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REGIONAL OUTPUT CONVERGENCE IN MEXICO[*]

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We examine the behavior of output disparities of Mexican regions relative to the richest region, the Capital, during the period 1940-2009, and the dynamics of the output gap series of the U.S.-Mexico border region. Our estimations suggest that whilst other Mexican regions have been catching up with the Capital region, the Mexican border region has lagged behind its U.S. counterpart. Moreover, we find evidence that the economic liberalization reforms of the 1980s negatively affected the output gap of most regions, without reverting the catching-up process. The border region is a notable exception, where the reforms actually accelerated the catching-up process.

JEL classification: O10, O40, R1

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1. INTRODUCTION

Since Bernard and Durlauf's (1996) seminal paper, the empirical study of the convergence hypothesis has relied on unit-root and cointegration tests to obtain evidence in favor of or against the predictions of economic theory. Bernard and Durlauf argued that the traditional cross-sectional notion of convergence is weaker than the time-series notion of convergence, among other things because it does not allow differentiation between the case of convergence and that of catching-up. The time-series approach allows for the following potential outcomes: catching-up or stochastic convergence (the weaker definition of convergence), convergence or deterministic convergence (the stronger definition of convergence), and divergence.[1] In this setting, the researcher is interested in analyzing the statistical properties of

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1. These cases will be formally defined in Section 3.

the difference in per capita output series to examine how one economy is performing relative to another—usually a richer one—or relative to a group of economies.

Several studies applied to Mexico analyze the convergence hypothesis. Most of these use the traditional β-and σ-convergence (cross-sectional) approach of Barro and Sala-i-Martín. The latter precludes them from (i) analyzing the regional output pattern over an extended period of time and (ii) examining potentially relevant trend shifts within the period. Moreover, under the notion of cross-sectional convergence, evidence of a negative relationship between growth rates and initial output levels cannot be taken as evidence of output convergence; instead, it merely conveys the idea of catching up (Bernard and Durlauf, 1996). The study of regional growth dynamics within a time-series framework offers insight into the experience of individual regions, given that this type of test analyzes the difference in per capita output between a pair of economies, thus enabling the individual characteristics of growth dynamics for each region to be identified.

This paper examines the behavior of the output disparities of several Mexican regions relative to the richest, the Capital region, in order to study the validity of the convergence hypothesis. We characterize the statistical properties of these time series. Furthermore, the inclusion of structural breaks allows us to identify relevant shifts in the evolution of the output gap and to relate these to significant economic events. By doing so, we are able to identify the effect of the Mexican reforms of the 1980s (which other studies find important), as well as other points in time when the convergence process changed significantly during the period under analysis.

It is important to mention that we aim to obtain an adequate statistical representation of the evolution over time of the output gap. In order to do so, we applied different econometric time-series techniques. The methods employed are not intended to reveal the causes or sources of the behavior of the output gap. Nevertheless, the discussion of the results (the behavior of the output gap and changes in it) has been related to the economic policy changes that occurred in the country, especially those of the 1980s.

The remainder of the article is organized as follows: Section 2 presents a review of the literature concerning the studies applied to Mexico. Section 3 briefly reviews the characteristics of the different potential results in the study of the convergence hypothesis in a time-series

setting. Section 4 shows the data and defines the regions analyzed in the study. Section 5 presents the empirical results. Finally, Section 6 outlines the main conclusions.

2.   LITERATURE ON OUTPUT CONVERGENCE IN MEXICO

Studies of the output convergence hypothesis as applied in Mexico (see Esquivel, 1999 and Chiquiar, 2005, *inter alia*) have found evidence in favor of output convergence. This evidence is stronger for the 1940s, 1950s, 1960s, and 1970s, and weaker after the 1980s. Such studies usually conclude that Mexico's trade reforms modified the existing growth dynamic until the 1980s. Their results are consistent with a catching-up process in which a structural break occurred.

Esquivel (1999) finds evidence of β–convergence among Mexican states for the period 1940-1995. He performs an analysis of the convergence hypothesis for the whole period and for different subperiods: 1940-1960, 1960-1980 and 1980-1995. His results suggest that the convergence process was strongest during the subperiod 1940-1960; thereafter it diminished, though it remained significant during the period 1960-1980, before becoming not statistically significant between 1980 and 1995.

Chiquiar (2005) and Rodríguez and Sánchez (2002) show that after the mid-1980s, β-and σ-convergence among Mexican regions was lost following economic liberalization. They argue that trade reforms negatively affected poor regions because these were unable to take advantage of the new source of growth that international trade offered due to their limited infrastructure and human capital endowments. In particular, they find that the regions closer to the U.S.-Mexico border seem to have obtained most of the benefits of the reforms.

