

Mexico's inter-regional inequality: a convergent process?

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Abstract Using a recently proposed Euclidian measure to quantify inter-regional inequality in per capita GSP (gross state product), we study the convergence among Mexican states during the 1940–2010 period. In ten cases, we find that GSP inequality diverges while the rest of the states' GSP inequality can be described as the following *catching-up* or *lagging behind* processes. For the later processes, we also find evidence of structural breaks. The shifts in the evolution of regional inequality in Mexico for various cases coincide with two distinct periods: the “Mexican Miracle” phase and the “oil/debt crisis” phase.

Keywords Inter-regional inequality · Euclidean inequality measure · Mexico · Unit roots · Deterministic trends · Structural breaks

JEL Classification O10 · O40 · R1

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1 Introduction

We study the convergence properties of regional per capita GSP (gross state product) inequality in Mexico through a time series analysis of a recently proposed measure of inequality based on the Euclidean distance (see Germán-Soto 2016). Our contribution to the convergence literature is twofold: First, instead of employing per capita GSP as the key variable to determine whether a process is divergent, convergent or catching-up, we use a measure of inter-regional inequality. In other words, we assess the convergence of regional inequality instead of convergence in income level. Second, our inequality measure overrides the need of a numeraire (or benchmark) region to analyze convergence; a numeraire region is traditionally used to assess whether a time series of income is (or not) stochastically converging.

Evidence of convergence can be sensitive to the selection of the numeraire. The latter tends to move in time and, in consequence, it could also modify the fundamental trend of the variables under analysis. The Euclidian distance index derived in Germán-Soto (2016) does not require a numeraire region; it is intrinsic to the corresponding index of inter-regional inequality. The inter-regional distance index used here is built by weighting the relative GSP between a given region and the remaining regions of the system. The resulting index for each region is therefore not conditioned to measuring the gap solely with respect to the numeraire region, but with respect to the whole set of regions.

We investigate whether inequality follows a divergent, convergent or catching-up process, as proposed by Bernard and Durlauf (1995, 1996). GSP inequality and convergence patterns are of great relevance to Mexico, a country that exhibits one of the largest levels of inequality worldwide (OECD 2015). Research shows that income inequality across countries tends to converge (Ravallion 2003). However, the time series patterns of per capita GSP inequality convergence are virtually unknown at the regional level, particularly for an emerging economy.

The hypothesis of GSP inequality convergence at the regional level implies that states with similar economic structures tend to move to the same steady state of income distribution. A deeper understanding of regional GSP inequality and its time series properties, convergence in particular, can help in the policy design of income distribution and wages (Benabou 1996). It can be argued that the finding of convergence has implications for models predicting multiple steady states (Piketty 1997) and can also be regarded as an extension of neoclassical growth models, which imply income convergence, but also income inequality convergence (Lin and Ho-Chuan 2012).

Benabou (1996), Ravallion (2003) and Ezcurra and Pascual (2005) can be cited as examples of income inequality studies at the country level for developed countries. As for regional per capita GSP inequality convergence for emerging economies, the literature is smaller, but there are some studies, such as Bleaney and Nishiyama (2003), Panizza (2001) and Gomes (2007). It is worthwhile mentioning that all these studies find evidence favorable to the convergence hypothesis.

The standard approach to test convergence in most of the studies relies on the concepts of β -convergence and σ -convergence by Barro and Sala-i-Martin. However, such notions have been questioned due to: (i) inconsistent estimates arising from the use of cross-sectional methods (Evans and Karras 1996); (ii) the stable variance in

cross-country output leading to the finding of convergence (Quah 1993); and (iii) the multiple equilibria, possibility leading to a more frequent rejection of no convergence (see Bernard and Durlauf 1996).

Carlino and Mills (1993) and Bernard and Durlauf (1996) suggest that traditional cross-sectional methods to test convergence do not allow to differentiate between catching-up and the various outcomes of convergence offered in the time series approach: stochastic convergence, deterministic convergence and divergence. Moreover, such methods do not consider the possibility of structural shifts in the convergence process within the period of analysis.

In this paper, we test the convergence of per capita GSP inequality among the 32 States in Mexico for the period 1940–2010 by studying the stochastic or deterministic trends underlying the GSP time series. Such trending mechanisms are then interpreted as evidence of divergence, convergence or catching-up/lagging behind. Moreover, we also allow for structural breaks in the trend of GSP inequality. The break dates found clearly reveal two distinct phases in the time evolution of regional income inequality: the “Mexican Miracle” phase, and the “oil/debt crisis aftermath” phase, which is persisting nowadays. That said, we find that per capita GSP inequality is a divergent process for ten states.¹

The paper is organized as follows: Sect. 2 introduces a newly created Index of Regional Income Inequality recently proposed by Germán-Soto (2016). We then proceed in Sect. 3 to describe the time series methods used to identify the convergence properties of the series (divergence, *catching-up/lagging behind*, loose catching-up, long-run convergence). Section 4 describes the data employed and analyzes the convergence results by state, while Sect. 5 concludes.

2 The inter-regional GSP inequality measure

Inequality stands as an inherent feature of modern societies. Despite its relevance, its measurement at the regional level is often constrained by the data. Traditional measures of income inequality are able to identify cross sections and time-varying patterns. However, thorough analyses require a long-run view, which is a big shortcoming in some developing economies like Mexico, where inequality data are not usually available for long time spans.

The few income inequality analyses in Mexico rely on regular data available only for short time periods, such as the National Survey of Income and Expenditures (ENIGH)—see Szekely (2005) and Germán-Soto and Chapa-Cantú (2015). The data in these cases are representative of national patterns of income and consumption, but most regions in Mexico lack representativeness; in fact, there are few reliable sources of data on income or GSP at the regional level.

Among the few measures available to understand economic disparities at the regional (states) level, we find the human development index (HDI) derived by López-

¹ It is worthwhile to mention that these results could be reversed had the data been adjusted for relative prices among states. Unfortunately, technical limitations prevent us from using such adjustment. A more detailed explanation is provided below. We would like to thank an anonymous referee for pointing us this possibility.

Calva and Székely (2006) for Mexico. Although this is a widely used measure, the HDI index has various criticisms (García-Verdu 2010) and it is only available for short spans of time, making our evidence very limited.

