Pair-Wise Approach to Test the Regional Convergence Hypothesis in Mexico

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Abstract: This paper assesses the gross domestic product (GDP) per capita convergence of the 32 Mexican States in the period 1940-2010 through the method proposed by Pesaran (2007), which is based on the convergence stochastic criterion. One of the main advantages of this method is not only on a model of leading economy, also on a pair-wise approach that considers all possible gap pairs of per capita logarithms of all the Mexican States analyzed in the sample. According to this method, all the differences or output gaps of the States must be stationary around a constant mean. Most results provide evidence against the hypothesis of convergence especially for the total sample from 1940 to 2010 and the first period from 1940 to 1985. However, mixed evidence of this hypothesis was observed in the second period from 1986 to 2010. Additionally, the test results applied to a set of States considered as the richest suggest these findings are not due to the unique behavior of these States.

Keywords: Unit root, Panel data models, Pair-wise test, Economic growth, Stochastic convergence.

INTRODUCTION

The question is if the GDP per capita of different countries or regions converge now or it will be in the future, it has played a central role in the empirical growth literature. In this context the concept of convergence has been used in several different contexts. One of the more frequently utilized is the beta-convergence approach, which considers the speed with the GDP of a country or region converges over time to its stationary state (Pesaran, 2007). This approach assumes a process of deterministic growth according to Binder and Pesaran (1999), which may be inappropriate if the technological progress is stochastic.

Pesaran (2009) proposes a probabilistic version of the concept of GDP convergence that does not requires that the economies which are converging be identical. This version is based on the stochastic convergence criteria proposed by Bernard and Durlauf (1995). It is said there is stochastic convergence between two per capita incomes if the differential is a stationary process around a constant.

In this sense, the divergences observed in the gaps of the GDP per capita are only a temporary or transient phenomenon and it is expected to tend to disappear in the future. Applying unit root or stationarity tests to the differential or output gap of GDP per capita has been the common way to test convergence. The presence of a unit root revealed by the test is sufficient to reject the hypothesis of convergence. However, a condition for accepting the convergence hypothesis is that the differential does not shows a deterministic trend.

Unit roots or stationarity panel tests provide the possibility to test convergence for several countries in a simultaneously fashion. But, a drawback of these methods is that they require a model of leading or average economy, which is not always clear enough, Le Pen and Sévi (2010).

Pesaran (2007) proposes to test through a new method, which main idea is to consider all the possible pairs of countries or regions and to apply either unit roots or stationarity tests on every differential or output gap.

An advantage of the pair-wise approach proposed by Pesaran (2009), unlike the cross section tests and the panel data models used to test convergence, is that its definition is more related to the concept of convergence club developed by Durlauf and Johnson (1995), Quah (1996a, b, 1997) and Galor (1996).

In this paper it was applied the pair-wise approach to the series of GDP per capita of the Mexican States in the period 1940-2010. Also, this paper is organized as follows: Section 2 provides a review of some of the main studies that have empirically addressed the issue of convergence in Mexico. Section 3 provides the

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definition of convergence as well as the econometric tests from the Pesaran (2007) proposal, used in this paper. Data and empirical results are discussed in Section 4. Lastly, Section 5 presents the conclusions.

2. REVIEW OF THE EMPIRICAL LITERATURE

The economic development of Mexico is characterized by a significant regional imbalance, reason why it is considered opportune to ask if this imbalance is new or is a constant in the economic development of the country?, Esquivel (2000). Several studies have attempted to establish the answer to this question, in what follows we will state some of them.

Among the main studies that have tested regional convergence in Mexico are Caraza-Herrasti (1993); Juan-Ramón and Rivera-Batiz (1996); Diaz-Pedroza *et al*. (2009); Esquivel (1999); Cermeño (2001); Carrillo (2001); Diaz-Bautista (2003) and Mendoza (2004). The majority of these studies agree to define two large periods, taking as an inflection point 1985, this with the aim to determine whether, from the process of trade liberalization, there has been a convergence process compared with the prior period, in which the Mexican economy remained virtually closed.