The Mexican liberalization process can be traced back to 1983, after a disequilibrium in the balance of payments that led the government to declare a moratorium on debt payments. The process of liberalization included a wide range of policies, with those affecting the country's foreign trade being among the most important. Mexico began to move away from import substitution policies towards a more open economy; it joined the General Agreement on Tariffs and Trade (GATT) in 1986 and actively pursued and secured numerous free trade agreements. The reforms also included a tariff reduction program designed to promote external competition; the elimination of existing licenses;

the gradual elimination of official prices for imports and exports; and the establishment of incentives for foreign countries in the form of fiscal and trade credits in order to promote Mexico's exports. By 1998, liberalization in the manufacturing sector was complete, whereas the agricultural and services sector remained closed. When the North American Free Trade Agreement (NAFTA) came into effect in 1994, it pushed liberalization to a new level (a new round of tariff elimination). In this phase the agricultural sector was gradually liberalized and was expected to be fully liberalized by 2010. According to the International Monetary Fund (IMF), as of 2009, Mexico had signed agreements with 49 countries, granting Mexico's export industry access to more than 1.09 billion consumers. Similarly, whereas Mexico's trade-weighted average tariff in 1985 was 23.5 percent, by 2010 the average tariff had decreased to 6.1 percent.

3.   DEFINING CONVERGENCE IN THE TIME-SERIES APPROACH

Bernard and Durlauf (1996) proposed two definitions of convergence (see cases a) and b) in Definition 1, below) based on the permanence of contemporaneous output differences. These definitions represent the implications of the neoclassical growth model when the economies under study have identical savings rates, population growth rates, production functions, and probability distribution of shocks.[2] All these assumptions can be made in our case study, i.e., the analysis of convergence among regions of the same country.

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2. It is important to note that β-convergence and σ-convergence were conceived as an empirical evaluation of the Solow model. Endogenous growth models establish theoretical grounds for the opposite prediction, i.e., non-convergence between poor and rich economies due to difficulties in the transfer of technology, the stock of effective skills, and the lack of a quantitative, analytical mentalité" (see Howitt and Mayer-Foulkes, 2005: 149-150 for a more detailed explanation). Quah (1997) and Canova (2004) find evidence in favor of convergence clubs, the latter using a predictive-density approach. In earlier work, Quah (1996) argues that catching-up evidence (using β-convergence) may be due, at least partially, to spurious inference provoked by a unit root. He provides insight into this using a data set of countries. However, when this methodology is applied to U.S. states, he does not find evidence of such income polarization/convergence clubs. In the words of Durlauf (1996), the literature related to convergence clubs represents "[...] an alternative approach to studying the evolution of a population of economies. [...] [it is argued that] the behaviour of any such population needs to be studied as the evolution of an entire distribution, rather than through a cross-section regression which looks for average behaviour in the cross-section. Such a consideration is particularly important if one is interested in the behaviour of very poor versus very rich economies, for example. Quah outlines a number of ways of studying the evolution of cross-sections, and concludes that conventional convergence findings can mask the presence of convergence clubs and the polarization of a population into rich and poor." The convergence club, a concept first suggested by Baumol (1986), states that "countries [are] catching up with one another but only within particular subgroups (Quah, 1997: 28), or, simply stated: "the poor getting poorer and the rich richer, with the middle class vanishing" (Quah, 1996: 1354).

From the perspective of the empirical work so far undertaken, the outcomes of the convergence analysis depend upon the statistical properties of the following time series:

$$y_t = x_{i,t-1} - x_{j,t} \tag{1}$$

where $x_{i,t}$ and $x_{j,t}$ represent the log of real GDP per capita in economies i and j at time t, respectively. Consequently, empirical studies focus on applying econometric techniques in order to identify which data-generating process (DGP) best suits the series under analysis. So far, the literature that has empirically analyzed the hypothesis of convergence has considered the following potential results:

Definition 1

a)   *Long-run convergence:* the log difference in per capita GDP between economies i and j is mean-stationary, i.e., the reductions (increases) in per capita output differences have ended. The output disparity series remains stable over time.

b)   *Catching-up (lagging-behind):* the series under analysis is stationary around a negative (positive) deterministic trend, i.e., there is a tendency for the difference in per capita output to narrow (widen) over time.

c)   *Loose catching-up (loose lagging-behind):* the weaker notion of catching-up (lagging-behind) arises if the series under examination contains both a negative (positive) deterministic trend and a stochastic trend simultaneously. This case implies that the reduction (increase) in the GDP gap is unsteady but inexorable.[3]

d)   *Divergence:* the output gap series follows a random walk, i.e., per capita output difference is unpredictable.