This study overcomes these limitations by employing an original measure of income distance across regions developed by Germán-Soto (2016). The index, based on the Euclidian Norm, has the advantage of being homogeneous and comparable; it uses the gross state product (GSP) in Mexico as input. We employ the Euclidean Norm Index, ENI hereafter, as a measure of inter-regional inequality. The ENI captures the aggregate regional inequality between the n regions (states) in the economy. It is important to emphasize that ENI is a measure of the “between” or “distance” inequality among all the economies in a given moment in time: It is the relative distance between the state and the rest of the states in the country. This is not a “within” inequality measure as in the majority of inequality indexes available in the literature (Gini, Atkinson, Theil, etc.). However, as a summary statistic of the distribution of incomes, ENI is quite useful to assess how inequality in a given region has changed over time, that is, it allows the practitioner to compare different distributions, an objective of this work. ENI also allows the analyst to measure the width of income distance in time. For each region i and each period t , the ENI (D_{it}) can be expressed as

$$D_{i,t} = ||X_{i,t} - X_{j,t}|| = \sqrt{\sum_{j=1}^n (X_{i,t} - X_{j,t})^2} \quad \forall j = 1, 2, \dots, n \quad (1)$$

where ENI is defined as $D_{i,t}$, i.e., inter-regional GSP inequality; $X_{i,t}$ is per capita GSP in real terms; and n is the number of states in Mexico (32). For the case where $i = j$, the distance becomes zero. The measure of distance defined by Eq. (1) is an assignment of a real number to a vector satisfying the properties of the Euclidian distance. Let V be a vector space with n -regions. Then, in agreement with Simon and Blume (1994) and Hekmatfar and Farahani (2009), any function defined within the space of $\mathbf{R}$ (i.e., $N : V \rightarrow \mathbf{R}$) is a Norm if it satisfies the following properties:

1. *Property 1* $N(\mathbf{i}) \geq 0 \quad \forall \mathbf{i} \in V$. Distances are nonnegative.
2. *Property 2* $N(\mathbf{i}) = 0$ if $\mathbf{i} = 0$. If the i th economy does not belong to V , then there is no distance to calculate.
3. *Property 3* $N(r\mathbf{i}) = |r| N(\mathbf{i}) \quad \forall r \in \mathbf{R}^1$ and $\forall r \in V$. Any scalar affecting i (or its norm) increases the distance of that factor.
4. *Property 4* $N(\mathbf{i}+\mathbf{j}) \leq N(\mathbf{i}) + N(\mathbf{j}) \quad \forall \mathbf{i}, \mathbf{j} \in V$. The Norm satisfies triangular inequality.

In addition to satisfying all these properties, the ENI tends to zero and it is equal to zero under absolute equality.² Each element (state) contributes to the measure of joint inequality. Analysis of correlation with variables of social well-being has shown that the ENI is also highly consistent with the theoretical expectations—see Lewis and Ulph (1998), Kaplow (2005) and Cowell (2011). Germán-Soto (2016) demonstrates that ENI satisfies desirable properties for inequality indices such as the principles of

² Germán-Soto (2016) shows that the lack of an upper limit in ENI does not affect the results in the estimations of convergence. This is due to ENI's property of scale independence. We thank an anonymous referee for pointing out his concern about the interpretation of ENI in absolute terms.

symmetry, scale independence, population replication and the Pigou–Dalton transfer principle, among others. So its application with time series methodologies is appropriate. More details and discussion on the Euclidean Norm properties and advantages as an inequality index are extensively discussed in Germán-Soto (2016).

3 Testing for inequality convergence

We use the ENI to test the hypothesis that per capita GSP inequality converges for the 32 states in Mexico. We adopt the neoclassical growth model framework and define convergence in terms of the persistence of contemporaneous differences in per capita GSP inequality. Neoclassical growth models and convergence tests traditionally employ per capita income levels. We extend such literature to consider the possibility of per capita GSP inequality convergence, i.e., states with high levels of per capita GSP inequality show falling per capita GSP inequality, whereas states with low levels of per capita GSP inequality show rising inequality. We assume that states in Mexico have similar preferences, population growth rates and probability distribution of shocks.

In particular, the specific type of convergence results from the examination of each time series generated according to Eq. (1). Following Bernard and Durlauf (1996), there are four possibilities:

1. *Long-run convergence* The ENI of a given state, $D_{i,t}$, is mean stationary, i.e., reductions (or increases) in income inequality have ended. The series remains stable over time.³
2. *Catching-up* The ENI of a given state, $D_{i,t}$, is stationary around a negative deterministic trend, i.e., there is a tendency for the difference in income inequality to narrow over time.
3. *Lagging-behind* The ENI of a given state, $D_{i,t}$, is stationary around a positive deterministic trend, i.e., there is a tendency for the difference in income inequality to widen over time.
4. *Divergence* The ENI of a given state, $D_{i,t}$, is governed by an unpredictable stochastic trend, i.e., it behaves as a random walk.

We use these definitions to examine the behavior of income inequality in each of the states in Mexico.

4 Data and empirical findings

The ENI employed in this study was built upon estimations of state per capita real GSP by the National Institute of Statistics and Geography (INEGI) and homogenized under the same year base by German-Soto (2005), updated to cover the 1940–2010

³ To be precise, two economies are said to converge if $\lim (D_{i,t})_{t \rightarrow \infty} = \delta_i$. Convergence is considered absolute if $\delta_i = 0$, and conditional if not.

period. The final data set consists of per capita GSP inequality time series that span the period 1940–2010 for the 32 States in Mexico.⁴

The data show in general that the present levels of inter-regional income inequality are much lower than those observed during the 1940s, 1950s or 1960s. A general inspection of inequality suggests two episodes of decreasing income inequality: the first reaching a local minimum in the beginning of the 1970s, when it stabilized for a short period of time (around four years) and, the second, reaching a global minimum in the beginning of the 1980s. After these events, most time series experienced a heterogeneous, but positive rise of income inequality.

The fall and rise of inequality in the states of Mexico for the period 1940–2010 are consistent with recent results on national income inequality time series patterns using the Gini coefficient (Guerrero et al. 2009; Germán-Soto and Chapa-Cantú 2015). The heterogeneous time series pattern of income inequality of states in Mexico also corresponds to the heterogeneous performance observed during the 1980s, a decade characterized by crisis of payments, rise of inflation and high levels of unemployment. States exhibit different patterns of income inequality, some of them explained by demographic conditions such as Baja California Sur, with a very low population density, or by specific economic conditions, such the states of Campeche and Tabasco driven by oil production.

We employ a battery of tests to formally identify the relevant time series properties that can be associated with divergence (unit root); convergence (stationarity), catching-up (lagging behind), with breaks (deterministic trends, possibly with trend breaks).

