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Article

Strength in Diversity: A Spatial Dynamic Panel Analysis of Mexican Regional Industrial Convergence, 1960–2003

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Using a spatial dynamic panel, the long-run industrial sector convergence rate across Mexico's states is found to be 2%. The model is a system-General Method of Moments with correction for spatial autocorrelation and an explicit human capital input. The significant inequality between the richest and poorest states is caused by differences in factor accumulation. Physical capital accumulation dominates in richer states while the human capital accumulation is in poorer states. Regional inequality is predicted to grow unless there is government intervention to address the bipolar regional divide. More investment in human capital in non-industrialized states to draw strength from Mexico's diversity is recommended.
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INTRODUCTION

Mexico has always been known as a country of great diversity in fields from literature to economics. For example, regional economic diversity within Mexico has led to the poorest regions having a disproportionate amount of migrants leaving the household (Arias *et al.*, 2010). Despite the importance of regional differences, the explicit consideration of a spatial dimension to empirical analysis of the regional Mexican economy is rare (Torres-Preciado *et al.*, 2014). Our inclusion of the spatial dimension is in the spirit of Ali *et al.* (2007), who explicitly recognize the importance of more assessment of spatial heterogeneity in the traditional growth empirical analysis. For the regional Mexican economy, the spatiality has recently been found to be an important component (Jordaan and Rodriquez-Oreggia, 2012).

The convergence of Mexico's regions has been examined in the literature for several decades with some studies focusing on industry only (eg, Bannister and Stolp, 1995; Chavez-Martin del Campo and Fonseca, 2013) and others suggesting centuries of extractive regimes leave a legacy that is difficult to overcome (Acemoglu and Robinson, 2012, Chapter 1). Convergence was followed by divergence starting in the 1980s with the opening up of the Mexican economy (eg, Esquivel, 1999; Cermeño, 2001; Chiquiar, 2005; Carrion-i-Silvestre and German-Soto, 2007, 2009). Though convergence studies were sometimes motivated by trying to explain why growth slowed substantially in the open era (Torres-Preciado *et al.*, 2014), regional analysis was often hampered by a lack of data for the open era and omission of a human capital input commonly used in growth studies of other countries. This study seeks to add to a very recent literature trying to fill this gap. For example, Chavez-Martin del Campo and Fonseca (2013) show that while the opening of the Mexican economy improved technical efficiency and reduced the labor productivity gap between the 32 states, a persistent lagging of southern regions continues. The lag is also found by Torres-Preciado *et al.* (2014) as innovation spillovers across regions impact the north and central regions more than other areas of Mexico. New northern agglomerations of economic activity discussed in Jordaan and Rodriquez-Oreggia (2012) also illustrate the north/south differences.

These recent studies ignore the bias from using years of schooling to measure human capital discussed in the general regional literature (eg, Mulligan and Sala-i-Martin, 2000), although better measures are available for Mexico (German-Soto, 2007). In addition, they do not consider both long-run and spatial issues together. Using the improved human capital index recently applied to Mexican growth (Brock and German-Soto, 2013), we expand the convergence analysis to include regional heterogeneity, spatial autocorrelation and the weak instruments problem with a system-General Method of Moments (GMM) approach, in the spirit of similar work for the United States (Yamarik, 2006). Therefore, the resulting industrial convergence estimates come from a recently developed method that addresses many of the data/econometric concerns of prior work.

In addition to regional diversity, Mexico over the last 50 years is a good example of an economy opening up to world trade and foreign investment.

A closed economy with strong incentives for domestic industrial growth and very little connection to the rest of the world prevailed in Mexico in 1960. The policy objective was self-sufficiency. Policy measures included encouraging the consumption of internally manufactured products, reduced imports of final consumption goods, increased tariffs, infant industry protection and costly import quotas (Hanson, 1998; Esquivel and Rodríguez-López, 2003). Moreover, licenses were required to import almost any foreign product. In the 1960s and 1970s some positive economic outcomes occurred such as annual rates of growth between 6% and 9%, mild inflation, exchange rate stability and some reduction in income inequality. However, in the mid-1970s factor productivity growth stopped and by the early 1980s it was in decline (Arias *et al.*, 2010). The 1980s became known as the 'lost decade' (Bergoeing *et al.*, 2002), though Mexico did join General Agreement on Tariffs and Trade (GATT) in 1986. According to the literature, we characterize the 1960–1985 period as the 'closed era', followed by the 1986–2003 'open era'.

