Long-Run Cross-State Growth Comparison in Mexico

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Abstract

In this paper, we examine economic growth in Mexican states over 1940–2015, focusing on the issue of their convergence interpreted as catching-up. A nonlinear econometric model with asymptotically decaying trends of the income gap is applied for the analysis. Particular cases of the baseline model capture other types of the income gap dynamics, namely, time-invariance, zero gap, and deterministic divergence. We analyze convergence of every state to the national level and convergence in each of 496 state pairs. Both analyses suggest one or other type of regularity to be peculiar to roughly 40% of income gap time series. Convergence is found in 6% to 15% of cases. Depending on approach to choosing among competing versions of the model, we find 55 or 76 convergence clubs; an individual club includes 3 to 7 members. The clubs heavily overlap, which makes interpretation of the pattern obtained to be a daunting task.

Keywords: regional convergence; nonlinear model; unit root; convergence club
JEL Codes: C22; I31; O18; R11

1 INTRODUCTION

This study aims at obtaining a long-term pattern of economic growth in Mexican states, focusing on the issue of their convergence. Since at present the very notion of convergence in the context of economic growth is ambiguous, we need to clarify the concept of convergence to be exploited.

In common usage, the term 'convergence' means approaching, becoming less unequal. Similarly, in the literature on economic growth (e.g., Barro & Sala-i-Martin, 1992), this term definitely meant approaching economies to one another over time, narrowing the income gap between them, catching-up. The confusion apparently has started since Bernard and Durlauf's (1995) article. They put forward the following formal definition of convergence:

$$\lim_{t\to\infty} E\left(y_{ij,t} \,|I\right) = 0, \qquad (1)$$

where $y_{ij,t} = y_{it} - y_{jt} = \log\left(Y_{it}/Y_{jt}\right)$ is the income gap between economies i and j, Y_{it} and Y_{jt} are incomes per capita in these economies, t denoting time. Intuitively, economies i and j converge if the long-term forecasts of their incomes (conditional on information available by the moment of forecast, I) are equal.

Albeit this definition is fairly general, the authors attach a much narrower sense to it, testing whether time series y_{ijt} are stationary with no trend. In doing so, they proceed from the neoclassical growth model: "the time-series approach requires that the economies under analysis are near their long-run equilibria […]. The tests may therefore be invalid if data are largely driven by transition dynamics" (Bernard & Durlauf, 1996, p. 172). In fact, the time-series approach itself has nothing to do with this; the point is that the authors consider situations when the process of convergence as such ('transition dynamics', i.e., catching-up) has already ended, referring to such situations as 'convergence'. Since then, this version of the term started spreading. Pesaran (2007), proposing a much more evolved methodology (pairwise testing), also interprets being near long-run equilibria as the indication of convergence.

At the same time, researchers who exploit the cross-section analysis of economic growth (beta-convergence) still consider convergence as a transition process, searching for indications of approaching economies to one another. (The case of closeness of economies under study to the long-run equilibrium would manifest itself in $\beta = 0$, which is interpreted as the failure of the test for beta-convergence). The same notion of convergence is accepted when studying the evolution of cross-economy inequality (sometimes referred to as ‘sigma-convergence’) as well as the evolution of the entire cross-economy income distribution (the distribution dynamics approach put forward by Quah, 1993). The time-series approach as such also does not prevent from interpreting convergence as catching-up. Nahar and Inder (2002) model convergence processes in a pair of economies by a trend of a priory unknown form, approximating it by a power series and test whether the estimated trend corresponds to narrowing the income gap between the economies. Phillips and Sul (2007) propose a panel data model for analyzing economic transition behavior, in particular, transition toward a long run growth path. For empirical analysis, this fairly general model has to be concretized with the use of a specific economic model, as in Phillips and Sul (2009), where the neoclassical growth model serves as the base for the analysis.

There are a few theoretical considerations against considering convergence as being near long-run equilibria. First, the assumption of closeness to the long-run equilibria is greatly questionable even for developed economies. Second, the neoclassical growth model predicts convergence to a common equilibrium only for microeconomically identical economies. Therefore, it comes as no surprise that Bernard and Durlauf (1995) have not found convergence (as they interpret it) among developed countries from their sample. Third, the neoclassical model is not a sole model of economic growth. There are a number of growth models that do not predict convergence, e. g. those by Romer (1986), Azariadis & Drazen (1990), Galor (1996), etc. The latter consideration motivates performing empirical analysis atheoretically, without referring to a specific growth model. Such a way is used by Nahar and Inder (2002), in studies applying the distribution dynamics approach, and in some other papers.

In this paper, we consider convergence in its initial meaning, namely, as catching-up. In doing so, we proceed from Bernard and Durlauf’s (1995) definition expressed by formula (1). Applying the time-series analysis, we follow Gluschenko (2011, 2020) in atheoretically modeling convergence processes in pairs of economies by asymptotically decaying trends. (Particular cases of the general model make it possible to identify other types of dynamics, namely, deterministic divergence and time-invariance of income gap.)

We use gross state product per capita as the income indicator. The time span is 76 years, 1940–2015; the spatial sample covers all 32 Mexican states. Our analysis includes two veins. The first consists of analyzing convergence of regional incomes to the national level (Mexican GDP per capita). The second is the analysis of convergence in each of $N(N-1)/2$ pairs of Mexican states (thus avoiding the need to choose a specific state as a benchmark), which provides a spatial pattern of convergence. Benefiting from it, we apply a recently proposed methodology for straightforwardly revealing convergence clubs.

The results obtained suggest that only 13 out of 32 states converge to the national income level or have a constant (including zero) gap with it. A positive feature is that no one case of deterministic divergence is found. The pairwise analysis identifies circa 43% of state pairs with convergence or constant income gap; however, there are 3% to 4% of deterministically diverging pairs. Depending on approach used to select the models, the analysis detects 55 to 76 convergence clubs. The clubs contain 3 to 7 members and heavily overlap.

The issue of economic growth and convergence in Mexico has been considered in a number of publications. Interest on heterogeneous path of the regional Mexican convergence/divergence process is in the core of analyses by Sánchez-Reaza and Rodríguez-Pose (2002) and Chiquiar (2005), who have shown the role of the Mexico's trade reforms in breaking the regional convergence trend. Carrion-i-Silvestre and German-Soto (2007, 2009) extend the evidence using a stochastic approach with structural breaks in both individual trends and panels. In recent studies, Mendoza-Velázquez et al. (2019) and Mendoza-Velázquez et al. (2020) apply a different approach, basing on indices of regional inequality.

This study contributes to the above literature in three aspects. First, it obtains a pattern of convergence to the national level across states of Mexico, distinguishing between different types of convergence dynamics. Second, it provides – for the first time – a comprehensive spatial pattern of convergence between all Mexican states. Third, it identifies a full set of convergence clubs among Mexican states (in two versions) on the basis of a recent methodology.

The paper is structured as follows. Section 2 considers the methodology. Section 3 describes the data. In Section 4, empirical results are presented and discussed. Finally, Section 5 summarizes.

2 METHODOLOGY

Recall that Y_{it} and Y_{jt} denote incomes per capita in economies (states) i and j at time t.

The subject of interest is dynamics of relative income Y_{it}/Y_{jt} over $t = 0, \ldots, T$ in the form of income gap between the economies: $y_{ij,t} = y_{it} - y_{jt} = \log\left(Y_{it}/Y_{jt}\right)$, sometimes referred to as income differential.