Hence, in order to study such properties, we examine the trending mechanism (deterministic or stochastic). We first employ standard tests (i.e., ADF, ADF-GLS, KPSS and PP) for this aim and present summarized results on regional income inequality in Mexico—see Table 1.

All standard tests fail to reject the unit root hypothesis for Aguascalientes, Campeche, Coahuila, Chiapas, Chihuahua, Morelos, Nayarit, Querétaro, San Luis Potosí, Tlaxcala and Veracruz. It is worthwhile noting that the standard unit root tests lack power to reject the null when the series is subject to structural shifts. Perron (1989) has already shown that the existence of structural breaks reduces the power of standard test and may therefore lead to erroneously favor the unit root hypothesis.

We therefore employ the Kapetanios test for unit roots controlling for one, two or three breaks (see Tables 5, 6 and 7 in appendix). A rejection of the null in at least one case (one, two, or three breaks) is taken as evidence of stationarity. Hence, we fail to reject the hypothesis of $I(1)$ processes for the inter-regional inequality series of the states of Coahuila, Chiapas, Chihuahua, Guerrero Jalisco, Mexico City, Morelos, Nayarit, Nuevo León and San Luis Potosí. When the $I(1)$ process includes a drift, we considered it as evidence of loose catching-up or lagging behind. If the $I(1)$ process is

⁴ An anonymous referee suggested us to replicate the results using relative price-adjusted data. Unfortunately, INEGI does not provide prices at the regional level (only at the city level for only 25 states out of the 32 and for a much shorter period), which prevent us from considering such results as being reliable enough. Nonetheless, this adjustment remains a relevant and interesting proposal, so we provide the results as an online appendix, along with the caveats that it entails. It is worthwhile to mention that the measures of real GSP employed in this study remain, however, consistent with several previous studies on growth and convergence [see for instance Bernard and Durlauf (1996) and Evans and Karras (1996)].

Table 1 Unit roots, standard tests. *Source:* Authors' estimations. All tests include a constant and a deterministic trend. The tests control for autocorrelation by including a number of lags selected by the Schwarz Information Criterion (SIC)

State	ADF	ADF-GLS	KPSS	PP	Estado	ADF	ADF-GLS	KPSS	PP
Aguascalientes	I(1)	I(1)	I(1)	I(1)	Morelos	I(1)	I(1)	I(1)	I(1)
Baja California	I(0)	I(1)	I(1)	I(0)	Nayarit	I(1)	I(1)	I(1)	I(1)
Baja California Sur	I(1)	I(1)	I(1)	I(0)	Nuevo León	I(1)	I(0)	I(1)	I(0)
Campeche	I(1)	I(1)	I(1)	I(1)	Oaxaca	I(0)	I(1)	I(1)	I(0)
Coahuila	I(1)	I(1)	I(1)	I(1)	Puebla	I(0)	I(1)	I(1)	I(0)
Colima	I(0)	I(1)	I(1)	I(0)	Querétaro	I(1)	I(1)	I(1)	I(1)
Chiapas	I(1)	I(1)	I(1)	I(1)	Quintana Roo	I(0)	I(1)	I(1)	I(0)
Chihuahua	I(1)	I(1)	I(1)	I(1)	San Luis Potosí	I(1)	I(1)	I(1)	I(1)
Durango	I(1)	I(1)	I(1)	I(0)	Sinaloa	I(1)	I(1)	I(1)	I(0)
Guanajuato	I(0)	I(1)	I(1)	I(0)	Sonora	I(1)	I(1)	I(1)	I(0)
Guerrero	I(1)	I(1)	I(1)	I(0)	Tabasco	I(1)	I(0)	I(0)	I(1)
Hidalgo	I(0)	I(1)	I(1)	I(1)	Tamaulipas	I(0)	I(1)	I(1)	I(0)
Jalisco	I(1)	I(1)	I(1)	I(0)	Tlaxcala	I(1)	I(1)	I(1)	I(1)
Mexico	I(0)	I(1)	I(1)	I(0)	Veracruz	I(1)	I(1)	I(1)	I(1)
Mexico City	I(1)	I(1)	I(1)	I(0)	Yucatán	I(0)	I(0)	I(1)	I(0)
Michoacán	I(1)	I(1)	I(1)	I(0)	Zacatecas	I(1)	I(1)	I(1)	I(0)

driftless, then the process is considered divergent. In order to infer about the existence of a drift, we employ the test proposed by Gómez-Zaldívar and Ventosa-Santaulària (2010), GVS hereafter. Such a test indicates whether the $I(1)$ process has a drift (and a break) or not. We fail to reject the null of a drift in all the cases. Hence, inter-regional inequality can safely be considered as divergent processes for these states (detailed results of the GVS test appear in Table 10 the appendix).

For the cases where at least one of the Kapetanios tests rejects the unit root, we employ Bai and Perron (1998) sequential *UD Max* and *WD Max* tests of no structural breaks against multiple unknown structural changes. Tables 8 and 9 show the results of the test applied to each series at the 5% significance level. As in Bai and Perron (2003), we allow for up to five structural breaks, a trimming of $\epsilon = 0.05$ and allow for serial correlation in the errors and different variances of the residuals across segments. The *UD Max* and *WD Max* tests are highly significant and provide evidence for different breaks. First, the following states show a deterministic trend, but no breaks: Baja California, Baja California Sur, Campeche, Colima, Durango, Guanajuato, Hidalgo, Querétaro, Quintana Roo, Tabasco, Veracruz and Zacatecas. Then, the following states show a trend with at least one break: Aguascalientes, Mexico, Michoacán, Oaxaca, Puebla, Sinaloa, Sonora, Tamaulipas, Tlaxcala and Yucatán.

Bai and Perron (1998) test, B&P hereafter, allows us to identify important break dates in regional inequality. We find two breaks in the early 1950s and seven breaks during the 1960s in Aguascalientes, Mexico, Michoacán, Oaxaca, Puebla, Tamaulipas and Tlaxcala. This evidence is consistent overall with the high rates of growth for the Mexican economy in those periods Hernández-Laos (2000), together with important reductions in poverty and inequality Szekely (2005). There is also documented evidence on the convergence pattern of Mexican states, as well as the breaks in the 1950s and 1960s—see Carrion-i Silvestre and Germán-Soto (2007). Around 1979–1982 during the aftermath of the oil crisis, we find breaks of inequality in the states of Mexico, Sinaloa, Sonora, Tlaxcala and Yucatán. A final break date is detected in 1997 in the case of Aguascalientes.

Using the break dates provided by B&P (see Table 2), we estimated (through Ordinary Least Squares, OLS) the value of the trend and of the trend breaks for those states for which evidence of catching-up/lagging behind was found. Results appear in Table 3.