Cermeño (2001) through a panel model with restrictions on the parameters, models the GDP per capita rate of growth of the 32 Mexican States, with the aim to analyze the process of conditional convergence of 1970-2000. Their results show evidence of conditional convergence for all the States; excluding Campeche and Tabasco (oil States).

Likewise, Mendoza (2004) uses four panel models in order to test the conditional convergence between 1970-2002. According to his findings, the more consistent specification is the random-effects model, in virtue of which his parameters are more stable and show evidence of conditional convergence in the two samples considered in all the Mexican States and excluding Campeche and Tabasco, with convergence rates of 2.6 and 2.5%, respectively.

Aroca, Bosh and Maloney (2005) based on non-parametric and parametric techniques (stochastic kernel density functions, Markov transition matrices, analysis of global and local spatial dependence, with correlation coefficients of Moran and LISA) found that the process of divergence of the period 1985-2002 has been characterized by the integration of cluster (groups) which identified with traditional geographical regions. If in an analysis it is integrated a spatial dependence, then it is possible to detect the integration of States in the South, the group of States placed in the North are considered as Border States, and the identification of those placed in the center is partial.

In Sastré and Rey (2008), based on the methodology of spatial decomposition of the Theil inequality index, the temporal profile of interregional disparity and the spatial polarization analysis derivative from the Theil index, analyze several regions proposals established by others and conclude that the dispersion of income among the Mexican States is accompanied by an increase in the regional heterogeneity, suggesting that the increase in the disparity is due to a deepening regional polarization.

Carrion-i-Silvestre and Germán-Soto (2007 and 2009) utilized several techniques of time series and panel models in per capita production variables in order to analyze the stochastic process of the Mexican regional convergence at the States level. The test results show that over time economic convergence has changed with varying effects, though the changes tended to converge in most of the cases. The authors conclude that such process cannot be understood if it is not considered the structural change of the eighties.

Asuad and Quintana (2010) identified the formation of convergence clubs and diverging that the economic growth has encouraged in the Mexican States and the role and importance of the geo-spatial factors in these convergence clubs. Asuad and Quintana (2010) carried out a comparative analysis between the economic growth and the convergence hypothesis, from a cross section spatial regression model.

Their results show the existence of several processes of convergence in the States of the country, identifying the presence of convergence clubs, which tend to different steady states; maintaining the differences in the per capita income and the development of States. Also, they reveal the importance and close relationship between the geo-spatial location and the formation of convergence clubs in the economic growth of the Mexican States.

Diaz, Sánchez and Mendoza (2009) carried out unit root tests and panel cointegration tests to assess the hypothesis of convergence of the Mexican States to the Mexico City GDP in the period 1970-2004. Their results show evidence in favor of the conditional convergence; in addition, their estimates of the convergence rate indicate that the richest regions converge faster than the poor.

Rodríguez, Mendoza and Venegas (2016a) analyze the hypothesis of regional convergence in Mexico for the period 1970-2012, with data from Mendoza-González (2014), this though a nonlinear growth model and excluding the States of Campeche and Tabasco. The empirical results of the nonlinear model applied to the GDP per capita of several groups of States in Mexico suggest that the model proposed is higher to the linear model and show evidence of partial and absolute convergence for the group of 11 "richest" States, in certain periods.

On the contrary, when they analyze the convergence of the remaining States regarding the average of the richest States, no convergence evidence was found. Likewise, when the tests for all the States, excluding Campeche and Tabasco were carried out, it could not be rejected the hypothesis of divergence. These results show that convergence is present in the groups of States with similar characteristics and in specific periods, which reinforces the idea that in Mexico are convergence clubs or at least one of them.

On the other hand, Rodríguez, López and Mendoza (2016b) researched the hypothesis of convergence in the States' GDP per capita for the period 1970-2012 through a non-linear model with time-varying coefficients proposed by Phillips and Sul (2007). This method has the advantage of being extremely flexible in order to model a large amount of paths of transition to convergence, beside the these do not require a type of assumption regarding the stationarity of the series of panel data. The authors find evidence of relative convergence in six convergence clubs. Excluding or not the considered as oil States, the outcomes, and if these States are excluded, the results are practically the same.