In the table below we summarize how to interpret each case according to the statistical properties of the time series.

The aim of this work is to fully characterize the difference in the per capita output series of the regions of interest using econometric tools and to infer whether the regions within Mexico (and the U.S. Border

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3. The outcome "loose catching-up (loose lagging-behind)" was proposed by Gómez-Zaldívar and Ventosa-Santaulària (2010a). They argue that this possible outcome, overlooked in studies that analyze the convergence hypothesis, allows the result of divergence to be rejected more frequently.

Table 1.   Relevant DGP when analyzing convergence from a time-series perspective

DGP	Interpretation	Representation
1	Divergence	$y_t = y_{t-1} + y_{yt}$
2	Long-run Convergence	$y_t = \mu_y + u_{yt}$
3	Catching-up or Lagging-behind*	$y_t = \mu_y + \beta_y t + u_{yt}$
4	Loose Catching-up or Loose Lagging-behind**	$y_t = Y_0 + \mu_y t + \sum_{i=1}^{t} u_{yi}$

Source: Bernard and Durlauf (1996) and Gómez-Zaldívar and Ventosa-Santaulària (2010a).
* Catching-up: where $\beta_y < 0$; Lagging-behind: where $\beta_y > 0$.
** Loose Catching-up: where $\mu_y < 0$; Loose Lagging-behind: where $\mu_y > 0$.
The process u_y satisfies the conditions stated by Phillip's (1986: 369) lemma, with the variance σ_y^2, long-run variance λ^2, and autocovariances ϱ_{yi} for $i=1,2,...$

region, as defined in Table 2) are catching up, diverging or have already converged towards the richest region in the country.

5.   DATA

The data set employed in this study consists of the per capita gross regional product (GRP) series for 1940–2009 of the various Mexican regions.[4] All states are included in one of the regions described in Table 2 and the map in Appendix A.[5] We use the same regional partitions used in previous papers to make the results comparable.

For the analysis of the U.S. Border region, we compute the GRP of those states that share a border with Mexico. Annual GRP for the period 1963-2006 was constructed from data taken from the Bureau of Economic Analysis. Figures 1 and 2 show the evolution of the per capita output gap series.[6]

In general, we can assert that the output gap has been decreasing throughout the period analyzed, except during the 1950s, when it increased; nevertheless, the dynamic has not been homogeneous across

4. The series were constructed from data obtained from the Economic Information Bank (BIE) of Mexico's National Institute of Statistics and Geography (INEGI).

5. The empirical analysis also includes a region labeled 4b (Region 4, adjusted to exclude Campeche and Tabasco). Related studies have mentioned that these two states may bias the convergence analysis, since a very large portion of their output is generated through the exploitation of oil reserves.

6. The series shown in Figure 1 are the log difference of per capita output between the Capital and each of the regions. The series in Figure 2 is the log difference of per capita output between the U.S. Border region and the Mexican Border region.

Table 2.   Regions

| Region		States
1	Capital	Federal District and State of Mexico
2	Center	Hidalgo, Morelos, Puebla and Tlaxcala
3	Northern-center	Aguascalientes, Durango, Guanajuato, Querétaro, San Luis Potosí and Zacatecas
4	Gulf	Campeche, Quintana Roo, Tabasco, Veracruz and Yucatán
4b	Gulf-adj	Quintana Roo, Veracruz and Yucatán
5	Mexican Border	Baja California, Chihuahua, Coahuila, Nuevo León, Sonora and Tamaulipas
6	Pacific	Baja California Sur, Colima, Jalisco, Nayarit and Sinaloa
7	South	Chiapas, Guerrero, Michoacán and Oaxaca
8	U.S. Border	Arizona, California, New Mexico and Texas

Source: Esquivel (1999).