A summary of the main findings in terms of convergence is shown in Table 4. Except for the ten states where we don't reject the hypothesis of unit roots (see Fig. 1), inequality has been *catching-up* in several states during the whole sample—the series are stationary under a negative deterministic trend. These *catching-up* cases include Baja California, Baja California Sur, Campeche, Colima, Guanajuato, Hidalgo, Querétaro, Quintana Roo, Tabasco and Zacatecas. The difference in the observed inequality tends to narrow over time (see Fig. 2).

The states of Aguascalientes and Tlaxcala initially showed a *lagging behind* behavior, but then, eventually, passed to *catching-up* in 1961 and 1966, respectively (see Table 3). The behavior of inter-regional inequality in these pair of states turned again to *lagging behind* in 1997 and 1979, respectively. Lagging behind means that inequality is stationary around a positive deterministic trend; differences in inter-regional GSP inequality tend to widen over time. A similar pattern is shown by the States of Mexico

Table 2 Unit root/stability/drift tests. *Source:* Authors' estimations

State	Kapetanios test ^d			B&P test ^b		GVS drift test ^c
	1 Break	2 Breaks	3 Breaks	No. of breaks	Break dates	
Aguascalientes	I(1)	I(0)	I(0)	2	1960, 1972, 1948	–
Baja California	I(0)	I(0)	I(0)	0	1971, 1979, 1953	–
Baja California Sur	I(0)	I(0)	I(0)	0	1975, 1985, 1995	–
Campeche	I(1)	I(0)	I(0)	0	1981, 2001, 1987	–
Coahuila	I(1)	I(1)	I(1)	–	–	No drift
Colima	I(0)	I(0)	I(0)	0	1985, 1974, 1995	–
Chiapas	I(1)	I(1)	I(1)	–	–	No drift
Chihuahua	I(1)	I(1)	I(1)	–	–	No drift
Durango	I(0)	I(1)	I(1)	0	1989, 1975, 1946	–
Guanajuato	I(0)	I(0)	I(0)	0	1975, 1946, 1993	–
Guerreero	I(1)	I(1)	I(1)	–	–	No drift
Hidalgo	I(0)	I(0)	I(0)	0	1980, 1961, 1966	–
Jalisco	I(1)	I(1)	I(1)	–	–	No drift
Mexico	I(1)	I(1)	I(0)	3	1980, 1950, 1961	–
Mexico City	I(1)	I(1)	I(1)	–	1981, 1952, 1963	No drift
Michoacán	I(1)	I(1)	I(0)	1	1960, 1948, 1966	–

Table 2 continued

State	Kapetanios test ^a			B&P test ^b		GVS drift test ^c
	1 Break	2 Breaks	3 Breaks	Break dates	No. of breaks	Break dates
Morelos	I(1)	I(1)	I(1)	–	–	No drift
Nayarit	I(1)	I(1)	I(1)	–	–	No drift
Nuevo León	I(1)	I(1)	I(1)	–	–	No drift
Oaxaca	I(1)	I(0)	I(0)	1981, 1951, 1975	1	1967
Puebla	I(0)	I(0)	I(0)	1963, 1974, 1979	2	1964, 1950
Querétaro	I(0)	I(0)	I(1)	1960, 1946, 1995	0	–
Quintana Roo	I(1)	I(0)	I(0)	1950, 1989, 1971	0	–
San Luis Potosí	I(1)	I(1)	I(1)	–	–	No drift
Sinaloa	I(1)	I(1)	I(0)	1961, 1983, 1976	1	1981
Sonora	I(0)	I(0)	I(0)	1971, 1979, 2003	1	1979
Tabasco	I(1)	I(0)	I(0)	1975, 1996, 1964	0	–
Tamaulipas	I(0)	I(1)	I(1)	1980, 1971, 2005	1	1962
Tlaxcala	I(1)	I(0)	I(1)	1978, 1960, 1972	2	1966, 1979
Veracruz	I(1)	I(1)	I(0)	1961, 1980, 1968	0	–
Yucatán	I(1)	I(0)	I(0)	1979, 1966, 1952	1	1980
Zacatecas	I(0)	I(1)	I(0)	2003, 1979, 1947	0	–

^a Kapetanios (2005) test^b Bai and Perron (1998) test^c Gómez-Zaldívar and Ventosa-Santaulària (2010) test

Table 3 Trend (T) and trend break estimation by OLS. *Source:* Authors' estimations

State	Trend	$T + DT_1$	$T + DT_1 + DT_2$	$T + DT_1 + DT_2 + DT_3$
Aguascalientes	0.0022 (1940–1961)	– 0.002 (1961–1996)	0.0045 (1997–2010)	
Baja California	– 1.3207			
Baja California Sur	– 1.2733			
Campeche	– 2.8482			
Colima	– 4.6509			
Guanajuato	– 1.8891			
Hidalgo	– 1.3668			
Mexico	– 0.0332 (1940–1951)	– 0.0051 (1952–1962)	– 0.0005 (1963–1980)	0.0004 (1981–2010)
Michoacán	– 0.0166 (1940–1965)	– 0.0096 (1966–2010)		
Oaxaca	– 0.0523 (1940–1966)	– 0.0086 (1967–2010)		
Puebla	– 0.0431 (1940–1949)	– 0.0093 (1950–1963)	– 0.0053 (1964–2010)	
Querétaro	– 3.1126			
Quintana Roo	– 2.6963			
Sinaloa	– 0.0052 (1940–1980)	– 0.005 (1981–2010)		
Sonora	– 0.0069 (1940–1978)	0.0021 (1979–2010)		
Tabasco	– 2.6064			
Tamaulipas	– 0.0195 (1940–1961)	– 0.0019 (1962–2010)		
Tlaxcala	0.0008 (1940–1965)	– 0.0207 (1966–1978)	0.0082 (1979–2010)	
Yucatán	– 0.0032 (1940–1979)	– 0.0016 (1980–2010)		
Zacatecas	– 2.5025			

Trend break dummies are denoted as DT_i for $i = 1, 2$ or 3 , respectively

Table 4 Convergence properties of inequality per state. *Source:* Authors' estimations