3. METHODOLOGY

3.1. Definition of Convergence

If y_{it} the logarithm of the GDP per capita of the region i over time t, then this can be represented by:

$$y_{it} = c_i + g_i t + \theta_i' f_t + \varepsilon_{it} + \eta_{it} \tag{1}$$

where $(c_i + g_i t)$ is the deterministic component (constant and trend), while $(\theta_i' f_t + \varepsilon_{it})$ is a multifactorial model with f_t a $m \times 1$ vector of common components, θ_i is the associated vector of parameters, and ε_{it} is the specific idiosyncratic component of every country, while η_{it} is a stationary process.

The definition of Bernard and Durlauf (1995) regarding convergence on which the Pesaran (2007) proposal is based, established that the i and j countries converged if:

$$\lim_{k\to\infty} E\left(y_{i,t+k} - y_{j,t+k} \middle| I_t\right) = 0,\ \forall\ t \tag{2}$$

Where I_t is the set of information over t time, which integrates at least the current and past values of the series y_{it-s}. And replacing $y_{i,t}$ and $y_{j,t}$ by (1) in equation (2) it might be observed that countries i and j converged in the sense of Bernard and Durlauf if $c_i = c_j$ y $g_i = g_j$, and also $\theta_i = \theta_j$ in the case where $\theta_i' f_t$ it integrates a unit root, Nourry (2009). From here it might be observed that a necessary condition for the convergence of the regions i and j is that the series $y_{i,t}$ and $y_{j,t}$ are cointegrated with the cointegrating vector.

The definition of Pesaran (2007) is much loose. Regions i and j converged if for some positive C constant and a probability measure of tolerance $\pi \geq 0$,

$$\Pr\left\{\left|y_{i,t+k} - y_{j,t+k}\right| < C \middle| I_t\right\} > \pi,\ \forall\ s = 1,2,\ldots,\infty \tag{3}$$

From here it might be observed that the regions i and j converged if $g_i = g_j$ and $\theta_i = \theta_j$. In the theory of cointegration those conditions are the cointegrating and cotrending restrictions respectively. In an analysis with multiple regions, the definition is as follows: the regions $i = 1,2,\ldots,N$ are said to converge to a positive constant C if

$$\Pr\left\{\bigcap_{i=1,\ldots,N-1;\, j=i+1,\ldots,N} \left|y_{i,t+s} - y_{j,t+s}\right| < C \middle| I_t\right\} > \pi,\ \forall\ s = 1,2,\ldots,\infty \tag{4}$$

The definition of pair-wise convergence of Pesaran (2007) should be maintained for all the $N(N-1)/2$ pairs of regions under study.

The econometric test used to prove convergence in GDP per capita in the Mexican States has been proposed by Pesaran (2007), which is based on the convergence criterion of Bernard and Durlauf (1995). If

y_{it} and y_{jt} show the GDP per capita of Mexican states i and j in time t, respectively, and $d_{ij,t} = y_{it} - y_{jt}$ its differential with T as the number of observations, $t = 1,...T$. It is said that output gaps converge in the direction of Bernard and Durlauf (1995) if the differential is a process $I(0)$ around a constant, Le Pen and Sévi (2010). Thus, under the assumption of convergence it is possible to write:

$$H_c : d_{ij,t} = y_{it} - y_{jt} = c_i - c_j + \psi_{ijt} \quad \text{for all } i \neq j \tag{5}$$

Where ψ_{it} indicates a stationary process with zero mean. In the definition of Bernard and Durlauf (1995) the differential $c_i - c_j$ is equal to zero. Pesaran allows this parameter to be different from zero, which means that the differences have an upper bound in the long term. Although the definition of Pesaran (2007) is less restrictive, two both criteria imply that both GDP per capita share the same deterministic and stochastic trends.