We consider a convergence process as a superposition of two processes that can be called long-run, or deterministic, convergence, and short-run, or stochastic convergence: $y_{ij,t} = y^{*}_{ij,t} + dy_{ij,t}$. The long-run convergence is a deterministic part of the income gap that tends to zero over time as formula (1) requires: $y^{*}_{ij,t} = h(t)$, where $h(t)$ is an asymptotically decaying trend such that $h(\infty) = 0$ and $d\left|h(t)\right|/dt < 0$. (To economize notation, the economy indices are suppressed somewhere.) Short-run convergence is an autocorrelated stochastic process containing no unit root, *i.e.*, a stationary process $dy_{ij,t} = (\lambda + 1)dy_{ij,t-1} + \varepsilon_t$, where $\lambda + 1 = \rho < 1$ is the autoregression coefficient, and ε_t is the Gaussian white noise. This process describes random deviations of the income gap from its deterministic trajectory: $dy_{ij,t} = y_{ij,t} - h(t)$.

Intuitively, the short-run convergence characterizes the behavior of transient random shocks. A unit shock deflects the income gap from its long-run path, dying out over time with half-life $\theta = \ln(0.5)/\ln(\lambda + 1)$, so that the deflection eventually vanishes. Thus, the superposition of long-run and short-run convergences is a process that is stationary around the asymptotically decaying trend $h(t)$. That is, albeit random shocks force the process to deviate from the deterministic trend, it permanently tends to return to the trend, thus satisfying condition (1). Since $dy_{ij,t-1} = y_{ij,t-1} - h(t-1)$, we get the following econometric model of convergence:

$$\Delta y_{ijt} = h(t) - (\lambda + 1)\cdot h(t-1) + \lambda y_{ij,t-1} + \varepsilon_t, \quad t = 1, \ldots, T \qquad (2)$$

where Δ is the first difference operator, $\Delta y_{ijt} = y_{ijt} - y_{ij,t-1}$. Similarly to the half-life time of random deviations from the long-run path, the semi-convergence time of the deterministic income disparity, Θ, can be defined as the time the income gap takes to halve, that is, $Y_{i,t+\Theta}/Y_{j,t+\Theta} - 1 = \left(Y_{it}/Y_{jt} - 1\right)/2$. It can be computed from the following equation: $h(t+\Theta) = \log\left(0.5\left(e^{h(t)} + 1\right)\right)$.

The same model (2) describes a process of divergence if $d\left|h(t)\right|/dt > 0$. It is also a process that is stationary around trend $h(t)$; however, the trend is a rising one. In this case, Θ is the doubling time, *i.e.*, the time the income gap takes to double: $Y_{i,t+\Theta}/Y_{j,t+\Theta}-1=2\left(Y_{it}/Y_{jt}-1\right)$. It can be computed from $h(t+\Theta)=\log\left(2e^{h(t)}-1\right)$. Note that such a process is a superposition of short-run convergence and long-run (deterministic) divergence. Hence, it fundamentally differs from stochastic divergence which is a non-stationary process (random walk).

We use two concrete modes of trend $h(t)$: the log-exponential trend $h(t)=\log\left(1+\gamma e^{\delta t}\right)$ and exponential trend $h(t)=\gamma e^{\delta t}$; $\delta<0$. The respective nonlinear econometric models have the forms:

$$\Delta y_{ijt}=\log\left(1+\gamma e^{\delta t}\right)-(\lambda+1)\cdot\log\left(1+\gamma e^{\delta(t-1)}\right)+\lambda y_{ij,t-1}+\varepsilon_t; \quad (2a)$$

$$\Delta y_{ijt}=\gamma e^{\delta t}-(\lambda+1)\gamma e^{\delta(t-1)}+\lambda y_{ij,t-1}+\varepsilon_t=\gamma e^{\delta t}\left(1-(\lambda+1)\gamma e^{-\delta}\right)+\lambda y_{ij,t-1}+\varepsilon_t. \quad (2b)$$

An advantage of model (2a) is the ease of interpretation. Parameter γ is the initial (at t = 0) income disparity: $\gamma=Y_{i0}/Y_{j0}-1$, and δ is the convergence rate that is simply connected with the semi-convergence time: $\Theta=\log(0.5)/\delta$. A shortcoming is the absence of symmetry with respect to permutation of indices i and j. Permutations change the absolute values of γ and δ as well as the value of λ. As a result, it may happen that y_{ijt} converges, while y_{jit} does not (or vice versa). Contrastingly, a permutation of indices in model (2b) changes only the sign of γ, leaving its absolute value and values of δ and λ intact. The initial income disparity in model (2b) is $e^{\gamma}-1$. However, the semi-convergence time involves both γ and δ and depends on t, except for the case of halving the initial disparity (as t = 0), when it looks like $\Theta=\log\left(\log\left(0.5\left(e^{\gamma}+1\right)\right)/\gamma\right)/\delta$.

Deterministic divergence occurs if $\delta > 0$. Then the doubling time in model (2a) is $\log(2)/\delta$; and that in Model (2b) is $\left(\log\left(\log\left(2e^{\gamma}-1\right)\right)/\gamma\right)/\delta$ for doubling the initial disparity. (If $e^{\gamma}\le 0.5$ in the latter, γ should be replaced by its absolute value, which is equivalent to the permutation of i and j in y_{ijt}).

Model (2) also encompasses a regular behaviour of income gap that is neither convergence nor divergence. This is a particular case of time-invariant long-run path $h(t)=\gamma$. Substituting this 'trend' into equation (2), the conventional AR(1) model with a constant is arrived at:

$$\Delta y_{rst} = \alpha + \lambda y_{rs,t-1} + \varepsilon_t, \quad (3)$$

where $\alpha = -\lambda\gamma$. Ignoring random shocks, this case implies a proportional change in per capita incomes: $Y_{it} = cY_{jt}$ with $c = e^{\gamma}$. Alternatively, incomes in *i* and *j* (in the logarithmic terms) are driven by the same trend shifted by a constant: $y_{it} = y_{jt} + \gamma$.

An important special case is $\gamma = 0$. Thus, only short-run (stochastic) convergence remains, generating the conventional AR(1) model with no constant:

$$\Delta y_{ijt} = \lambda y_{ij,t-1} + \varepsilon_t \quad (4)$$

This means that the income gap between the economies under consideration is due to random shocks only. Hence, incomes per capita in these economies, Y_{it} and Y_{jt}, have a common trend. Intuitively, this implies that convergence as such has completed by the moment $t = 0$, the income gap fluctuating around the income parity. (It is just this case that Bernard and Durlauf, 1995, and some other authors refer to as 'convergence'.)

We estimate all models – (2a), (2b), (3) and (4) – for each time series in our empirical analysis, selecting a version of Equation (2) that provides the best fit (the minimal sum of squared residuals) if (2a) and (2b) prove to be competitive. If no one model proves to be valid for a given series y_{ijt}, the series is deemed stochastically diverging.[1] In the unit root test and test for statistical significance of parameters γ, α and δ, we accept 10% as the critical level.

To test the unit root hypothesis, $H_0 : \lambda = 0$ (against $\lambda < 0$), we apply the augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test. The hypothesis of non-stationarity H_0 is deemed rejected if both tests reject it. A modified Bayesian information criterion with a sample-dependent penalty factor (Ng & Perron, 2001) serves for choosing optimal lag lengths in the ADF test. When estimating the auxiliary regression with different lag lengths in this test, the effective number of observations is held fixed according to Ng and Perron (2005). The PP test applied exploits the OLS autoregressive spectral method – and not a kernel-based method – in order to avoid size distortions (Perron & Ng, 1996).

The unit root test statistics, *t*-ratio of λ, $\tau = \lambda/\sigma_{\lambda}$, for models with nonlinear trends are non-standard and not tabulated. To obtain their empirical distributions under

[1] Note that this is a matter of convention. In fact, the series may contain some deterministic trend that cannot be described by our set of models. An example is a linear trend crossing line $y = 0$ at some point in time, thus changing convergence to divergence at this point.

the null hypothesis, we estimated τ in Equations (2a) and (2b) over 1 million random walks $y_t = y_{t-1} + \varepsilon_t$. Table 1 reports selected values of the τ-statistic from the obtained empirical distributions for sample size $T + 1 = 76$ (used in our empirical analysis).