Figure 1. Per capita output gap relative to the Capital region
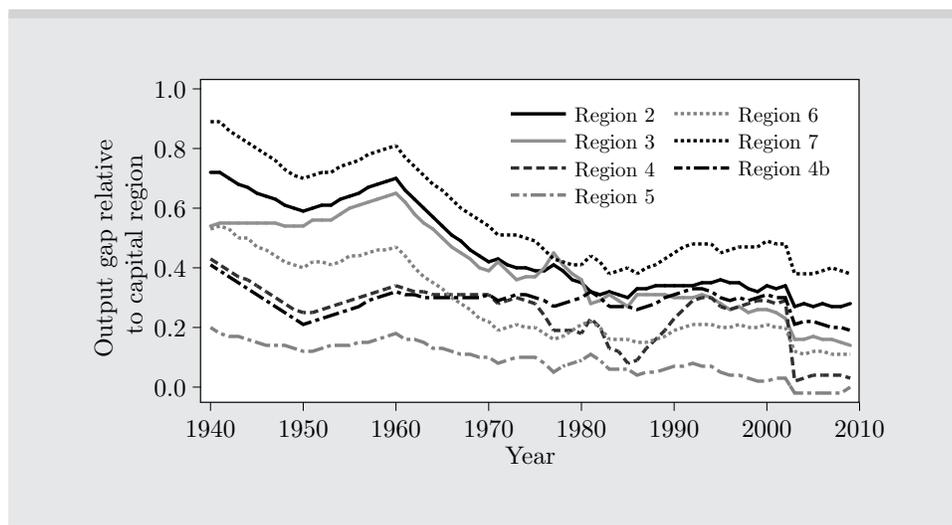
regions. It would appear that the output gap stopped decreasing (or even increased) after the mid-1980s, mainly in regions 2, 3, 4, 6, and 7. The behavior of the disparity between the Capital region and the Mexican Border region (Region 5) does not seem to experience any modification in its tendency to decrease throughout the entire sample period.

In the case of the border regions, the output difference increased persistently up to the late 1980s, when the gap seemed to reach its peak. After that date, it has appeared to fluctuate around that level.

Figure 2. Per capita output gap between border regions
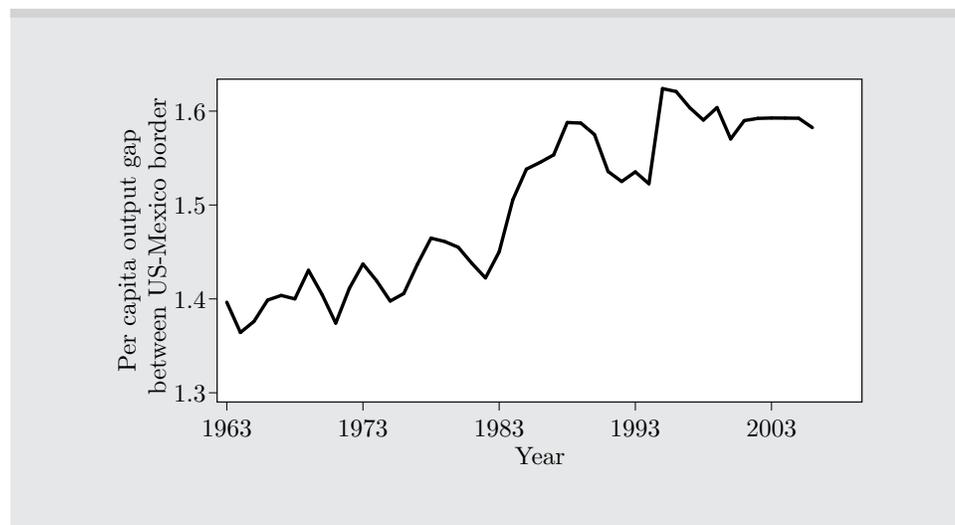
6.   EMPIRICAL RESULTS

The study of the convergence hypothesis within a time-series framework can be neatly summarized in the identification of the trending mechanism governing the output gap. Doing so requires first gathering evidence of whether such trending mechanism is stochastic or deterministic. We first apply two unit-root tests, the augmented Dickey-Fuller (ADF) test and the $MZ_\alpha/MZ_t/MSB/MPT$ test, developed by Ng and Perron (2001).[7] We present the results in Table 2. The first seven columns show the results of these tests applied to the per capita output difference between the Capital and each of the other regions, while the last column corresponds to the per capita output difference between the U.S. Border region and the Mexican Border region.

There is strong evidence against the hypothesis of divergence/loose catching-up/loose lagging-behind for regions 4 and 5 only, whilst there is no such evidence for regions 2, 3, 6, 7, 4b, and the two Border regions. For Region 4 (Gulf), there is neither a unit-root nor a deterministic trend; this implies convergence between Region 4 and the Capital region, given that the output gap can be regarded as a mean-stationary

7. All the test regressions include a constant and a deterministic trend; the number of lags to control for autocorrelation was selected using the Schwarz Information Criterion. The Ng and Perron test is designed to overcome size distortions and low power problems.

process.[8] Moreover, our results suggest that the latter mean is positive and different from zero, which implies that their output levels are different. For Region 5 (Mexican Border), our results suggest that the output gap behaves as a trend-stationary process with a negative trend, which suggests a catching-up relationship. The trend parameter ranges from -0.0011 to -0.0021 and is statistically significant. This implies that Region 5 is catching up with the Capital region at a rate of somewhere between 1 and 2% a year during the period under analysis.