A problem with the implementation of stochastic convergence is that conventional unit root tests cannot handle a large number of time series in the same time, Pesaran (2007). Researchers overcome this difficulty by taking as a benchmark of leading economy to a state or an average region against which the convergence hypothesis is tested, however, this causes that results depend heavily on this reference, Le Pen and Sévi (2010). The pair-wise approach proposed by Pesaran (2007) avoids this problem by considering all possible pairs of states or regions to which is applied the test. If the sample contains countries, then it is tested the convergence of $N(N-1)/2$ possible pairs of output gaps. Another aspect of Pesaran method is that differential fraction is characterized as stationary around a mean which provides evidence on the convergence. In fact, Pesaran *et al*. (2009) argue that the average rate of rejection is likely to be more robust to the possibility of an unobserved factor $I(1)$, which may induce dependence of cross section that alternative methods available.

3.2. Stationary Test

Pesaran (2007) proposes to use the test of Kwiatkowski *et al*. (1992), KPSS, stationary around a constant to test the convergence hypothesis H_c, this test has the null hypothesis of stationary series, and the rejection of this hypothesis implies the rejection of the convergence hypothesis. The pair-wise approach proposed by Pesaran (2007) is to apply the stationary test to each output gap $N(N-1)/2$ and define the binary variable $Z_{ij,T}$ which takes the value of 1 if the null hypothesis of stationary is rejected and 0 otherwise. It should be noted that the size of the stationary test, α, it is defined as the probability of rejecting the null hypothesis of stationary even if convergence is real, i.e. $\lim_{t\to\infty} P\left(Z_{ij,T} = 1 \middle| H_c\right) = \alpha$. The fraction of $N(N-1)/2$ pairs which the convergence hypothesis is rejected given by:

$$\bar{Z}_{NT} = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} Z_{ij,T} \tag{6}$$

Pesaran shows that, under the null hypothesis of convergence H_c, $\bar{Z}_{NT}$ is a consistent estimator from α to N and T, i.e.:

$$\lim_{T\to\infty} E\left(\bar{Z}_{NT} \middle| H_c\right) = \alpha \tag{7}$$

Therefore, even under compliance of the convergence hypothesis, sometimes is possible to reject the hypothesis of stationary, but this rate of rejections is expected to converge at the level of the test, Le Pen and Sévi (2010). A reject rate $\bar{Z}_{NT}$ much higher than desired level of proof it means that the rejection of convergence cannot be explained by the type I error. Here, it is possible to see that a difference between this method and a unit root test panel lies in the way how the mean of each test statistic is calculated, the pair-wise approach proposed by Pesaran is based on the average of a binary variable describing the results of each individual test. This difference in methodologies may sometimes lead to opposite results.

3.3. Unit Root Test

The pair-wise approach proposed by Pesaran (2007) also considers the application of unit root tests to output gaps $d_{ij,T}$. For this test the null hypothesis is the divergence, denoted by $\bar{H}_c$. It contains divergence if the differentials has a unit root or a deterministic trend, or both. Similarly, $Z_{ij,T} = 1$ if the unit root hypothesis is rejected and $Z_{ij,T} = 0$ in another way. In this case, $\bar{Z}_{ij,T}$ estimates the differential fraction for which the null hypothesis of a unit root and non-deterministic trend is rejected. If the convergence hypothesis is true, H_c, so $\bar{Z}_{ij,T}$ is higher than α and the unit root test converges to the unit as in $N \to \infty$ y $T \to \infty$ simultaneously.

By contrast, if the hypothesis complies not convergence $\bar{H}_c$ it is expected that $\bar{Z}_{ij,T}$ being approach to α. In this case, the rejection of the unit root hypothesis reflects the occurrence of a type I error in the test.

Le Pen and Sévi (2010) argue that the Pesaran´s test (2007) is more robust than the unit root tests or stationary panel at least three reasons: i) the choice of a benchmark against one which generally the convergence is tested; ii) the fraction of the stationary differentials provides information on how these should be interpreted, if it is low it is likely that the result of gaps being only the effect of a type I error in the unit root tests, however, the fraction is high, the stationary gaps cannot be explained by a statistical error and then are thus evidence of the underlying convergence process; and iii) each differential is modeled separately and has its own dynamics under which the method is not based on an assumed average modeling behavior.

4. ECONOMETRIC RESULTS

The data used in this research is the GDP and population of 32 Mexican States during the period 1940-2010, both data provided by German-Soto (2005) and German-Soto (2015), respectively, from which the GDP per capita was obtained.