TABLE 1 Selected values of τ-statistics for models with nonlinear trends, $T + 1 = 76$

Probability	Log-exponential trend (2a)	Exponential trend (2b)
0.1%	–5.223	–4.575
1%	–4.150	–3.924
5%	–3.415	–3.298
10%	–3.067	–2.978
20%	–2.664	–2.605

It may happen that more than one model can be accepted. The issue of which one is to be chosen has no strict solution. Theoretically, the general-to-specific approach is preferable. As Model (2) encompasses Model (3), and Model (3) encompasses Model (4), it is logical to accept the first valid model in the sequence (2) $\rightarrow$ (3) $\rightarrow$ (4).

However, intuitive considerations suggest that a reverse sequence, the specific-to-general approach, may be more helpful. If a time series satisfies both Equations (3) and (4), it is reasonable to assume that despite constant α in Equation (3) is statistically significant, it is small and is caused by some accidental reasons (being a statistical artefact) rather than by properties of the process itself. Hence, it is logical to accept Model (4). Similarly, when a time series satisfies both Equations (2) and (3), the reason is a very weak trend, maybe, incidentally manifesting itself in the data. Hence, the model without trend, Model (3), should be accepted. In what follows, we report results for both approaches.

Having analyzed all $N(N-1)/2$ pairs of N economies under study, it is possible to find convergence clubs among the economies. There is no unambiguous definition of convergence club. Two main approaches can be distinguished in the literature. The first one proceeds from interpretation of convergence as being near long-run equilibria. In this case, a convergence club is a group of economies $C = \{i_1, ..., i_m\}$ with zero-mean stationary series y_{ijt} $(i \neq j)$ for all $i, j \in C$. Such a definition is exploited by e.g., Hobijn and Franses (2000), and Beylunioğlu et al. (2020). The second approach considers convergence club as a group of economies with declining income disparity within the group over time (Ben-David, 1994, p. 8). In other words, the club consists of economies converging to one another.

According to our interpretation of convergence as catching-up, we follow in general the second approach. However, if a club contains economy *i*, it can also contain economies that have the same trend as *i* (i.e., those that have already completed convergence with *i* by $t = 0$) if all other members of the club converge to them or have the same trend. Thus, our approach is a kind of combination of both above approaches. Besides, a club should contain not less than three members.

Beylunioğlu et al. (2020) propose a straightforward method of revealing convergence clubs. Its idea is briefly as follows. The results of the pairwise analysis can be presented as an undirected graph where vertices are economies and edges connect converging and already converged economies (convergence graph). In terms of $N \times N$ adjacency matrix $A = \left(a_{ij}\right)$, $a_{ij} = 1$ if Equation (2) with $d\left|h(t)\right|/dt < 0$ or Equation (4) holds for y_{ijt} and $a_{ij} = 0$ otherwise. A convergence club is a complete subgraph of the convergence graph (maximal clique) with not less than three vertices. That is, $C = \left\{i_1, ..., i_m\right\}$ is a convergence club if $m \geq 3$, every pair $\left\{i_k, i_l\right\} \subset C$ is a converging or converged one, and there is no C' such that $C \subset C'$. The problem is to find all maximal cliques in the convergence graph. This problem is known to be NP-hard, so being very time-consuming in the general case. In our case, fortunately, the solution takes a short time, because the adjacency matrix of the convergence graph obtained is relatively sparse and its dimension is not too great.

Because of nontransitivity of statistical inference, an economy can be a member of more than one convergence club. The fact that y_{ijt} and y_{ikt} satisfy Model (2) or (4) does not necessary imply that y_{jkt} also satisfies the same model (e.g., Model (3) or random walk may describe this process). For example, converging economy pairs (*i*, *j*), (*i*, *k*), (*i*, *l*), (*j*, *k*), and (*j*, *l*) form two overlapping convergence clubs {*i*, *j*, *k*} and {*i*, *j*, *l*}, given that economies *k* and *l* do not converge to each other. Here, *i* and *j* belong to two convergence clubs, while *k* and *l* belong to a single club.

3 DATA

This study uses the income per capita by state over 1940 to 2015 from German-Soto (2005). These regional series are based on official data published by INEGI, the Mexican Institute of Statistics. However, during the time span under consideration, the statistical methodology sustained several methodological changes. In addition, the data are expressed in different year base. Therefore, the data in their original version are not suitable for analyses. German-Soto (2005) has standardized them, providing temporal and spatial comparability. At the date, the database of gross state product in Mexico has been updated by the author to cover the period 1940–2015.[2] Table 2 reports incomes per capita across 32 states relative to the national one for some selected years. The data give a first look of the regional inequality. Some states decisively raised their income level as compared to the national average, while others lowered it. From here, possible transitional heterogeneity can be inferred.

TABLE 2 Relative income per capita relative to the national one

State	1940	1950	1960	1970	1980	1990	2000	2010	2015
1. Aguascalientes	1.055	0.464	0.486	0.793	0.789	0.999	1.217	1.319	1.474
2. Baja California	4.182	2.876	1.835	1.458	1.283	1.328	1.319	1.116	1.102
3. Baja California Sur	0.965	1.184	0.925	1.398	1.267	1.487	1.244	1.130	1.009
4. Campeche	0.879	0.845	0.761	0.843	0.760	2.844	1.523	1.061	0.776
5. Coahuila	1.552	1.289	1.230	1.205	1.146	1.172	1.366	1.372	1.426
6. Colima	1.294	0.831	0.621	0.862	0.911	1.089	0.993	0.947	0.952
7. Chiapas	0.391	0.404	0.386	0.496	0.873	0.510	0.424	0.408	0.349
8. Chihuahua	1.180	1.412	1.229	1.016	0.944	1.192	1.443	1.420	1.477
9. Ciudad de México	3.746	2.639	2.676	1.934	1.910	2.231	2.519	2.555	2.681
10. Durango	1.410	0.755	0.595	0.721	0.723	0.823	0.818	0.896	0.860
11.Guanajuato	0.485	0.464	0.502	0.716	0.649	0.666	0.746	0.765	0.870
12. Guerrero	0.329	0.401	0.414	0.519	0.530	0.576	0.518	0.519	0.493
13. Hidalgo	0.502	0.433	0.400	0.540	0.655	0.653	0.617	0.566	0.568
14. Jalisco	0.631	0.717	0.649	1.043	1.007	1.012	0.993	0.946	0.978
15. México	0.481	0.515	0.703	1.085	0.970	0.878	0.784	0.813	0.759
16. Michoacán	0.367	0.426	0.317	0.527	0.554	0.543	0.574	0.568	0.572
17. Morelos	0.834	0.790	0.693	0.846	0.765	0.936	0.861	0.901	0.893
18. Nayarit	0.654	0.745	0.566	0.760	0.710	0.718	0.594	0.596	0.576
19. Nuevo León	1.695	1.574	2.065	1.675	1.575	1.616	1.756	1.855	1.915
20. Oaxaca	0.206	0.363	0.248	0.354	0.398	0.474	0.420	0.413	0.417
21. Puebla	0.404	0.533	0.407	0.624	0.650	0.642	0.675	0.689	0.681
22. Querétaro	1.129	0.418	0.400	0.790	0.858	1.048	1.193	1.206	1.374
23. Quintana Roo	2.015	1.934	0.488	1.004	1.197	1.497	1.478	1.337	1.328
24. San Luis Potosí	0.554	0.700	0.448	0.587	0.583	0.700	0.729	0.832	0.872
25. Sinaloa	0.942	0.951	1.028	0.940	0.757	0.858	0.793	0.847	0.829
26. Sonora	1.318	1.562	1.372	1.393	1.084	1.222	1.236	1.246	1.267
27. Tabasco	0.649	0.574	0.724	0.728	2.506	0.962	0.604	0.631	0.589
28. Tamaulipas	1.538	1.282	0.943	1.054	1.028	1.016	1.076	1.077	1.021
29. Tlaxcala	0.440	0.371	0.290	0.457	0.551	0.620	0.548	0.508	0.490
30. Veracruz	0.901	1.288	1.085	0.817	0.724	0.658	0.581	0.620	0.582

[2] The GDP database is available at https://works.bepress.com/vicente_german_soto (in the database section).