Table 3. Standard unit-root tests

Tests	Regions							
	2	**3**	**4**	**5**	**6**	**7**	**4b**	**Borders**
ADF	-1.705	-2.953	-4.000**	-3.285*	-1.622	-1.410	-2.087	-2.452
MZ_α	-7.840	-7.492	-15.404*	-18.294**	-5.237	-5.377	-8.913	-11.498
MZ	-1.907	-1.929	-2.722*	-3.015**	-1.501	-1.503	-2.095	-2.380
SB	0.243	0.257	0.176*	0.164**	0.286	0.279	0.235	0.207
MPT	11.811	12.174	6.232*	5.035**	16.964	16.522	10.283	8.011

Source: Authors' estimations.
The numbers presented are the t-statistics of the autoregressive term parameter.
The symbols *, **, and *** denote rejection of the null hypothesis of unit root at the 10%, 5%, and 1% level, respectively.

For regions 4 and 5, for which we already found evidence of (trend) stationarity, we perform additional tests that allow for breaks in the deterministic trend or in the mean of the series to fully characterize the convergence process.[9] The results show, on the one hand, that the output gap between the Capital Region and Region 4 is mean stationary with three breaks in the mean of the series (see Figure 3), occurring in 1949, 1975 and 1989. The mean of the series had been decreasing from 1940 to 1988; it fell by almost 14% in 1949, declined again by 50% in 1975, and finally increased almost 31% in 1989. This is in accordance with the results of previous studies that suggest that the economic reforms of the 1980s appear to have had a negative impact on this particular region; this is revealed by the increase in the output gap, the first in 50 years, only a few years after the reforms started.

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8. The evidence in favor of deterministic components has been somewhat overlooked in the output covergence literature. This is paradoxical, considering that deterministic trends dominate asymptotically stochastic trends. Further insight may be found in Gómez-Zaldívar and Ventosa-Santaulària (2010b), in which the role of deterministic components in unit-root tests is studied.

9. These tests (Bai and Perron, 1998, 2003) are appropriate only if the series do not contain a stochastic trend. A more detailed explanation of the testing procedure can be found in Appendix B.

Figure 3. Per capita output gap between the Gulf region and the Capital

Figure 4. Per capita output gap between the Mexican Border region and the Capital
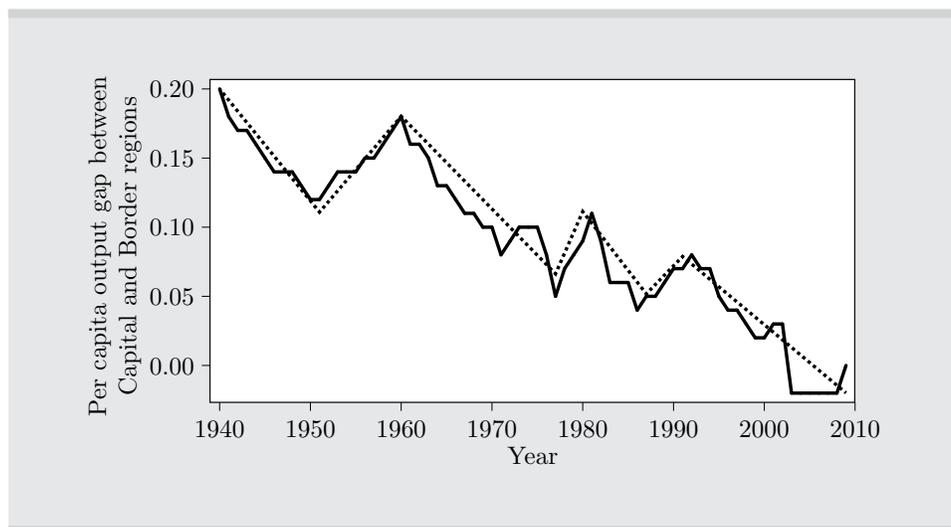
In contrast, the results imply that the output gap series of Region 5 can be represented as stationary with five structural breaks on the deterministic trend. Except for the period from 1951 to 1961, when the gap increased, in all other segments the gap decreased (see Figure 4). Moreover, this method calculates the rate at which Region 5 closes

the gap that had been increasing; the estimated parameter of the deterministic trend went from -0.0113 in the period 1961-1976 to -0.0118 in the period 1977-1991 and to -0.0122 in the period after the economic reforms. These estimations seem to support the hypothesis that the Mexican Border region benefited from the reforms. These findings are in line with Chiquiar (2005: 273), who argues that, after 1985, "only some of the relatively richer states had appropriate infrastructure to take advantage of the new sources of growth derived from enhanced opportunities to trade. In particular, the regions that are closer to the U.S. border seem to have reaped most of the benefits from the reforms."