The open era includes both an increased openness to trade with North American Free Trade Agreement (NAFTA), in 1994, and the 1995 Peso crisis. Foreign direct investment (FDI) increased and technology improved, though Mexico had trouble allowing inefficient firms from the closed era to exit (Bergoeing *et al.*, 2002) compared with other countries also opening at this time. Further, perhaps due to the drop in public spending, formal employment fell and income inequality increased (eg, Cragg and Epelbaum, 1996; Hanson and Harrison, 1999; Esquivel and Rodríguez-López, 2003). Reforms left many important sectors with closed-era monopolies and the economy overall with too many rigid local laws and social institutions (Arias *et al.*, 2010).

To study the entire era and the issue of regional inequality, we use the theory of convergence with the augmented-human-capital Solow model developed by Mankiw *et al.* (1992) for international convergence, with criticism found in Islam (1995), Caselli *et al.* (1996) and others. The system-GMM technique, developed by Blundell and Bond (1998), allows a good mix of instruments and reduces the problem of weak instruments obtained when only difference-GMM is used (Roodman, 2009). Also, we consider the filtering of spatial dependence of the data as suggested by Badinger *et al.* (2004). The DPD98 software, created by Arellano and Bond (1998) for equations where the lagged dependent variable is included as independent one, is applied. The software has advantages over other packages, mainly in the treatment of the serial correlation and the choice of instrumental variables within system-GMM regressions, by allowing flexibility to manipulate the general conditions of estimation.

The rest of the work is as follows. The next section discusses the theory of convergence and motivates the system-GMM method. The subsequent section explains the data. The penultimate section analyzes the results and, the final section concludes.

THE METHOD

A spatial two-step system-GMM method is used to address some of the more common problems with lagged dependent variables on the right hand side of the panel equation. Its calibration allows us to deal with two main concerns: spatial and serial autocorrelation. For spatiality, we first filter out spatial autocorrelation and then run regressions instead of using an explicit spatial econometric method. As for serial autocorrelation, system-GMM combines instruments in levels and first differences that are able to reduce its presence in the data at lower bounds (Blundell and Bond, 1998). Such an approach allows us to directly compare our results with Badinger *et al.* (2004) who initially suggested the use of this two-step estimation procedure when estimating a dynamic spatial panel data model for European Union (EU) regions. While we leave some method details to their paper, we include a brief discussion of this idea and some of the background literature. The model builds on the production function of Mankiw *et al.* (1992) with a Cobb–Douglas technology and labor-augmenting technological progress, but excludes a human capital input which we put back in:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta} \tag{1}$$

where: Y = output, K = physical capital, H = human capital, L = labor. Moreover, the parameters α, β and $(1-\alpha-\beta)$ denote the factor's share in output. If $y = Y/AL$, $k = K/AL$ and $h = H/AL$ are quantities per effective unit of labor, and $(n+g+\delta)$ are the rates of growth of the labor, technology and depreciation, then the factor accumulation is defined as:

$$\begin{aligned} \dot{k}_t &= s_k y_t - (n+g+\delta)k_t \\ \dot{h}_t &= s_h y_t - (n+g+\delta)h_t \end{aligned} \tag{2}$$

The speed of convergence is $\lambda = -(1-\alpha-\beta)(n+g+\delta)$ and is determined by

$$\frac{d\ln y}{dt} = \lambda\left(\ln y^* - \ln y\right) \tag{3}$$

Equation 3 is then modified using y_0 as the output in effective labor units in the initial year and τ as the time period to get the widely used absolute convergence equation:

$$\ln y_t = \left(1 - e^{-\lambda\tau}\right) \ln y^* + e^{-\lambda\tau} \ln y_0 \tag{4}$$

Substituting y^* with observed values and now including the Islam (1995) critique of the need for panel data to allow for differences across regions, equation 4 yields:

$$\begin{aligned} \ln y_t - \ln y_0 = & \left(1 - e^{-\lambda\tau}\right) \ln c - \left(1 - e^{-\lambda\tau}\right) \ln y_0 + \left(1 - e^{-\lambda\tau}\right) \frac{\alpha}{1-\alpha-\beta} \ln s_k \\ & + \left(1 - e^{-\lambda\tau}\right) \frac{\beta}{1-\alpha-\beta} \ln s_h - \left(1 - e^{-\lambda\tau}\right) \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+g+\delta) + \varepsilon \end{aligned} \tag{5}$$