31. Yucatán	1.125	0.874	0.782	0.720	0.716	0.756	0.788	0.828	0.819
32. Zacatecas	0.439	0.554	0.375	0.517	0.471	0.558	0.545	0.715	0.710
Descriptive statistics									
Maximum	4.182	2.876	2.676	1.934	2.506	2.844	2.519	2.555	2.681
Minimum	0.206	0.363	0.248	0.354	0.398	0.474	0.420	0.408	0.349
Mean	1.072	0.943	0.801	0.888	0.923	1.009	0.968	0.959	0.960
Standard deviation	0.885	0.632	0.551	0.370	0.434	0.509	0.460	0.445	0.481

An overall scrutiny of the growth differences suggests non-monotonic changes in regional inequality. The decrease of the standard deviation in the earlier years changed to increase after seventies and then again to decrease. The highest relative income was progressively lowering until 1970; from then on, was increasing, although with fluctuations. However, the gap between the maximum and the minimum relative income in general narrowed over time. In 1940, their ratio reached 20 times (= 4.182/0.206), while in 2015 it was only 7.7 times (= 2.681/0.349). The standard deviation almost halved in 2015 as compared to 1940.

Figure 1 gives a more detailed view of the evolution of inequality, depicting the Gini index. It clearly shows the break in the trend of inequality and its fluctuations. The regional inequality in Mexico first falls and then rises, mainly since the eighties. This behavior is consistent with the patterns of national income inequality reported by studies that also use the Gini index, albeit based on different methodologies (Guerrero et al., 2009; Germán-Soto & Chapa-Cantú, 2015; Mendoza-Velázquez et al., 2019).

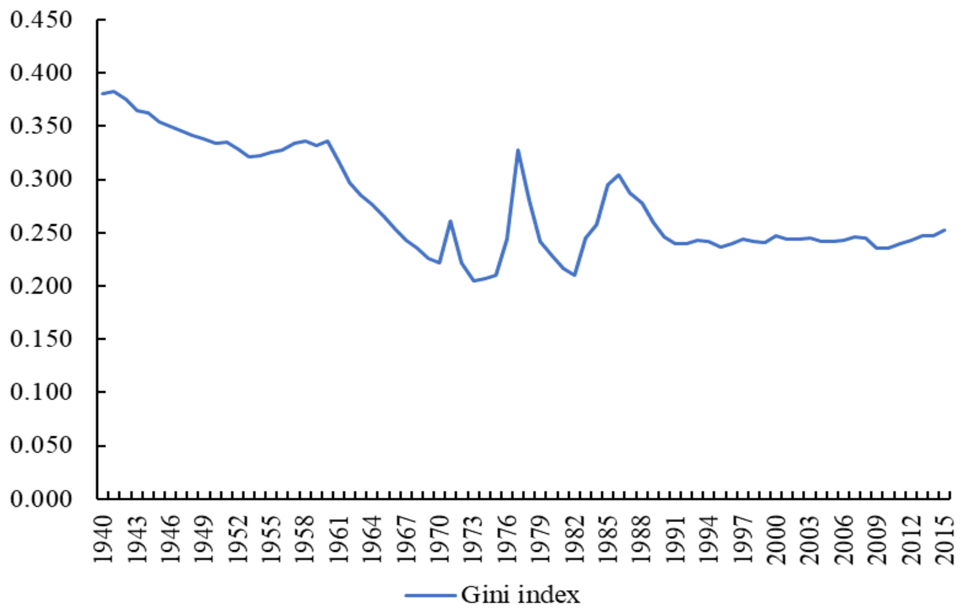

FIGURE 1 Gini index of relative incomes in Mexican states

Figure 2 relates the data to geography. Incomes per capita in the legends are reported in thousands Mexican pesos of 1993. Over the period under study, the real national GDP per capita has grown by the factor of 4.4 (from 3.9 thou. pesos in 1940 to 17.2 thou. pesos in 2015). However, no fundamental changes in the geographical distribution of incomes occurred.

(a)

(b)

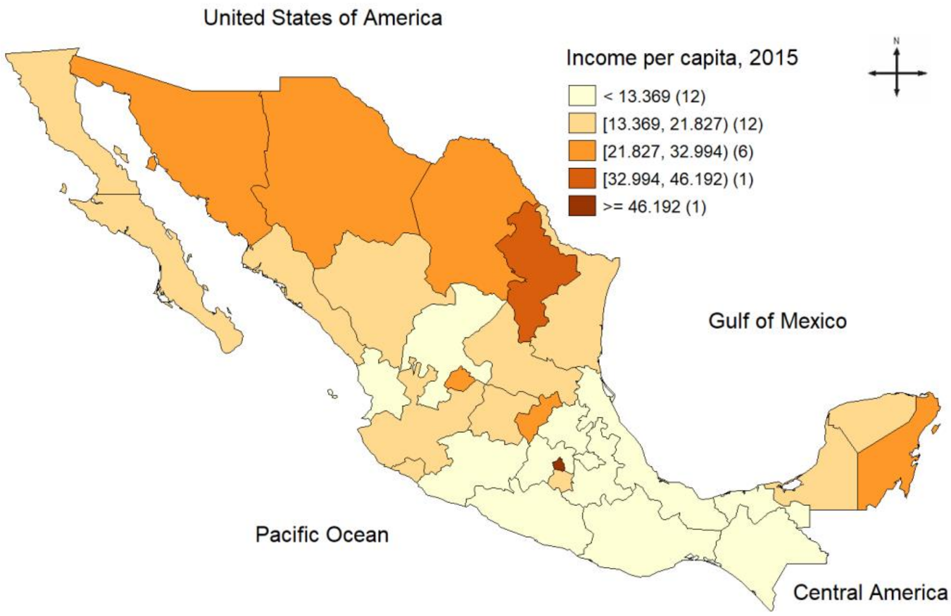

FIGURE 2 Mexico’s regional growth: state GDPs per capita at (a) the beginning of the period under study and (b) the end of the period

Despite the economic distances between states (measured by relative GDP per capita) were decisively falling, higher incomes still prevailed in the northern states by 2015.

4 EMPIRICAL RESULTS

As mentioned in the Introduction, our analysis consists of two parts. At first, we analyze convergence of income per capita in every state to the national GDP per capita (Subsection 4.1). Then we perform the pairwise analysis, that is, the estimation of our models for every pair of states, thus obtaining a comprehensive spatial pattern of convergence. Based on the pattern obtained, we identify convergence clubs among Mexican states (Subsection 4.2).

4.1 Convergence to the national level

In this subsection, the series analyzed are y_{i0t}, where 0 indexes Mexico as a whole. Table 3 reports the estimation results for significant models (i.e., where both unit root tests as well as coefficient estimates have p-values not more than 0.1). In some cases, two models are valid for a given time series; both are reported then.

As it is seen, the income gap between a state and Mexico as a whole exhibits regular behavior only in 13 states or about 41% of all states. Thus, the time series of income gap in remaining 19 regions are recognized as random walks. What is positive, no evidence of deterministic divergence is detected. Albeit using a different methodology, Carrion-i-Silvestre and German-Soto (2007) find a similar number of convergent cases (12 states catching up from both above and below) while studying the role of the structural changes in the regional growth pattern. German-Soto and Salazar (2016) reveal 17 cases of convergence, applying polynomial trends (as in Nahar & Inder, 2002).