State	Income inequ. dynamics	
	Process	Break dates
Aguascalientes	Catching-up + break	1962, 1997
Baja California	Catching-up	–
Baja California Sur	Catching-up	–
Campeche	Catching-up	–
Coahuila	Divergence	–
Colima	Catching-up	–
Chiapas	Divergence	–
Chihuahua	Divergence	–
Durango	Divergence	–
Guanajuato	Catching-up	–
Guerrero	Divergence	–
Hidalgo	Catching-up	–
Jalisco	Divergence	–
Mexico	Catching-up + break	1981, 1952, 1963
Mexico City	Divergence	–
Michoacán	Catching-up + break	1966
Morelos	Divergence	–
Nayarit	Divergence	–
Nuevo León	Divergence	–
Oaxaca	Catching-up + break	1967
Puebla	Catching-up + break	1964, 1950
Querétaro	Catching-up	–
Quintana Roo	Catching-up	–
San Luis Potosí	Divergence	–
Sinaloa	Catching-up + break	1981
Sonora	Catching-up + break	1979
Tabasco	Catching-up	–
Tamaulipas	Catching-up + break	1962
Tlaxcala	Catching-up + break	1966, 1979
Veracruz	Divergence	–
Yucatán	Catching-up + break	1980
Zacatecas	Catching-up	–

and Puebla. These two states, however, started *catching-up* and gradually changed in 1981 and 1964 to *lagging behind*, respectively. Differences in inequality in Mexico and Puebla tend to widen over time too. Some states like Michoacán, Oaxaca, Sinaloa, Tamaulipas and Yucatán show an initial *catching-up* behavior that continues after the break dates of 1966, 1967, 1981, 1962 and 1980, respectively, but at slower rates (see Fig. 3).

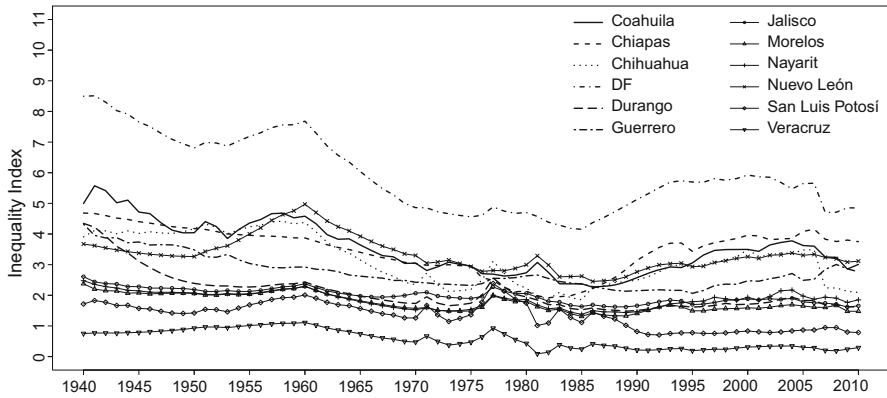


Fig. 1 States with inequality divergent time series

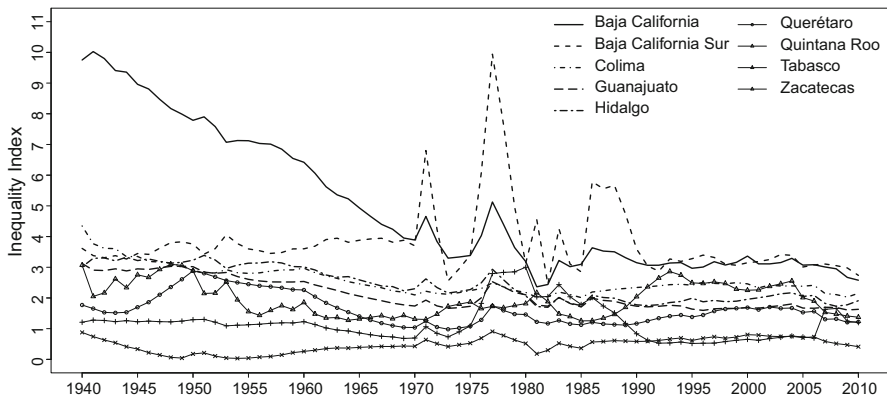


Fig. 2 States with inequality catching-up and one structural break

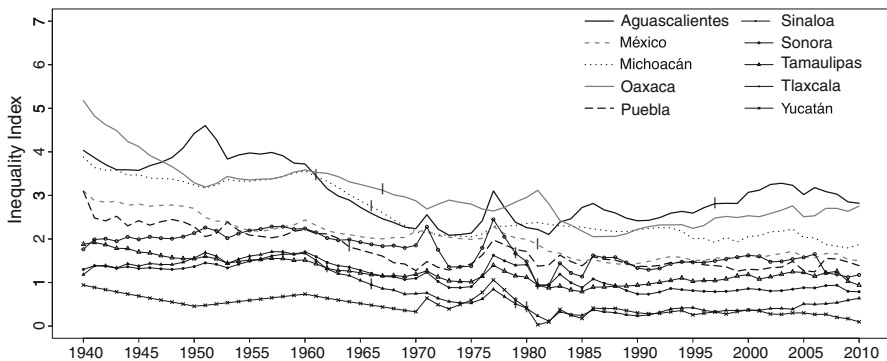


Fig. 3 States with inequality catching-up and one structural Break

5 Concluding remarks

We tested the convergence properties of inter-regional GSP inequality of Mexican states during the period 1940–2010. We are able to identify ten states where inter-regional inequality follows a divergent process, with the rest of the cases with inter-regional inequality following either *catching-up* or *lagging behind* processes. The testing procedures also identify in general two clear break phases: the “Mexican Miracle” phase from the early 1950s to the mid-1970s and the “oil/debt crisis” phase.

Indeed, the identified break dates during the 1960s coincide with the so named “Mexican Miracle”. During this period (1952–1976), the country experienced sustained economic growth together with diminishing regional inequality, an inverse relationship already suggested by previous studies—see Hernández-Laos (1992, 2000) and Szekely (2005). The general reduction in inequality during the “Mexican Miracle” broke up during in the 1979–1982 period, right in the wake of the Peso devaluation and the debt and oil crisis. The break of 1997 in Aguascalientes is very much aligned with the aftermath of the Tequila crisis. This last case is consistent with the poverty increase reported by Szekely (2005).

Our estimated break dates match those found by previous works on regional convergence in Mexico. For example, Carrion-i Silvestre and Germán-Soto (2007) detect time breaks around the two phases identified in this study. In such studies, the authors were interested in the identification of one and up to two breaks, while in this work we are more interested in the identification of multiple structural changes and breaking moments. Hence, this study complements the evidence previously documented on the convergence of Mexican regions.

In particular, we find that inter-regional GSP inequality of several states in Mexico is unpredictable, i.e., inequality follows a divergent process. These cases include Coahuila, Chiapas, Chihuahua, D.F., Guerrero, Jalisco, Morelos, Nayarit, Nuevo León and San Luis Potosí.