The unit root tests are applied to gaps of all pairs of per capita income of the 32 States in natural logarithm of the complete sample, which is consider the period from 1940 to 2010. Table **1** shows the percentages of pairs for which it is rejected the hypothesis of the unit root levels of significance of 5 and 10%, with tests $ADF(p)$, and $ADF-GLS(p)$ $ADF-WS(p)$ with the lags number (p) determined by the information criteria of Akaike (AIC) and Schwarz (SC). As it is discussed above, in the case of tests ADF the proportion of stationary pairs is expected to be close to the level of significance of the test under the hypothesis of non-convergence, $\bar{H}_c$. The sample consists of 32 States of the Mexican Republic or 496 differential pairs or output gap of GDP per capita. According to the results of the various tests ADF applied, there is no evidence of convergence for the sample comprising the entire period reviewed because the proportion of rejections of the null hypothesis of the unit root are slightly above the level of significance of the test, which is more evident at the level of significance of 5% in the test version of Park and Fuller (1995): $ADF-WS(p)$ only an intercept and in the case of statistical $ADF-GLS(p)$ proposed by Elliot *et al*. (1996) with the same level of significance incorporating intercept and linear trend. While the proportion of rejections that is most closely to the significance level of 10% are the statistical $ADF-WS(p)$ under both test specifications: with an intercept and trend.

Table 1: Proportion of output gap pairs for which the unit-root hypothesis is rejected

Case II: An Intercept Only		
Sample period	1940-2010 ($T=71$)	
Number of States	$N=32$	
Number of pairs	496 pairs	
Test (significance level) (%)	5	10
$ADF(p)$		
$p(AIC)$	0.09879	0.16532
$p(SC)$	0.11290	0.16129
$ADF-GLS(p)$		
$p(AIC)$	0.09879	0.19556
$p(SC)$	0.08468	0.16331
$ADF-WS(p)$		
$p(AIC)$	0.07460	0.14113
$p(SC)$	0.07661	0.11895
Case III: An Intercept and a Linear Trend		
Sample period	1940-2010 ($T=71$)	
Number of States	$N=32$	
Number of pairs	496 pairs	
Test (significance level) (%)	5	10
$ADF(p)$		
$p(AIC)$	0.13306	0.19355
$p(SC)$	0.15524	0.21169
$ADF-GLS(p)$		
$p(AIC)$	0.06855	0.12298
$p(SC)$	0.07863	0.12903
$ADF-WS(p)$		
$p(AIC)$	0.07056	0.11694
$p(SC)$	0.07863	0.12500

Furthermore, the KPSS test also provides support for the non-convergence hypothesis for the entire period of analysis, 1940-2010, which the proportion of pairs that rejects the null hypothesis of stationary is greater than 74% (mean stationary) and greater than 81% (trend stationary) as it can be seen in Table **2**.

Table 2: Proportion of Output Gap Pairs for which the Stationary Hypothesis is Rejected (Mean or Trend Stationary)

Sample period	1940-2010 ($T=71$)	
Number of States	$N=32$	
Number of pairs	496 pairs	
Test level (%)	5	10
Mean stationarity		
$l=3$	0.74395	0.83871
Trend stationarity		
$l=3$	0.81250	0.89113

In order to validate results of previous studies reporting convergence in the period prior to 1985 through the test with pairs approach, were applied tests on gaps of GDP per capita in both periods of 1940-1985 and 1986-2010, the results are presented in Table **3** to the various tests ADF and Table **4** the test of $KPSS$. Unlike the results found by the ADF tests in the total sample, in this case the proportion of pairs for which the hypothesis of the unit root is rejected are much closer to the levels of significance of 5 and 10% and even in some cases they are lower, as the case of tests $ADF-GLS(p)$ with intercept only. While in these tests with an intercept and linear trend approach significantly to the significance levels as it is the case of the test: $ADF-WS(p)$. In this way, the test ADF neither provide support to the convergence hypothesis in the first period. In the same way, the test $KPSS$ does not support this result for this period because the proportion of pairs that rejects the null hypothesis of stationary is greater than 68% (mean stationary) and greater than 64% (trend stationary) as follows in Table **4**.