Durango, Morelos, Sonora, and Tamaulipas are states where the trend model, (2a) or (2b), is selected. Incomes in Durango and Morelos grow faster than the country average, so tending to converge with it ‘from below’. Contrastingly, Sonora and Tamaulipas tend to converge ‘from above’, having income per capita exceeding the national level. As the semi-convergence times suggest, convergence in three states is very slow: it takes 23 to 45 years for the initial income gap to halve. The process of convergence is relatively fast only in Tamaulipas, where the semi-convergence time is about 5 years.

TABLE 3 Convergence to the national income level (significant cases only)

State	Model	λ	ADF/PP test p-value	γ/α	P-value of γ/α	δ	P-value of δ	Θ, years
2. Baja California	(4)	–0.038 (0.011)	0.002/0.002					
3. Baja California Sur	(3)	–0.335 (0.087)	0.004/0.004	0.078 (0.036)	0.031			
4. Campeche	(4)	–0.030 (0.029)	0.035/0.031					
10. Durango	(2a)	–0.114 (0.017)	0.000/0.000	–0.915 (0.031)	0.000	–0.031 (0.005)	0.000	22.5
	(3)	–0.110 (0.033)	0.022/0.091	–0.031 (0.010)	0.002			
11. Guanajuato	(4)	–0.017 (0.010)	0.090/0.090					
12. Guerrero	(3)	–0.049 (0.013)	0.021/0.057	–0.031 (0.010)	0.002			
	(4)	–0.009 (0.003)	0.014/0.043					
14. Jalisco	(4)	–0.031 (0.011)	0.030/0.004					
15. México	(4)	–0.026 (0.007)	0.048/0.051					
17. Morelos	(2b)	–0.202 (0.066)	0.083/0.083	–0.366 (0.071)	0.000	–0.018 (0.006)	0.003	44.9
23. Quintana Roo	(4)	–0.081 (0.040)	0.033/0.081					
26. Sonora	(2b)	–0.372 (0.090)	0.006/0.006	0.457 (0.069)	0.000	–0.014 (0.004)	0.003	43.1
28. Tamaulipas	(2a)	–0.081 (0.019)	0.008/0.028	4.062 (1.338)	0.003	–0.134 (0.022)	0.000	5.2
	(4)	–0.066 (0.012)	0.001/0.004					
31. Yucatán	(3)	–0.117 (0.034)	0.013/0.013	–0.029 (0.008)	0.001			

Note: Standard errors are in parentheses; γ relates to Models (2a) and (2b), and α relates to Model (3).

Two models prove to be valid for Durango and Tamaulipas. Therefore, under the specific-to-general approach inferences alternative to convergence are possible. According to model (3), the income gap in Durango can be supposed constant on average, income per capita remaining about 75% $\left(= e^{-(-0.031/-0.110)}\right)$ of the national average. Model (4) is an alternative for Tamaulipas, suggesting that income per capita there has approximately a common trend with the national GDP per capita.

Regional income changed proportionally to the national one in Baja California Sur, Guerrero, and Yucatán, obeying to model (3). Thus, their income gap remained constant on average, respectively, +26.4%, –46%, and –21.7%. Model (4) is also valid for Guerrero, implying that income per capita there has a common trend with Mexican GDP per capita.

Model (4) is unambiguously selected for six states, namely, Baja California, Campeche, Guanajuato, Jalisco, México, and Quintana Roo. Thus, incomes per capita evolve in these states in line with the national GDP per capita.

Figure 3 plots selected examples of behavior of income gap between a given state and the country as a whole, namely, convergence, non-zero constant gap, zero income gap, and stochastic divergence (random walk). The figure depicts the actual evolutions of the income gap versus their theoretical long-run paths.

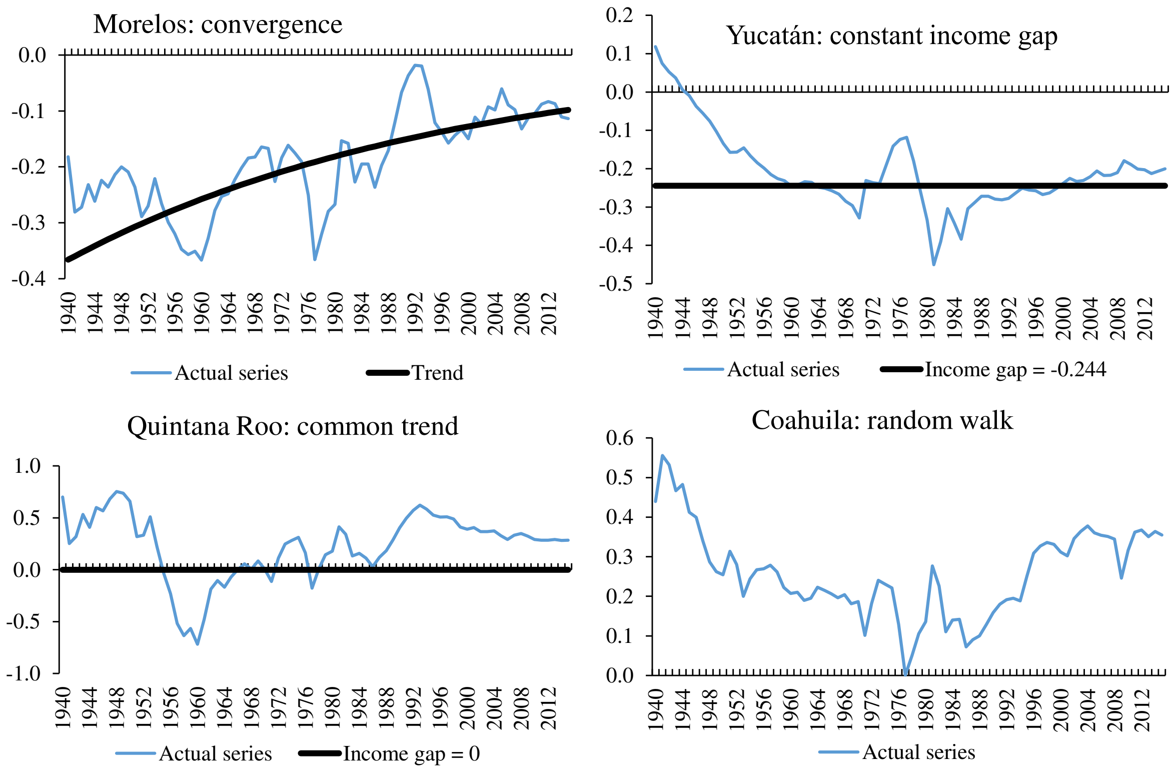

FIGURE 3 Relative income per capita versus estimated paths (selected results)

Briefly summing up the results reported in this subsection, convergence to the national level as well as common or parallel trend with it takes place in less than a half of regions over the whole time span of 1940–2015. However, as the Gini index suggests (Figure 1), the situation in this period was not uniform. During 1940–1970, regional inequality generally decreased. This gives ground to believe that convergence processes were widespread in that time. The next two decades were turbulent times characterized by dramatic fluctuations in inequality. In those times, the Mexican economy experienced extremely high rates of inflation, unemployment, and devaluation; macroeconomic policy was aimed at trade liberalization, making the economy to be more open. Then, since about 1990 until the end of the time span under consideration, regional inequality remained more or less stable. Therefore, it seems that it is dramatic shocks in the 'turbulent decades' that 'spoil' time series of income gap in many states, which prevents the unit root tests from rejecting the hypothesis of random walk.

4.2 Pairwise analysis and convergence clubs

Let us turn to analyzing convergence in each of the 496 pairs of Mexican states. Table 4 reports – in a summarized form – results of the analysis under both general-to-specific and specific-to-general approaches to selecting models.

Each line of the table, except for the last two lines, shows the number of states with which the given state converges, has a constant income gap, etc. The last but one line shows these figures for 'average' state. The last line gives these in percentages. They can be also interpreted as proportions of all state pairs with some or other behavior of income gap.[3] Appendix Table A.1 provides more detailed information, reporting valid models for every state pair in the matrix form.