As for the remaining series (regions 2, 3, 4b, 6, 7, and the Border regions), the standard unit-root tests were not able to reject the unit-root hypothesis. This might be due to structural shifts in the convergence/catching-up pattern not considered in the testing procedure. Therefore, we employ unit-root tests that allow structural breaks for the regions for which we were unable to find evidence against unit root. Allowing for breaks is particularly important given that we are analyzing data relating to an extended period of time where there could be discontinuities in the convergence process of some of the regions. As pointed out by Perron (1989), the existence of structural breaks biases the results of unit-root tests towards the non-rejection of the null hypothesis. Therefore, we use a data-dependent method in which the break points are determined endogenously. The results of the Kapetanios (2005) test, Model B, are shown in Table 3. Regions 4 and 5 have been excluded, since previous tests already rejected the unit-root hypothesis. A more detailed explanation of the Kapetanios testing procedure can be found in Appendix C.

The first row of Table 4 shows the *t*-statistics associated with the autoregressive term, t_α. According to the results, it is possible to reject the null hypothesis of unit root (divergence) for regions 2, 3, 7, 4b, and the Border regions. The difference in per capita output with respect to the Capital Region and regions 3 and 6 seems to contain a stochastic trend. The results in the third row reveal that the overall trend of the output gap is decreasing in regions 2, 7, and 4b in the period being analyzed. Rows 4 to 6 show the estimates of the trend and date breaks. In general, the trend becomes more negative in the late 1950s (early 1960s); this implies that regions closed the gap faster from then on. Furthermore, there are positive trend breaks (regions 2 and 7) during the 1980s that imply that the output gap started

Table 4.   Unit-root tests with endogenous break points

Parameter		Regions					
		2	3	6	7	4b	Borders
t_α		-7.9298***	-4.3693	-4.9182	-6.8370***	-5.7282***	-5.8060***
μ_0		0.5925	—	—	0.5279	0.2812	6.0446
μ_1		-0.0036	—	—	-0.0042	-0.0136	0.0146
φ_1		-0.0177 (1960)	—	—	-0.0152 (1958)	0.0164 (1950)	0.0313 (1983)
φ_2	(Break dates)	0.0131 (1982)	—	—	0.0131 (1984)	-0.0029 (1964)	-0.0360 (1996)
φ_3		-0.0043 (2001)	—	—	-0.0082 (2001)	-0.0077 (2001)	—
# of Lags		9	6	8	9	3	8
Wald Joint test		0.0000			0.0015	0.0000	0.0024

Source: Authors' estimations.
The symbol *** denotes rejection of the null hypothesis of unit root at the 1% level.

to increase at that stage. This is comparable to what related papers have found. Mexico's reforms led to a divergent dynamic in per capita output levels, in which poor regions interrupted their convergence process relative to the Capital Region. Nevertheless, by the end of the 1990s the convergence process had begun anew.

We have found that the trend of the relative output gap is decreasing (negative) with structural breaks (some positive and some negative). We test whether it is possible to say that the trend plus all the trend breaks are equal to zero. The results of the Wald tests, shown in the last row of Table 4, indicate that it is possible to affirm that $\mu_1 + \varphi_1 + \varphi_2 + \varphi_3 \neq 0$. In other words, the sum of all breaks and the determinative trend is found to be negative. This reveals that regions 2, 7, and 4b are catching up with the Capital Region.

Finally, the economic intuition described above is similar for the border regions. In this case the estimate of the trend is positive, which implies that the output gap is increasing over the whole period, i.e., the Mexican Border region is lagging behind the U.S. Border region. Similarly, it seems that Mexico's reforms negatively affected the divergence process relative to the U.S. Border region because it increased during the 1980s but decreased again in the final years of the past century. The Wald test reveals that the sum of the trend and its breaks is positive; i.e., for the overall period the Mexican Border is lagging behind its U.S. counterpart.

For regions 3 and 6, for which it is not possible to reject the hypothesis of unit root, we employ a recently developed statistical procedure to analyze whether these regions diverge or follow a loose catching-up/ lagging behind process. With this test,[10] it is possible to infer whether a series contains a deterministic trend and a stochastic one (loose catching-up/lagging-behind) or merely a stochastic trend (divergence). Finding evidence in favor of a deterministic trend will allow us to reject the hypothesis of divergence in favor of loose catching-up or loose lagging-behind (case *c*) in Definition 1. Table 5 presents the results: the test statistic (R^2), the deterministic trend estimate (β), the estimate of break in the deterministic trend (Υ), and the break date.