Here $(1-e^{-\lambda\tau})\ln c$ is the time-invariant individual effect term with the superiority of the panel method confirmed in Monte Carlo analysis (Goddard and Wilson, 2001). Using equation 5, Badinger *et al.* (2004) apply the spatial autocorrelation filter of Getis and Griffith (2002). The filtering starts with the index of Getis and Ord (1992) defined as a distance-weighted and normalized average of observations from a relevant variable x:

$$G_i(\delta) = \frac{\sum_j w_{ij}(\delta) x_j}{\sum_j x_j} \qquad \forall i \neq j \tag{6}$$

where $w_{ij}(\delta)$ denotes the elements of the spatial weight matrix W, which depends upon a distance decay parameter δ. The G_i statistic varies with this parameter and with the choice of δ dependent on the nature of the regions. As the expected value will be free of spatial autocorrelation, the filtering process compares it with the corresponding gross value:

$$x_i^* = \frac{x_i \left[\frac{W_i}{(N-1)}\right]}{G_i(\delta)} \tag{7}$$

where x_i is the original observation, W_i is the sum of all geographic connections w_{ij} (links) usually weighted as one per link for each i and j within δ of i ($i \neq j$), N is the number of individuals, $(x_i - x_i^*)$ represents the pure spatial component and x_i^* the filtered component of the data. If there is no autocorrelation at i to distance δ, then the observed and the expected values, $(x_i - x_i^*)$, will be positive indicating spatial autocorrelation among high values of x. When $G_i(\delta)$ is low, the difference $(x_i - x_i^*)$ will be negative indicating spatial autocorrelation among low values of the variable x. A lack of spatial autocorrelation may be tested for using Moran's I index because both indices can be standardized to a corresponding Normal $(0, 1)$ distribution with well-known critical values. Moran's *I* statistic has the following distribution,

$$I_t = \left(\frac{N}{S_0}\right) \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(z_{it} - \bar{z}_t)(z_{jt} - \bar{z}_t)}{\sum_{i=1}^{N} \sum_{j=1}^{N} (z_{it} - \bar{z}_t)(z_{jt} - \bar{z}_t)} \qquad \forall i \neq j$$
$$\text{where } S_0 = \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} \tag{8}$$

where z_{it} and z_{jt} represent per capita output of the regions i and j, respectively, in the year t (in logarithms); $\bar{z}_t$ is the mean value in the year t, N is the number of individuals and S_0 is a factor to scale the W matrix. In the choice of W and δ we follow the literature with inverse distance weights. The resulting weights are:

$$w_{ij} = \frac{1}{d(\delta)_{ij}^2} \text{ or } w_{ij} = \frac{1}{d(\delta)_{ij}} \tag{9}$$

with d_{ij} denoting the distance between the capital cities of the any two regions i and j. In defining δ we assume all regions have at least one adjacent neighbor as suggested by Anselin (2005). The filtered data are then used in the growth model as the second step with Blundell and Bond's (1998) system-GMM. The system-GMM imposes further restrictions on the initial conditions to improve the properties of the standard first-differenced GMM estimator. All the moments are exploited by a linear GMM estimator in a system of first-differenced and levels equations. Monte Carlo simulations show better performance of the first-differenced GMM estimator when the autoregressive parameter is moderately high and the number of time-series observations is moderately small.

THE DATA

The large literature in regional economics with aggregate production functions has not been applied to Mexico due to lack of data. Recent work by German-Soto (2007, 2008) and German-Soto *et al.* (2013) now makes this possible. Regional data series usually begin with the Mexican industrial censuses done roughly quinquennially by INEGI (National Institute of Statistics) between 1960–2003. Comprehensive coverage of Mexican industry across the 32 Mexican states includes such important industrial input/output data as GDP, labor, physical investment and wages. The data are for 10 years, 2003, 1998, 1993, 1988, 1985, 1980, 1975, 1970, 1965 and 1960, at multi-year intervals and provide a long period where business cycle effects and serial correlation are less problematic in comparison to annual data (Islam, 1995; Bond *et al.*, 2001;