In total, 41.7% of the states are found to converge to other ones or to have a constant (including zero) income gap with them and 3.8% deterministically diverge under the general-to-specific approach. With the alternative of the specific-to-general approach, these figures are 42.8% and 2.8%, respectively. The totals are close to that obtained in the analysis of convergence to the national level.

[3] Note that discrepancies between the last and last but one lines are due to rounding, e.g., actual average number of deterministically diverging regions is 1.1875, i.e., 3.8%, under the general-to-specific approach and 0.875, i.e., 2.8%, under the specific-to-general approach, both rounding to 1.

TABLE 4 Results of the pairwise analysis (general-to-specific/specific-to-general).

State	Convergence: model (2a)/(2b)	Constant income gap: model (3)	No income gap: model (4)	Deterministic divergence: model (2a)/(2b) with $\delta > 0$	Stochastic divergence: none model
1. Aguascalientes	7 / 7	0 / 0	1 / 2	**8 ^{w} / 7 ^{w}**	15
2. Baja California	**10 ^{b}** / 1	4 / 1	13 / 25	0 / 0	**4 ^{b}**
3. Baja California Sur	3 / 2	8 / 8	4 / 5	0 / 0	16
4. Campeche	**0 ^{w} / 0 ^{w}**	0 / 0	17 / 17	0 / 0	14
5. Coahuila	3 / 2	3 / 3	8 / 10	2 / 1	15
6. Colima	5 / 2	6 / 4	5 / 10	1 / 1	14
7. Chiapas	**0 ^{w} / 0 ^{w}**	1 / 1	2 / 2	2 / 2	26
8. Chihuahua	4 / 3	3 / 4	4 / 4	0 / 0	20
9. Ciudad de México	2 / 1	4 / 4	2 / 3	1 / 1	22
10. Durango	7 / 3	11 / 4	5 / 16	0 / 0	8
11. Guanajuato	7 / 3	1 / 0	5 / 11	1 / 0	17
12. Guerrero	2 / 1	7 / 3	4 / 9	1 / 1	17
13. Hidalgo	3 / 3	6 / 4	1 / 3	2 / 2	19
14. Jalisco	2 / 2	3 / 1	8 / 9	0 / 0	18
15. México	7 / 6	1 / 1	8 / 9	0 / 0	15
16. Michoacán	6 / 2	4 / 2	3 / 9	2 / 2	16
17. Morelos	7 / 3	0 / 0	6 / 10	0 / 0	18
18. Nayarit	5 / 3	1 / 1	6 / 8	1 / 1	18
19. Nuevo León	1 / 1	3 / 3	1 / 2	1 / 0	25
20. Oaxaca	1 / 1	11 / 6	4 / 10	2 / 1	13
21. Puebla	9 / 4	5 / 3	3 / 11	2 / 1	12
22. Querétaro	8 / 7	0 / 0	1 / 4	6 / 4	16
23. Quintana Roo	2 / 2	6 / 6	6 / 6	0 / 0	17
24. San Luis Potosí	6 / 4	3 / 2	4 / 7	0 / 0	18
25. Sinaloa	7 / 5	1 / 1	5 / 7	0 / 0	18
26. Sonora	**10 ^{b} / 9 ^{b}**	2 / 4	2 / 2	1 / 0	16
27. Tabasco	**0 ^{w} / 0 ^{w}**	0 / 0	3 / 3	0 / 0	**28 ^{w}**
28. Tamaulipas	6 / 3	2 / 1	9 / 13	1 / 1	13
29. Tlaxcala	1 / 1	3 / 3	4 / 4	2 / 2	21
30. Veracruz	7 / 7	1 / 0	2 / 3	1 / 1	20
31. Yucatán	7 / 2	6 / 5	6 / 13	1 / 0	11
32. Zacatecas	7 / 4	4 / 3	0 / 4	0 / 0	20
On average (rounded)	5 / 3	3 / 2	5 / 8	1 / 1	17
On average, %	15.3 / 9.5	11.1 / 7.9	15.3 / 25.4	3.8 / 2.8	54.4

Note: the superscripts *b* and *w* indicate the 'best' and the 'worst' cases, respectively.

Consider several interesting features of the pattern obtained. Baja California exhibits the greatest number of cases of regular behavior of its income gaps with other states, 27 out of all possible 31, stochastically diverging with four states only. It also has, along with Sonora, the greatest number of convergences under the general-to-specific approach. This number dramatically decreases, though, under the specific-to-general approach (when competitive option of common trend, model (4), replaces a model with trend), leaving Sonora to be the best in this respect.

No one case of convergence is peculiar to Campeche, Chiapas, and Tabasco, meaning that they exhibit dissimilar growth dynamics as compared to other regions. They are states in the South of the country where an economic backwardness persists, despite significant share of oil extraction (Campeche and Tabasco) and natural gas extraction (Chiapas) in their economies, which makes them unlike other states.[4] There is a difference between them, though. While Tabasco and Chiapas diverge (stochastically and deterministically) with 90% of other states, Campeche has common trends with more than a half of states, taking the first place in this respect under the general-to-specific approach and the second place under the specific-to-general approach.

Comparing Table 4 with Table 2 gives the impression that there is no relationship between state's income level and its pattern of convergence (like the impression from the analysis of convergence to the national level). For instance, the richest and poorest states do not stand out against a background of other states. Indeed, (not reported) simple regressions of different indicators from Table 2 (e.g., the number of stochastic divergences) on income corroborate the absence of correlation.

Benefiting from the full set of pairwise estimates, we can identify all convergence clubs among Mexican states. Recall that the convergence club is a set of not less than three states mutually converging or already converged to one another, not being a subset of any other club. Recall also that the same region can participate in more than one club.

Under the general-to-specific approach, we find 55 convergence clubs. Appendix Table A.2 reports their compositions. Out of these clubs, there are 11 clubs with 3 states, 21 with 4 states, 9 with 5 states, 13 with 6 states, and one with 7 states. Four clubs contain only states with common trends (i.e., with zero income gaps between them); four more clubs consist of converging states only; the rest of the clubs are 'mixed'.

Selecting models with the use of the specific-to-general approach, we reveal 76

[4] In contrast to a number of other countries, oil extraction in Mexico does not necessarily improve the income of the producing regions because oil production is considered as national.

convergence clubs. Their compositions are presented in Appendix Table A.3. The changes as compared to the above approach are caused by the replacement of model (2a)/(2b) with $\delta > 0$ (divergence) – or model (3) – with model (4) if both are valid. Among these clubs, there are 7 clubs with 3 states, 19 with 4 states, 21 with 5 states, 26 with 6 states, and 3 with 7 states. Seven clubs contain only states with common trends; the rest of the clubs are 'mixed'. There are 18 clubs that are the same under both approaches (see Appendix Tables A.2 and A.3).

Table 5 gives summarized information on the membership of states in convergence clubs. Columns 'Clubs' report the number of clubs in which the given state participates. Columns 'States, total" contain the number of states with which the given state is connected in the clubs; columns 'Converging' and 'Common trend' give the numbers of states with which the given state converges or has a common trend, respectively, in the clubs.

As it is seen from Table 5, convergence clubs heavily overlap, containing state pairs that are common to more than one club (common edges in different cliques). For instance, the pair Baja California–Tamaulipas is a part of 15 clubs under the general-to-specific approach. Under the alternative approach, it enters into 20 clubs; moreover, the pair Baja California–Durango enters into 36 clubs and the pair Baja California–Morelos enters into 22 clubs under this approach. Baja California has the highest levels of connectivity. It is a member of 38 (69% of the total) to 61 (80%) clubs. Three states only – Chiapas, Nuevo León, and Oaxaca – participate in no one club under the general-to-specific approach; there are no such states under the specific-to-general approach. An interesting case is that of Campeche. It has a common trend with 17 states (and converges to no one); all these pairs enter into convergence clubs.