In contrast, inter-regional inequality in other states is stationary around a negative deterministic trend. In other words, differences in the observed inequality tend to narrow overtime. These are the cases where inequality follows a *catching-up* process during the whole sample (Baja California, Baja California Sur, Campeche, Colima, Guanajuato, Hidalgo, Querétaro, Quintana Roo, Tabasco and Zacatecas). Inter-regional inequality in the states of Michoacán, Oaxaca, Sinaloa, Tamaulipas and Yucatán also follows a *catching-up* process, but shows a lower *catching-up* rate after the break dates of 1966, 1967, 1981, 1962 and 1980, respectively.

A final group of states show a *lagging behind* behavior, i.e., inter-regional inequality is stationary around a positive deterministic trend. For these cases, inter-regional inequality is increasing and differences in inequality tend to widen over time. These cases include Aguascalientes and Tlaxcala before 1961 and 1966, as well as after 1997 and 1979, respectively. The time series pattern of inequality in the states of Mexico and Puebla changed to *lagging behind* in 1981 and 1964, respectively.

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Appendix

See Tables 5, 6, 7, 8, 9 and 10.

Table 5 Kapetanios test with one structural break. *** Significant at the 1% level. *Source:* Authors' estimations

State	1 Break		
	DU	DT	DU + DT
Aguascalientes	−4.3871 (1960)	−3.4773 (1972)	−4.2998 (1960)
Baja California	−3.5118 (1960)	−5.535*** (1972)	−5.6049*** (1971)
Baja California Sur	−5.7419*** (1989)	−6.0376*** (1977)	−6.8999*** (1975)
Campeche	−3.8434 (2006)	−3.127 (2003)	−3.7708 (1981)
Coahuila	−3.171 (1989)	−2.8312 (1982)	−2.9164 (1981)
Colima	−6.495*** (1985)	−5.0302*** (1970)	−5.842*** (1985)
Chiapas	−4.4333 (1985)	−3.0864 (1978)	−3.9387 (1975)
Chihuahua	−3.2306 (1960)	−2.4373 (1969)	−3.1902 (1960)
Distrito Federal	−4.0219 (1960)	−2.4754 (1969)	−3.8156 (1960)
Durango	−4.9955*** (1960)	−4.6124*** (1984)	−4.6463 (1989)
Guanajuato	−3.9282 (1960)	−4.3687*** (1968)	−5.2791*** (1975)
Guerrero	−2.4092 (1995)	−2.3876 (1989)	−2.3908 (1987)
Hidalgo	−4.2362 (1996)	−4.5615*** (1987)	−4.9695*** (1980)
Jalisco	−3.9079 (1995)	−3.5209 (1987)	−4.3106 (1980)
Mexico	−3.0661 (1995)	−3.1852 (1987)	−3.9339 (1980)
Michoacán	−4.5383 (1963)	−3.766 (1973)	−4.4811 (1960)
Morelos	−3.7595 (1963)	−3.2937 (1984)	−3.7568 (1960)
Nayarit	−3.6936 (1960)	−3.2159 (1984)	−3.4985 (1961)
Nuevo León	−2.9887 (1964)	−2.3296 (1983)	−3.855 (1960)
Oaxaca	−3.5307 (1995)	−3.8279 (1988)	−4.7149 (1981)
Puebla	−6.0435*** (1963)	−4.9681*** (1970)	−6.0372*** (1963)
Querétaro	−4.7461*** (1960)	−3.8488 (1972)	−4.1203 (1960)
Quintana Roo	−3.5271 (1953)	−3.2861 (1955)	−3.7265 (1950)
San Luis Potosí	−4.6121 (1986)	−3.9807 (1958)	−4.4989 (1986)
Sinaloa	−3.9796 (1980)	−3.783 (1955)	−4.3432 (1961)
Sonora	−5.652*** (1971)	−4.7098*** (1950)	−5.6252*** (1971)
Tabasco	−3.4658 (1986)	−2.6048 (1977)	−3.5351 (1975)
Tamaulipas	−3.9065 (1991)	−4.3572*** (1984)	−4.6651 (1980)
Tlaxcala	−3.5693 (1961)	−3.3296 (1982)	−3.4399 (1978)
Veracruz	−3.8705 (1964)	−3.4287 (1991)	−4.1502 (1961)
Yucatán	−4.9623*** (1979)	−4.3088*** (1977)	−4.9244*** (1979)
Zacatecas	−4.3067 (2006)	−4.2726*** (2004)	−4.2052 (2003)

Table 6 Kapetanios test with two structural breaks. *** Significant at the 1% level. *Source:* Authors' estimations