Similarly, the last two columns of Tables **3** and **4** show the test results ADF y $KPSS$, respectively, under the pairs approach for the second period of the included sample from 1986 to 2010. For this period, the percentage of pairs for which the hypothesis of the unit root is rejected is also relatively small, especially in the case of proof $ADF-WS(p)$ de Elliot *et al*. (1996) at both levels of significance only with an intercept. The results in the same direction are provided by the KPSS test and the proportions of per capita output gaps for which the stationary hypothesis is rejected are relatively high. However, paradoxically the test results of $ADF(p)$ show the highest percentages of the whole test. Thus, in this research there is mixed evidence about the convergence hypothesis for this second period of analysis.

Finally, the tests were applied again for a subset of the ten richest Federative States; Aguascalientes, Baja California Sur, Campeche, Coahuila, Mexico City, Nuevo Leon, Queretaro, Quintana Roo, Sonora, Tabasco. This set contains a number of States also selected by Rodriguez Mendoza and Venegas (2016) as the richest States. The unit root tests with intercept at significance level of 5% cannot be concluded whether there is convergence for the richest States in the first period of analysis, while for the significance level of 10% for the same period the evidence does not support the convergence hypothesis. Similarly, neither is a clear trend towards convergence in these States in the second period, however this is most evident at the significance level of 5% for the second period, as four of the six tests of unit root intercept reject the null hypothesis.

Regarding to the *ADF* tests applied with intercept and linear trend is greater evidence of convergence in the first period as the proportion of rejections of the null hypothesis of the unit root are slightly higher than the significance level of 5% in all cases and four of the six cases the significance level of 10%. About the results of the *ADF* test with intercept and trend for the second quarter, the results do not show evidence of convergence for all rich States. Thus, it was found evidence of convergence for the richest States in the first period of analysis when the test is applied with intercept and trend.

Analogously to the results of tests applied for all the States, the KPSS test neither provides support for the convergence hypothesis for the richest States in both periods, because the proportion of pairs which rejects the null hypothesis of stationarity is greater than 64% (mean stationarity) and greater than 57% (trend stationarity) in the first period and greater than 31% (mean stationarity) and 82% (trend stationarity) as shown in Table **6**.

With these results, it is not possible to conclude that the evidence of convergence in the second period for all States of the Mexican Republic is due only to the richest States, because these results are not reinforced by those which were found to apply the same tests to the richest States of the Mexican Republic in the same periods in which was divided the time horizon

Table 3: Proportion of Output Gap Pairs for which the Unit-Root Hypothesis is Rejected

Case II: An Intercept Only				
Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 258$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test (significance level) (%)	5	10	5	10
$ADF(p)$				
$p(AIC)$	0.07863	0.11492	0.10081	0.17137
$p(SC)$	0.08871	0.12500	0.07863	0.15524
$ADF-GLS(p)$				
$p(AIC)$	0.05444	0.09476	0.08266	0.14718
$p(SC)$	0.06855	0.10685	0.06452	0.12298
$ADF-WS(p)$				
$p(AIC)$	0.03629	0.06250	0.06048	0.09476
$p(SC)$	0.04839	0.07258	0.04435	0.06855
Case III: An Intercept and a Linear Trend				
Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 25$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test (significance level) (%)	5	10	5	10
$ADF(p)$				
$p(AIC)$	0.09073	0.14516	0.22581	0.29032
$p(SC)$	0.11089	0.16935	0.21371	0.26008
$ADF-GLS(p)$				
$p(AIC)$	0.07258	0.11694	0.09677	0.17742
$p(SC)$	0.08669	0.12500	0.08468	0.14718
$ADF-WS(p)$				
$p(AIC)$	0.06653	0.08871	0.11089	0.18347
$p(SC)$	0.07863	0.10484	0.09073	0.14315

Table 4: Proportion of Output Gap Pairs for which the Stationary Hypothesis is Rejected (Mean or Trend Stationary)

Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 25$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test level (%)	5	10	5	10
Mean stationarity				
$l = 2$	0.67944	0.77016	0.53226	062702
Trend stationarity				
$l = 2$	0.63508	0.77218	0.64718	0.75000