Our estimations indicate the presence of a negative deterministic trend (in addition to the stochastic one) in regions 3 and 6. This implies

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10. Some specifics of the procedure are given in Appendix D. For a more detailed explanation, see Gómez-Zaldívar and Ventosa-Santaulària (2010b).

Table 5.   Testing for a deterministic trend
            when there is evidence of unit root

| | Regions | |
	3	6
R^2	0.9083*	0.9168*
β	-0.0052	-0.0221
γ	0.0238	0.0233
Break date	1982	1980

Source: Authors' estimations.
The symbol * denotes rejection of the null hypothesis of driftless unit root at the 10% level.

Table 6. Identified pattern of the output gap

	Region	Case/Pattern	Shifts
2	Center	Case b) / Catching-up	1960, 1982, and 2001
3	Northern-center	Case c) / Loose Catching-up	No significant shifts
4	Gulf	Case a) / Convergence	1949, 1975, and 1989
4b	Gulf-adj	Case b) / Catching-up	1950, 1964, and 2001
5	Mexican Border	Case b) / Catching-up	1951, 1961, 1976, 1981, and 1990
6	Pacific	Case c) / Loose Catching-up	No significant shifts
7	South	Case b) / Catching-up	1958, 1984, and 2001
8	U.S. Border	Case b) / Lagging-behind	1983 and 1996

Source: Authors' estimations.

that their growth dynamic is characterized by what we call loose catching-up; i.e., an erratic but inexorable reduction in the output gap with respect to the Capital Region. Furthermore, the procedure estimates a positive break in the deterministic trend in the 1980s, just around the period when economic reforms were implemented. In most cases, the magnitude of the structural break in the deterministic trend is enough to reverse the catching-up process observed prior to the reforms. Nevertheless, these parameters seem to be statistically not significant.

Overall, all of the regions are converging towards the Capital Region except the Gulf, which is found to have a stable output gap (convergence). Nevertheless, the catching-up process is more straightforward for regions 2,

4b, 5, and 7, whilst it seems less clear-cut for regions 3 and 6. As for the output gap between the border regions, this widened during the period. Although almost all of the patterns seem to suffer important structural shifts, the overall pattern remained unchanged.

7.   Concluding remarks

We analyze the convergence hypothesis among Mexican regions for the period 1940-2009. Our estimations suggest that in general, Mexican regions have been narrowing the per capita output gap relative to the Capital Region, the richest region in the country. To be precise, we found evidence in favor of convergence for the Gulf region, a loose catching-up process for the Northern-Center and Pacific regions, and in favor of a catching-up process for the remaining regions. Moreover, although the economic reforms initiated during the 1980s affected most of the regions (resulting in a period of several years during which the output gap increased), the effect had begun to reverse by the end of the millennium. The exception was Region 5, which evidence suggests benefited from the reforms, with the gap relative to the Capital Region decreasing faster after their implementation.

When we compare the Mexican Border region with that of the United States, we find that the output gap series is increasing. Although we estimate a negative structural break in this deterministic trend in 1996, its value is not enough to reverse the widening output gap. This result suggests that the Mexican Border region is lagging behind its U.S. counterpart.