State	2 Breaks		
	DU	DT	DU + DT
Aguascalientes	− 4.8303 (1960, 1995)	− 5.7132*** (1972, 1950)	− 4.7639 (1960, 1972)
Baja California	− 4.1881 (1960, 1951)	− 5.6522*** (1972, 1981)	− 6.8141*** (1971, 1979)
Baja California Sur	− 6.3419*** (1989, 1975)	− 6.6244*** (1977, 1972)	− 8.8744*** (1975, 1985)
Campeche	− 5.313 (1981, 2005)	− 3.239 (2003, 1987)	− 5.9353*** (1981, 2001)
Coahuila	− 3.8352 (1989, 1961)	− 3.4589 (1982, 2004)	− 3.6641 (1981, 1953)
Colima	− 7.6635*** (1985, 1960)	− 5.8831*** (1970, 2002)	− 6.2042*** (1985, 1974)
Chiapas	− 5.0195 (1985, 1975)	− 3.7043 (1978, 2000)	− 5.277 (1975, 1995)
Chihuahua	− 3.8821 (1960, 1985)	− 3.3449 (1969, 1957)	− 3.3912 (1960, 2002)
Distrito Federal	− 4.9245 (1960, 1985)	− 3.8374 (1969, 1958)	− 3.916 (1960, 1946)
Durango	− 5.1026 (1960, 1980)	− 4.6948 (1984, 2004)	− 5.3285 (1989, 1975)
Guanajuato	− 4.9565 (1960, 1975)	− 4.6705 (1968, 1948)	− 6.1177*** (1975, 1946)
Guerrero	− 3.2216 (1995, 2005)	− 3.074 (1989, 1956)	− 3.6467 (1987, 1963)
Hidalgo	− 4.8832 (1996, 1964)	− 4.9412*** (1987, 1951)	− 6.1409*** (1980, 1961)
Jalisco	− 4.6342 (1995, 1980)	− 3.9229 (1987, 1977)	− 4.856 (1980, 1962)
Mexico	− 3.6794 (1995, 1950)	− 3.5178 (1987, 1977)	− 5.6385 (1980, 1950)
Michoacán	− 4.6924 (1963, 1976)	− 4.6449 (1973, 1959)	− 4.8237 (1960, 1948)
Morelos	− 4.6234 (1963, 1980)	− 3.5339 (1984, 1957)	− 3.9209 (1960, 1953)
Nayarit	− 4.4613 (1960, 1980)	− 3.4857 (1984, 2003)	− 3.8547 (1961, 1980)
Nuevo León	− 4.1822 (1964, 1981)	− 4.4361 (1983, 1957)	− 4.1632 (1960, 1947)
Oaxaca	− 4.1353 (1995, 2005)	− 4.3853 (1988, 1944)	− 5.8617*** (1981, 1951)
Puebla	− 7.0573*** (1963, 1975)	− 5.7603*** (1970, 1960)	− 6.9078*** (1963, 1974)
Querétaro	− 5.1278 (1960, 1944)	− 4.8108*** (1972, 1948)	− 4.7276 (1960, 1946)
Quintana Roo	− 4.7844 (1953, 2004)	− 3.8028 (1955, 1946)	− 5.8869*** (1950, 1989)
San Luis Potosí	− 5.0431 (1986, 1980)	− 4.1148 (1958, 1998)	− 5.3822 (1986, 1975)
Sinaloa	− 4.8185 (1980, 1964)	− 4.2888 (1955, 1994)	− 5.0215 (1961, 1983)
Sonora	− 6.2251*** (1971, 1980)	− 5.5384*** (1950, 1984)	− 6.4919*** (1971, 1979)
Tabasco	− 5.8041*** (1986, 1975)	− 3.4804 (1977, 1972)	− 7.5426*** (1975, 1996)
Tamaulipas	− 4.6351 (1991, 2001)	− 4.6563 (1984, 2005)	− 5.601 (1980, 1971)
Tlaxcala	− 5.5835*** (1961, 1977)	− 4.5895 (1982, 1955)	− 4.8206 (1978, 1960)
Veracruz	− 5.3598 (1964, 1979)	− 4.6829 (1991, 1955)	− 5.7555 (1961, 1980)
Yucatán	− 5.8676*** (1979, 1974)	− 4.7879*** (1977, 1982)	− 5.7481 (1979, 1966)
Zacatecas	− 4.5673 (2005, 1979)	− 4.5289 (2004, 1946)	− 4.925 (2003, 1979)

Table 7 Kapetanios test with three structural breaks. *** Significant at the 1% level. *Source:* Authors' estimations

State	3 Breaks		
	DU	DT	DU + DT
Aguascalientes	– 5.1262 (1960, 1995, 1945)	– 5.8518*** (1972, 1950, 2005)	– 5.6512 (1960, 1972, 1948)
Baja California	– 4.9037 (1960, 1951, 1971)	– 5.7016*** (1972, 1981, 2005)	– 7.1081*** (1971, 1979, 1953)
Baja California Sur	– 8.5682*** (1989, 1975, 1981)	– 7.4571*** (1977, 1972, 1983)	– 10.1522*** (1975, 1985, 1995)
Campeche	– 7.245*** (1981, 2005, 1990)	– 6.0148 (2003, 1987, 1978)	– 6.1186 (1981, 2001, 1987)
Coahuila	– 4.3335 (1989, 1961, 1944)	– 3.7018 (1982, 2004, 1945)	– 5.1418 (1981, 1953, 2001)
Colima	– 7.774*** (1985, 1960, 1973)	– 6.4063*** (1970, 2002, 1961)	– 6.7803*** (1985, 1974, 1995)
Chiapas	– 5.7211 (1985, 1975, 1960)	– 5.0024 (1978, 2000, 1973)	– 5.3624 (1975, 1995, 2004)
Chihuahua	– 4.2685 (1960, 1985, 1977)	– 4.7141 (1969, 1957, 2005)	– 4.9079 (1960, 2002, 1980)
Distrito Federal	– 5.9571 (1960, 1985, 1954)	– 4.8126 (1969, 1958, 2001)	– 4.2187 (1960, 1946, 2005)
Durango	– 5.1847 (1960, 1980, 1972)	– 4.6939 (1984, 2004, 1989)	– 6.2925 (1989, 1975, 1946)
Guanajuato	– 6.2572 (1960, 1975, 1999)	– 5.1802 (1968, 1948, 1977)	– 7.4668*** (1975, 1946, 1993)
Guerro	– 5.0298 (1995, 2005, 1975)	– 3.4174 (1989, 1956, 1984)	– 4.0313 (1987, 1963, 2005)
Hidalgo	– 5.7743 (1996, 1964, 1980)	– 5.1204 (1987, 1951, 2004)	– 6.7253*** (1980, 1961, 1966)
Jalisco	– 5.3104 (1995, 1980, 1975)	– 4.7026 (1987, 1977, 2002)	– 5.4986 (1980, 1962, 2005)