Table 5: Proportion of Output Gap Pairs of the Richest Mexican States for which the Unit-Root Hypothesis is Rejected

Case II: An Intercept Only				
Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 25$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test (significance level) (%)	5	10	5	10
$ADF(p)$				
$p(AIC)$	0.06667	0.06667	0.17778	0.17778
$p(SC)$	0.08889	0.08889	0.13333	0.15556
$ADF-GLS(p)$				
$p(AIC)$	0.06667	0.13333	0.04444	0.13333
$p(SC)$	0.04444	0.08889	0.02222	0.06667
$ADF-WS(p)$				
$p(AIC)$	0.04444	0.06667	0.04444	0.08889
$p(SC)$	0.04444	0.04444	0.02222	0.04444
Case III: An Intercept and a Linear Trend				
Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 25$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test (significance level) (%)	5	10	5	10
$ADF(p)$				
$p(AIC)$	0.08889	0.08889	0.15556	0.17778
$p(SC)$	0.13333	0.13333	0.13333	0.15556
$ADF-GLS(p)$				
$p(AIC)$	0.06667	0.11111	0.00000	0.00000
$p(SC)$	0.11111	0.17778	0.00000	0.00000
$ADF-WS(p)$				
$p(AIC)$	0.06667	0.08889	0.00000	0.02222
$p(SC)$	0.11111	0.13333	0.00000	0.02222

Table 6: Proportion of Output Gap Pairs of the Richest Mexican States for which the Stationary Hypothesis is Rejected (Mean or Trend Stationary)

Sample period	1940-1985 ($T = 46$)		1986-2010 ($T = 25$)	
Number of States	$N = 32$		$N = 32$	
Number of pairs	496 pairs		496 pairs	
Test level (%)	5	10	5	10
Mean stationarity				
$l = 2$	0.64444	0.73333	0.31111	0.44444
Trend stationarity				
$l = 2$	0.57778	0.77778	0.82222	0.88889

analyzed. From the above it can be deduced that the patterns of convergence followed by the Mexican States is more complex under it is not possible to identify a clear and linear pattern from the analysis of the richest States or that this is due only the richest States, so, it is required further research on this subject.

CONCLUSIONS

In this paper we utilized a pair-wise test to assess the hypothesis of convergence of the gaps of the GDP per capita of the 32 Mexican States and a subset of Mexican States considered the richest. The method applied tested whether every of the gaps of the GDP per capita integrates or not a deterministic or stochastic trend.

One of the main advantages of this method is to consider all possible differentials or output gap of GDP per capita which can be integrated with the States' information, the outcomes do not depend on a reference of leading economy, generally an economy or large region with an outstanding development or the regional average. When considering the outcomes of all the gaps of the possible GDP per capita, the method provides some robust results in the sense that this allows to have a clearer idea of the behavior of every possible relationships between the regions under study.

In general terms, we found any evidence of convergence when applying the tests to the entire period under study, 1940-2010, neither in the first period, 1949-1985; paradoxically to the findings of other empirical studies on the subject in which it is reported the evidence of convergence in this latter period. However, we found mixed evidence of convergence in the second period analyzed, i.e. from 1986 to 2010. By contrast, the tests applied to the richest Mexican States showed signs of convergence only for the first period of analysis, 1940-1985, and found non-evidence of convergence for the second period, 1986-2010. This allows to deduce that the evidence of convergence found for the second period with all States is not due exclusively to the group of the richest States. However, it is also necessary to say that the choice of these States was arbitrary as the ten richest States, so it is not completely rule out the possibility that some smaller subset of States show a larger pattern of convergence.

We considered that this mixed evidence found regarding the hypothesis of convergence it can be attributed to the possible presence of complex convergence phenomena, which may occur at certain periods and in certain specific groups or convergence clubs, as works like Asuad and Quintana (2010), Rodriguez Mendoza and Venegas (2016a) and Rodriguez, Lopez Mendoza (2016b), among others established. In fact, it is recognized that the pair-wise tests outcomes may be precisely due to the presence of these convergence clubs and geographical factors, among others, so a further research about this subject is necessary.

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