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APPENDIX A

Figure A1.   Mexican regions
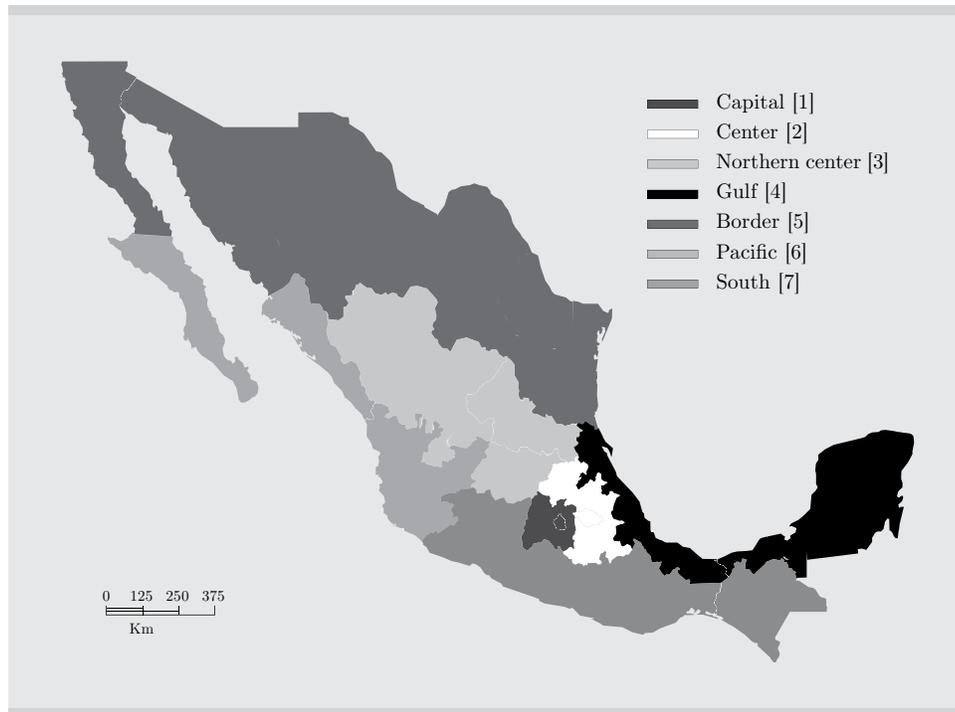
APPENDIX B

Structural breaks in the deterministic trend or in the mean of a stationary series

To estimate the possible structural breaks in the series that are stationary in regions 4 and 5, we follow the procedure used by Bai and Perron (1998, 2003). This method allows for general forms of serial correlation and heteroskedasticity in the errors, as well as different distributions of the errors. The estimated parameters and break dates, occurring at unknown times, are those that minimize the sum of squared residuals out of the entire potential set of break dates. To decide whether a structural break exists and to determine the number of structural changes, they proposed different tests: i) a test of no breaks versus a fixed number of breaks; ii) a test of no breaks versus an arbitrary positive number of breaks; and iii) a test of μ versus $\mu+1$ breaks.

APPENDIX C

The Kapetanios (2005) test

The maximum number of lags was determined using the rule suggested by Schwert (1989): $Lag_{max} = [12 \cdot (T/100)]^{1/4}$. The original Kapetanios test includes three different specifications all embedded in test Equation (C1) below,

$$
\begin{aligned}
y_t = \mu_0 + \mu_1 t + \alpha y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} \\
+ \sum_{i=1}^{m} \theta_i DU_{i,t} + \sum_{i=1}^{m} \varphi_i DT_{i,t} + \epsilon_t
\end{aligned}
\tag{C1}
$$

where y_t is the difference in per capita output of each region with respect to the Capital; $DU_{i,t} = 1(t > T_{b,i})$ and $DT_{i,t} = 1(t > T_{b,i})$ $(t - T_{b,i})$, where $T_{b,i}$ denotes the date of the ith structural break $(i = 1,2,...,m)$ and $1_{(\cdot)}$ is the indicator function. The first sum $\sum_{i=1}^{k} \gamma_i \Delta y_{t-i}$ accounts for k lags of the differenced dependent variable to control for possible autocorrelation. The first model, denoted as model A by Kapetanios, sets $\varphi_1 = \varphi_2 = ... \varphi_m = 0$, so that the null (UR) and the alternative correspond to Perron's (1989) crash model. Model B sets $\theta_1 = \theta_2 = ... \theta_m = 0$ defined as changing growth by Perron, while Model C allows for both types of breaks.

APPENDIX D

Testing for a deterministic trend and a structural break when there is evidence of unit root

To correctly estimate the presence of a deterministic trend (drift) when the unit-root tests have been unable to reject the null hypothesis, we utilize a test proposed by Gómez-Zaldívar and Ventosa-Santaulària (2010b). This formal statistical procedure helps us to distinguish between the null hypothesis of driftless unit root and that of unit root with drift, and a potential structural break on the drift. This method relies upon an auxiliary regression of the variable on a constant, a deterministic trend and trend-dummy variable, as shown in Equation (D1).

$$y_t = \alpha + \beta t + \gamma DT_{yt} + \varepsilon_t \tag{D1}$$

The break-finder algorithm consists of running Equation (D1) sequentially and allowing the break location to change along the sample. If there is indeed a break, the test statistic will be maximized. The test statistic is the R^2; if the R^2 is close enough to 1, the null hypothesis of a driftless unit root is rejected. If not, the null of a stochastic trend is not rejected. Using the normalized (by $T^{1/2}$) t-ratio of the parameter associated with the trend-break dummy (t_γ), it is also possible to test the hypothesis of a change in the drift.

This test is applied to the series for which we have so far been unable to reject the null hypothesis of unit root.