The pattern obtained is extremely complex. There is no one isolated club under both approaches; every maximal clique representing a convergence club has at least one common edge with other maximal clique. The reason of complexity is not our concept of convergence club. For comparison, we have found convergence clubs as they are interpreted by Beylunioğlu et al. (2020). That is, the clubs consist only of states that have common trends of their incomes per capita; in other words, model (4) describes the behavior of y_{ijt} for every pair of members of the club (club consisting of not less than three members). Appendix Table A.4 reports the results. They prove to be not less complex that the above results. Under the general-to-specific approach, 17 clubs are detected with 3 or 4 members; under the specific-to-general approach, their number is 68 (with 3 to 5 members). This increase is due to that model (4) replaces model (2) or/and (3) under the latter approach. (In this case, obviously, convergence clubs under the general-to-specific approach form a subset of clubs under the alternative approach.) All clubs under both approaches overlap. Campeche is a member of 15 and 25 clubs under the general-to-specific approach and specific-to-general approach, respectively; Baja California enters into 42 clubs under the latter approach.

TABLE 5 Membership of states in convergence clubs

State	General-to-specific approach				Specific-to-general approach			
	Clubs	States, total	Converging	Common trend	Clubs	States, total	Converging	Common trend
1. Aguascalientes	3	6	5	1	6	9	7	2
2. Baja California	38	21	10	11	61	25	1	24
3. Baja California Sur	2	6	2	4	4	7	2	5
4. Campeche	18	17	0	17	21	17	0	17
5. Coahuila	9	11	3	8	13	12	2	10
6. Colima	6	10	5	5	10	12	2	10
7. Chiapas	0	0	0	0	1	2	0	2
8. Chihuahua	3	7	3	4	2	6	2	4
9. Ciudad México	1	2	2	0	2	3	1	2
10. Durango	13	12	7	5	36	19	3	16
11. Guanajuato	9	11	7	4	16	14	3	11
12. Guerrero	3	6	2	4	6	10	1	9
13. Hidalgo	3	4	3	1	4	6	3	3
14. Jalisco	4	8	1	7	8	11	2	9
15. México	17	15	7	8	17	15	6	9
16. Michoacán	8	9	6	3	10	11	2	9
17. Morelos	12	13	7	6	22	13	3	10
18. Nayarit	11	10	5	5	11	11	3	8
19. Nuevo León	0	0	0	0	1	2	1	1
20. Oaxaca	0	0	0	0	7	11	1	10
21. Puebla	8	12	9	3	16	15	4	11
22. Querétaro	4	9	8	1	8	11	7	4
23. Quintana Roo	4	8	2	6	4	8	2	6
24. San Luis Potosí	6	10	6	4	15	11	4	7
25. Sinaloa	12	12	7	5	11	12	5	7
26. Sonora	5	10	9	1	10	11	9	2
27. Tabasco	2	3	0	3	2	3	0	3
28. Tamaulipas	16	15	6	9	21	16	3	13
29. Tlaxcala	3	5	1	4	2	5	1	4
30. Veracruz	7	7	6	1	7	10	7	3
31. Yucatán	14	13	7	6	19	15	2	13
32. Zacatecas	6	6	6	0	6	7	3	4

These features of convergence clubs detected with the use of the graph theory (numerous clubs with many intersections) make their interpretation to be a daunting task. To our knowledge, there is no similar experience in the literature. Interpreting their results, Beylunioğlu et al. (2020, p. 660) merely note that "the overlapping groups that enter more than one club act as common factors that are shared by all". Such an interpretation seems hardly sufficient (moreover, it is not comprehensible). The issue needs further reflections and discussions.

5 CONCLUSION

In this paper, we have investigated economic growth characterized by gross state product per capita across Mexican states over 1940–2015. The study focuses on convergence interpreted as catching-up, considering the dynamics of income gaps. To analyze processes of convergence, we use a nonlinear econometric model with asymptotically decaying trends of income gap. Along with convergence as such, particular cases of the baseline model reveal other types of the income dynamics: constant on average income gap (parallel trends of incomes in members of a pair), zero income gap (common trend of both members of a pair), and deterministic divergence. If no one version of the model describes the behavior of income gap, we class this case as stochastic divergence (random walk).

We explore convergence of every state to the national level (considering the gap between state income per capita and Mexican GDP per capita) and convergence in every pair of states (considering income gap between regions in the pair). The latter provides 'spatial anatomy' of convergence in the country. Based on it, convergence clubs among Mexican states are identified.

When analyzing convergence of states to the national level, we have found only 41% of the states to manifest a regular dynamics. Out of them, merely 2 to 4 catch up with the national level. At the same time, 6 to 8 states have common trend with Mexico as a whole. However, this can be hardly recognized as evidence of a balanced growth path, since these states significantly differ in microeconomic terms, so violating the prerequisites of the neoclassical growth model.

The analysis across all 496 pairs of Mexican states suggests that regular dynamics is peculiar to about 46% of pairwise income gaps. However, this regularity is a negative phenomenon in 3% to 4% of cases, being deterministic divergence. Thus, 42% to 43% of pairs have diminishing or constant income gap. States catch up with each other in 9%

or 15% of pairs, which is greater than among pairs state–Mexico. There are 15% or 25% of state pairs with common trends. This fact, again, can hardly be interpreted in terms of neoclassical convergence. Depending on approach to choosing among competing versions of the model, we have identified 55 or 76 convergence clubs among Mexican states. The clubs found contain 3 to 7 states. They heavily overlap: most of states are members of several clubs, up to 61. These features of the pattern obtained (numerous clubs with many intersections) make its interpretation extremely difficult, needing further reflections and discussions.

The findings of this paper imply two things at less. First, poor evidence of convergence among Mexican states suggests that the growth process even in a single state rarely is uniform over that long term, 76 years. For instance, convergence in some states changed to divergence, as an example of Coahuila in Figure 3 demonstrates. In addition, the growth was heterogeneous across states. Some of them narrowed their differences in incomes, approaching to the national level, while others widened it either upward (becoming richer) or downward (more lagging behind). The same is peculiar to cross-state comparisons. Second, the widespread consideration of convergence as a zero-mean stationary process (versus random walk) is much less informative than revealing different types of growth dynamics. The pattern proves to be much richer; pairwise income gaps manifest diverse behavior in addition to the above two types: catching-up, time-invariance, and deterministic divergence.

Cross-state and cross-time heterogeneity may be explained by changes in growth regimes due to economic situation or government interventions, such as the transition from closed to open economy in the eighties. From the theoretical viewpoint, we can assume that economic growth in Mexican states was in line with different growth models depending on stages of their development process. Most likely, the development in the earlier years was in accordance with the Solow-Swan model (being due to rise in the capital-labor ratio). Further, accumulation of capital above some threshold could result in switching the growth regime as in Azariadis & Drazen (1990). Subsequently, the growth based on increasing returns could start acting, like in respective models with endogenous technological progress. That is why an atheoretical analysis of growth over a long time span is preferable.

Results of an analysis similar to that performed in this paper have not only academic interest. They provide a comprehensive pattern of economic growth tendencies among regions of a country. This can be a basis for designing regional policies that seek to reduce inequalities and promote growth between regions. (Certainly, the analysis does not need to cover that long period then; for practical purposes, two-three last decades are sufficient.) Obviously, policy measures should be region-specific, since inequality is driven by various forces in different regions and regional peculiarities play a determinant role. Hence, an additional problem is to identify these forces and peculiarities. Regarding Mexico, it is especially necessary to find out reasons why convergence process in the country as a whole (see Figure 3) stopped precisely when its economy opened to the world and how this change affected the poorer regions.