Table 7 continued

State	3 Breaks		
	DU	DT	DU + DT
Mexico	– 5.7516 (1995, 1950, 1980)	– 5.5325*** (1987, 1977, 1955)	– 6.0139 (1980, 1950, 1961)
Michoacán	– 5.0163 (1963, 1976, 1951)	– 5.6815*** (1973, 1959, 1978)	– 4.9726 (1960, 1948, 1966)
Morelos	– 5.0537 (1963, 1980, 1990)	– 3.9634 (1984, 1957, 1969)	– 4.1994 (1960, 1953, 1983)
Nayarit	– 5.088 (1960, 1980, 1990)	– 3.6363 (1984, 2003, 1979)	– 4.7173 (1961, 1980, 1971)
Nuevo León	– 4.8178 (1964, 1981, 1953)	– 4.8015 (1983, 1957, 1948)	– 4.1082 (1960, 1947, 1986)
Oaxaca	– 4.4945 (1995, 2005, 1945)	– 4.8146 (1988, 1944, 1980)	– 7.1336*** (1981, 1951, 1975)
Puebla	– 7.9027*** (1963, 1975, 2005)	– 7.122*** (1970, 1960, 1977)	– 7.7339*** (1963, 1974, 1979)
Querétaro	– 5.5259 (1960, 1944, 1990)	– 5.3758 (1972, 1948, 2002)	– 4.921 (1960, 1946, 1995)
Quintana Roo	– 6.586*** (1953, 2004, 1989)	– 5.1468 (1955, 1946, 2003)	– 6.5023 (1950, 1989, 1971)
San Luis Potosí	– 6.168 (1986, 1980, 1975)	– 4.5612 (1958, 1998, 1977)	– 6.6757 (1986, 1975, 1955)
Sinaloa	– 5.6839 (1980, 1964, 1986)	– 4.3029 (1955, 1994, 1969)	– 7.3918*** (1961, 1983, 1976)
Sonora	– 7.0442*** (1971, 1980, 1985)	– 5.9486*** (1950, 1984, 2005)	– 7.3085*** (1971, 1979, 2003)
Tabasco	– 7.2954*** (1986, 1975, 2005)	– 7.4576*** (1977, 1972, 1995)	– 7.6493*** (1975, 1996, 1964)
Tamaulipas	– 5.0747 (1991, 2001, 1960)	– 4.9861 (1984, 2005, 1979)	– 6.2522 (1980, 1971, 2005)
Tlaxcala	– 5.8921 (1961, 1977, 1966)	– 4.9646 (1982, 1955, 1969)	– 6.2056 (1978, 1960, 1972)
Veracruz	– 6.0138 (1964, 1979, 1948)	– 5.1624 (1991, 1955, 1969)	– 7.7091*** (1961, 1980, 1968)
Yucatán	– 6.5418*** (1979, 1974, 1985)	– 6.104*** (1977, 1982, 1972)	– 6.4444 (1979, 1966, 1952)
Zacatecas	– 4.9635 (2005, 1979, 1945)	– 4.8342 (2004, 1946, 1971)	– 6.8616*** (2003, 1979, 1947)

Table 8 Bai–Perron tests. ***, **, *Significant at the 1, and 5%, level, respectively. *Source:* Authors' estimations

	Sequential test	Break	UD Max	WD Max
Aguascalientes	0 versus 1	1962, 1997	44.90617**	64.6468**
	1 versus 2		1950, 1962, 1997	1950, 1962, 1997
	2 versus 3			
Baja California	0 versus 1	0	15.9299**	27.39048**
	0 versus 1	0	1950, 1960, 1970, 1980	1950, 1960, 1970, 1980
Baja California Sur	0 versus 1	0	7.694412**	11.71152**
	0 versus 1	0	0	1950, 1962, 1976, 1990
Campeche	0 versus 1	0	17.09745**	32.39629**
	0 versus 1	1963	1965, 1981, 1991, 2001	1950, 1966, 1981, 1991, 2001
Colima	0 versus 1		43.39117**	43.39117**
	1 versus 2		1963	1963
Durango	0 versus 1	0	9.085468**	15.62191**
	0 versus 1	0	1950, 1964, 1982, 1998	1950, 1964, 1982, 1998
Guanajuato	0 versus 1	0	250.8945**	361.187**
	0 versus 1	0	1954, 1964, 1989	1954, 1964, 1989
Hidalgo	0 versus 1	0	321.2087**	567.1446**
	0 versus 1	0	1953, 1963, 1980, 2000	1953, 1963, 1980, 1990, 2000

Table 8 continued

	Sequential test	Break	UD Max	WD Max
Mexico	0 versus 1	181, 1952, 1963	232.0216**	402.1244**
Mexico	0 versus 1		1951, 1963, 1982, 1998	1951, 1962, 1972, 1982, 1998
	1 versus 2			
	2 versus 3			
	3 versus 4			
Michoacán	0 versus 1	1966	58.49046**	90.86174**
	1 versus 2		1950, 1966, 1995	1950, 1966, 1985, 1995
Oaxaca	0 versus 1	1967	18.16142**	39.85294**
	1 versus 2		1950, 1960, 1970, 1983, 1997	1950, 1960, 1970, 1983, 1997
Puebla	0 versus 1	1964, 1950	167.7862**	241.5445**
	1 versus 2		1950, 1964, 1989	1950, 1964, 1989
	2 versus 3			
Querétaro	0 versus 1	0	1.6559**	3.633663**
			0	0
Quintana Roo	0 versus 1	0	15.35325**	26.39898**
			1954, 1973, 1991, 2001	1954, 1973, 1991, 2001
Sinaloa	0 versus 1	1981	120.057**	263.4498**
	1 versus 2		1955, 1965, 1981, 1991, 2001	1955, 1965, 1981, 1991, 2001

Table 9 Bai–Perron tests. **Significant at the 5% level. *Source:* Authors' estimations

State	Sequential test	Break	UD Max	WD Max
Sonora	0 versus 1	1979	31.71829**	41.69282**
	1 versus 2		1965, 1980	1950, 1963, 1980
	0 versus 1		24.03265**	52.73661**
Tabasco	0 versus 1	0	1953, 1963, 1976, 1989, 2001	1953, 1963, 1976, 1989, 2001
	0 versus 1		76.49902**	167.8674**
	1 versus 2		1950, 1962, 1981, 1991, 2001	1950, 1962, 1981, 1991, 2001
Tamaulipas	0 versus 1	1962	325.6674**	714.6359**
	1 versus 2		1950, 1962, 1972, 1982, 2001	1950, 1962, 1972, 1982, 2001
	0 versus 1		15.38163**	18.66231**
Tlaxcala	0 versus 1	1966, 1979	1965, 1981	1950, 1965, 1980, 1990, 2000
	1 versus 2		22.09726**	22.09726**
	0 versus 1		1980	1980
Veracruz	1 versus 2	0	4.049076**	7.197587**
	2 versus 3		0	0
	0 versus 1		0	0
Yucatán	0 versus 1	1980	1965, 1981	1950, 1965, 1980, 1990, 2000
	1 versus 2		22.09726**	22.09726**
	0 versus 1		1980	1980
Zacatecas	0 versus 1	0	4.049076**	7.197587**
	0 versus 1		0	0
	0 versus 1		0	0

Table 10 GVS test. *Source:* Authors' estimations

State	Test Statistic	5 % Critical Value	No drift	No break
Coahuila	0.852	0.93	Not rejected	Not performed
Chiapas	0.885	0.93	Not rejected	Not performed
Chihuahua	0.681	0.93	Not rejected	Not performed
Distrito Federal	0.835	0.93	Not rejected	Not performed
Guerrero	0.899	0.93	Not rejected	Not performed
Jalisco	0.79	0.92	Not rejected	Not performed
Morelos	0.764	0.92	Not rejected	Not performed
Nayarit	0.687	0.93	Not rejected	Not performed
Nuevo León	0.687	0.93	Not rejected	Not performed
San Luis Potosí	0.687	0.93	Not rejected	Not performed

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