group made up mostly of economies characterized by high inequality (Group 2), and another group characterized by a state of low inequality (Group 1). This shows that the performance of Mexican states is not homogeneous. The results of this performance analysis show that on average the high inequality group presents more stable growth rates throughout the period, while in the low inequality group the average growth rate shows greater variability. There is also a considerable difference between the two main groups. In the low inequality group, the average ENI varies between approximately 2.5 and 4.3, while the mean for the high inequality group ranges from 3.4 to 6.4. In both cases, the trend decreases, and this trend is slightly more marked in the high inequality group.

Furthermore, regime dynamics and clustering results demonstrate that finding results depending on a single model, as is done in standard analyses using panel data, presents difficulties and obstacles that are difficult to overcome. Our study shows the variety and complexity in growth and inequality in the regional performance, and it motivates the econometric exercise in the second part. However, certain limitations must be taken into account. As shown in the analysis, the groups seem to be determined solely on the basis of inequality, which could be due to the fact that this variable fluctuates less in time compared to the growth variable. Therefore, by considering longer periods of time it could be possible to demonstrate significant changes in inequality. Finally, the designed methodology opens future lines of research that allow the introduction of concepts and forms of regime change and other notions of distance between economies. Moreover, in terms of the symbolization of the series, in the future it could be carried out using other partitions, such as regional annual averages (not the total sample), or partitions based on economic and non-statistical criteria. In addition, it could be interesting to examine the evolution of the groups in order to study convergence or divergence. We could take time windows and analyse the number of groups to see if the number remains the same over time as well as the group formations, in order to establish whether the states always remain in the same group or if there are group changes. It would also be interesting to consider sub-periods, since there were certain changes during the analysis period that may be interesting to examine. Another compelling option would be to include more variables, such as education, when defining regimes to group states.

A bi-directional causality between inequality and income *per capita* is found by first analysing the long-run dynamics in the groups. Second, regarding the relationship between inequality and income *per capita*, a U-shaped curve is found indicating the existence of an inequality trap. Therefore, Mexican states have to overcome income and inequality thresholds to obtain better levels of income distribution and economic growth.

Our econometric results show that the high inequality group (Group 2) is the most problematic, due to the fact that past inequality and past income are really persistent in this group, as demonstrated by the dynamic model. This means that even if there is a bi-directional causality between inequality and income, a larger effort to move the two variables is necessary to overcome a trap. Moreover, education literacy rate has a positive impact on distribution and economic growth, though the long-run income-literacy elasticity is smaller in Group 1. This would imply that an increase of 1% in literacy increases income to 1.42%, while in Group 2 and in Mexico (as a whole) the impacts are 1.61% and 2.27% respectively. The good news is that the long-run inequality-literacy elasticity is larger in Group 2 (1.72) than in Group 1 (0.93).

Hence, one may wonder whether education literacy has played a crucial role to overcome the inequality traps. Without a doubt, education is an important factor, but an insufficient one, since the data indicates that the Mexican states already exceed the threshold levels of education literacy rates. Hence, for further research, if there is availability of data, it would be important to test whether R&D activities (already well-known in the literature) complementing R&D workers or education systems, may be the crucial factor to finally overcoming the inequality traps.

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ENDNOTES

[1] For instance, Williamson (2010) calculated Gini coefficients in Latin America over five centuries based on social tables and GDP/wage ratios, and showed that inequality was not high by contemporary global standards until the 19th century. By contrast, he argues that the high levels of inequality in Latin America in the 20th century were the result of an increase in the *belle époque* (approximately 1880–1914), due to the forces of globalization. Coatsworth (2008) argued for a similar historical development of Latin American inequality, although in his interpretation the changes in power between elites and popular sectors were driven by cycles of economic growth. Arroyo Abad (2013) analysed the impact of trade and the change in factor endowments on inequality in the 19th century, measured as the ratio of wages to income from land rental. Like Williamson and Coatsworth, Arroyo Abad discovered that inequality was not always high and maintained that the income-wage ratio decreased in the 19th century and reached a low point in the Mexican Porfiriato given that the incorporation of land into agriculture in the north of the country displaced the factor endowments.

[2] The temporal structure of the data increases the chance of autocorrelation, violating the OLS assumption that the errors are independent of each other. Moreover, the cross-sectional structure of the data increases the chance that the variance in the error terms may differ across economies and that there will be spatial processes that affect different panels simultaneously. The consequence of these violations is that OLS coefficient estimates are still unbiased but inefficient. To deal with these problems we followed Beck and Katz (1995) using panel-Ccorrected standard errors. The majority of previous work approaches autocorrelation using a lagged dependent variable. Achen (2000) demonstrates, however, that this method can lead researchers to mistakenly discount the importance of variables particularly if they do not vary dramatically over time. Achen (2000) suggests transforming the data to address autocorrelation and yet avoid the pitfalls of using the lagged dependent variable. We estimate and report both models, thereby demonstrating the strength of our results.

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Resumen. Se utilizó el índice de desigualdad económica interregional y el producto estatal bruto *per cápita* de los estados mexicanos durante el periodo 1940-2015 con el fin de aplicar una dinámica de regímenes y el análisis de *cluster* jerárquico para segmentar la muestra en regímenes de estados mexicanos con un desempeño similar. Se estudiaron modelos econométricos robustos que muestran la dirección de la causalidad entre la desigualdad económica y la renta *per cápita*, y la existencia de una curva en forma de U para la interdependencia entre el crecimiento económico frente a la desigualdad económica, y los niveles de umbral. Además, se demostró la existencia de trampas de desigualdad. La tasa de alfabetización educativa como variable de control indica una curva en forma de U invertida.

抄録: 1940~2015年のメキシコの各州における地域間の経済的不平等指標と1人当たり国民総生産を用いて、レジーム動態と階層的クラスター分析により、パフォーマンスが同等の州ごとのレジームにサンプルを分割した。経済的不平等と1人当たり所得との因果関係の方向性と経済成長と経済的不平等の相互依存関係を示すU字型曲線の存在、閾値レベルを示す頑健な計量経済モデルを検討する。さらに、不平等の罠(inequality traps)の存在も確認する。対照変数としての教育と識字率は、逆U字曲線を示す。