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APPENDIX

TABLE A.1 Matrix of pairwise analysis

State	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1				≡	↑		↓	↑	↑		↓≡	↓	↓			↓			↑	↓	↓		↑			↑		↑	↓			
2			↑≡	≡	≡	↑≡	≡	≠		↑	↑≡	≠≡	≡	≡	≡	↑≡	↑≡	≡	≡	≠≡	↑≡			↑≡	≡	≡	≡	↑≡	≡	≠≡	≡	↑≡
3		↑≡		≡	≡	≠	≠	≡		≠		≠	≠	≠	≠			≠		↑		↑	≡									
4	≡	≡	≡		≡	≡		≡		≡	≡			≡	≡		≡				≡	≡	≡		≡		≡	≡				
5	↑	≡	≡	≡				≡	≠	↑≠	≡			≡	≡					≠≡	≠≡	↑	≡					↓			↓≠	
6		↑≡	≠	≡							≠≡	≠≡	≠	≡	≡	↑≠≡	≡	↓		≠	↑≠≡			≡		↑		↑	≠			
7	↓	≡	≠																	≡		↓										
8	↑	≠	≡	≡	≡				↑≠	≠												↑	≡								≠	↑
9	↑				≠			↑≠			≡			≡					≠≡	≠										↓		≠
10		↑	≠	≡	↑≠			≠			≡	≠≡	≠≡	≠≡	≡	≠≡	↑≠≡	≡	≠	≠≡	≠≡			≠≡	↑≡	↑		↑	≡		↑≡	≠≡
11	↓≡	↑≡		≡	≡	≠≡			≡	≡							↑≡					↑		↑	↑≡	↑		≡			↑≡	
12	↓	≠≡	≠			≠≡				≠≡			≠		↑		≡	↑≡					≠		≡				≡	≡	≠≡	
13	↓	≡	≠			≠				≠≡		≠				≠≡		↑		≠		↓			↑					↑		
14		≡	≠	≡	≡	≡			≡	≠≡							≡						≡	↑				≡		↑	≠≡	
15		≡	≠	≡	≡	≡				≡		↑				↑	↑				↑	↑	≡		≡			≡		↑	↑≡	
16	↓	↑≡				↑≠≡				≠≡			≠≡		↑			↑≡		≠≡	↑≠	↓	≠					≡	≡	↑	≡	
17		↑≡		≡		≡				↑≠≡	↑≡	≡		≡	↑						↑≠≡			↑		↑		≡			≡	
18		≡	≠			↓				≡		↑≡	↑			↑≡				≡	≡							≡	↑		≡	↑
19	↑	≡							≠≡	≠																↓≠					≠	
20	↓	≠≡	↑		≠≡	≠	≡		≠	≠≡			≠			≠≡		≡				↓≡	≠			≡		≠≡	≠	≡	≠	
21	↓	↑≡		≡	≠≡	↑≠≡				≠≡					↑	↑≠	↑≠≡	≡				↓≡	≠	≡	↑	↑		↑≠≡	≠	↑	≠≡	
22			↑	≡			↓	↑			↑		↓		↑	↓				↓≡	↓≡		↑	↑≡		↑			↓			
23	↑		≡	≡	≡			≡				≠		≡	≡	≠				≠	≠	↑		≠								≠
24		↑≡				≡				≠≡	↑			↑			↑				≡	↑≡	≠			↑		≡			≡	≠
25		≡		≡						↑≡	↑≡	≡	↑		≡						↑					≠		≡		↑	↑	↑
26	↑	≡				↑				↑	↑						↑		↓≠	≡	↑	↑		↑	≠			≠			↑≠	↑
27		≡		≡																											≡	
28	↑	↑≡		≡	↓	↑				↑	≡			≡	≡	≡	≡	≡		≠≡	↑≠≡			≡	≡	≠						↑≡
29	↓	≡				≠				≡		≡				≡		↑		≠	≠	↓										
30		≠≡							↓			≡	↑	↑	↑	↑				≡	↑				↑						↑	
31		≡			↓≠			≠		↑≡	↑≡	≠≡		≠≡	↑≡	≡	≡	≡	≠	≠	≠≡			≡	↑	↑≠	≡			↑		↑≡
32		↑≡						↑	≠	≠≡								↑					≠	≠	↑	↑		↑≡			↑≡	

Note: For the corresponding number of the state, see the Table 4 or 5. *Notations:* ↑ means convergence: model (2a) or (2b) with $\delta < 0$ is valid; ↓ means divergence: model (2a) or (2b) with $\delta > 0$ is valid; ≠ means constant nonzero income gap: model (3) is valid; ≡ means zero income gap: model (4) is valid (per capita incomes in the respective states have the same trend); empty cells stand for random walks. If more than one model is valid, we choose the leftmost model in the cell under the general-to-specific approach, and the rightmost model under the specific-to-general approach.

TABLE A.2 Convergence clubs detected under the general-to-specific approach

Club No.	Aguascalientes	Baja California	Baja California S.	Campeche	Coahuila	Colima	Chiapas	Chihuahua	Ciudad México	Durango	Guanajuato	Guerrero	Hidalgo	Jalisco	México	Michoacán	Morelos	Nayarit	Nuevo León	Oaxaca	Puebla	Querétaro	Quintana Roo	San Luis Potosí	Sinaloa	Sonora	Tabasco	Tamaulipas	Tlaxcala	Veracruz	Yucatán	Zacatecas
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Note: + marks states that are members of a given convergence club. Grey rows are convergence clubs coinciding with those detected under the specific-to-general approach (Table A.3). The correspondence is as follows (the first figure is the club number in this table, the second figure is the club number in Table A.3): 1 = 1, 4 = 7, 7 = 10, 8 = 13, 9 = 14, 10 = 15, 11 = 16, 15 = 20, 16 = 24, 18 = 26, 19 = 27, 21 = 32, 41 = 67, 42 = 68, 43 = 70, 44 = 71, 45 = 73, 46 = 74. Bold numbers mark clubs consisting of states with common trends only; bold italics mark clubs consisting of converging states only.

TABLE A.3 Convergence clubs detected under the specific-to-general approach

Club No.	Aguascalientes	Baja California	Baja California S.	Campeche	Coahuila	Colima	Chiapas	Chihuahua	Ciudad México	Durango	Guanajuato	Guerrero	Hidalgo	Jalisco	México	Michoacán	Morelos	Nayarit	Nuevo León	Oaxaca	Puebla	Querétaro	Quintana Roo	San Luis Potosí	Sinaloa	Sonora	Tabasco	Tamaulipas	Tlaxcala	Veracruz	Yucatán	Zacatecas
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Note: + marks states that are members of a given convergence club. Grey rows are convergence clubs coinciding with those detected under the general-to-specific approach (Table A.2). The correspondence is as follows (the first figure is the club number in this table, the second figure is the club number in Table A.2): 1 = 1, 7 = 4, 10 = 7, 13 = 8, 14 = 9, 15 = 10, 16 = 11, 20 = 15, 24 = 16, 26 = 18, 27 = 19, 32 = 21, 67 = 41, 68 = 42, 70 = 43, 71 = 44, 73 = 45, 74 = 46. Bold numbers mark clubs consisting of states with common trends only.

TABLE A.4 Convergence clubs in the manner of Beylunioğlu et al. (2020)

Club No.	Aguascalientes	Baja California	Baja California S.	Campeche	Coahuila	Colima	Chiapas	Chihuahua	Ciudad México	Durango	Guanajuato	Guerrero	Hidalgo	Jalisco	México	Michoacán	Morelos	Nayarit	Nuevo León	Oaxaca	Puebla	Querétaro	Quintana Roo	San Luis Potosí	Sinaloa	Sonora	Tabasco	Tamaulipas	Tlaxcala	Veracruz	Yucatán	Zacatecas
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Note: + and ⊕ mark states that are members of a given convergence club; + implies that the state enters into the club revealed under the specific-to-general approach only; ⊕ implies that the state enters into the club revealed under both specific-to-general approach and general-to-specific approaches. Club 14 obtained under the under the specific-to-general approach splits into two clubs under the general-to-specific approach.