Badinger *et al.*, 2004). Output is industrial GDP for each state and year divided by the total number of workers. For industrial physical capital (K) we use the series derived by German-Soto (2008) incorporating the private investment and employment data series from the censuses. The series is built using a simple vintage model of the relation between investment and employment in the industrial sector. Parameters of the model were estimated using a regression equation to obtain a reasonable rate of depreciation. Each region has a different depreciation rate (Table 1). Industrial human capital (H) is derived from census wage data (German-Soto *et al.*, 2013) using Mulligan and Sala-i-Martin's (1997) labor income approach. The series is derived as the ratio of the total labor income to the wage of someone with zero years of schooling. The explicit inclusion of these data alone represents a new contribution to the literature on Mexican regions.

To compute $(n+g+\delta)$, we take n as the average rate of growth of industrial labor and assume g is constant across states, as in the literature. The variable g reflects the advancement of knowledge, which is assumed to be neither country nor region specific (Mankiw *et al.*, 1992). While an argument could be made that depreciation rates (δ) also do not vary across regions, we use the varying regional rates just described. The varying rates are more realistic given the diversity of the structure of regional economies in Mexico. The rates fluctuate between 3.8% and 10% in part because an inter-regional variation in capital vintage is assumed.

Table 1: Capital stock depreciation rates

State	Depreciation rates	State	Depreciation rates
Aguascalientes	0.100	Morelos	0.100
Baja California	0.071	Nayarit	0.100
Baja California Sur	0.071	Nuevo León	0.067
Campeche	0.053	Oaxaca	0.100
Coahuila	0.050	Puebla	0.071
Colima	0.083	Querétaro	0.067
Chiapas	0.100	Quintana Roo	0.100
Chihuahua	0.091	San Luis Potosí	0.100
Distrito Federal	0.053	Sinaloa	0.100
Durango	0.083	Sonora	0.100
Guanajuato	0.067	Tabasco	0.038
Guerrero	0.071	Tamaulipas	0.056
Hidalgo	0.059	Tlaxcala	0.059
Jalisco	0.059	Veracruz	0.100
México	0.071	Yucatán	0.071
Michoacan	0.083	Zacatecas	0.071

Source: German-Soto (2008)

Table 2: Regional industrial output shares for 29 non-oil states in 2003

Rank	Industrial states	%	Rank	Non-industrial states	%
1	Distrito Federal	16.94	15	San Luis Potosí	1.97
2	México	14.69	16	Michoacán	1.63
3	Nuevo León	8.26	17	Durango	1.33
4	Jalisco	6.13	18	Aguascalientes	1.33
5	Coahuila	5.95	19	Morelos	1.28
6	Veracruz	4.22	20	Oaxaca	0.98
7	Chihuahua	4.14	21	Yucatán	0.84
8	Guanajuato	4.12	22	Sinaloa	0.84
9	Puebla	3.99	23	Guerrero	0.75
10	Baja California	3.22	24	Tlaxcala	0.69
11	Tamaulipas	3.00	25	Colima	0.58
12	Sonora	2.64	26	Zacatecas	0.38
13	Querétaro	2.48	27	Nayarit	0.25
14	Hidalgo	2.07	28	Baja California Sur	0.23
			29	Quintana Roo	0.22
	Total	81.85		Total	13.30

Source: Author's own calculations

Three time periods: long run (1960–2003), closed era (1960–1985) and open era (1986–2003) help to examine the long-term benefits of opening the economy. Also they link the contemporary Mexican regional literature with historical regional analysis (eg, Mora-Torres, 2001) before 1960. In each period we consider four groups of states: (1) all 32 states, (2) the non-oil state sample of 29 states excluding Campeche, Chiapas[1] and Tabasco, which also excludes some severe data problems due to oil sharing, (3) the 14 industrial states that dominate Mexican industrial production and (4) the 15 non-industrial states. The 2003 state share in overall industrial GDP was used to split the 29 state sample into industrialized and non-industrialized states with an arbitrary 2% serving as the dividing line (Table 2). Such a division also serves as a sensitivity test for any inter-regional heteroscedasticity that is sometimes found with aggregate regional growth (Temple, 1998) and is referred to as ‘many Mexicos’ in the historic literature (eg, Mora-Torres, 2001).

Looking at the sample descriptive statistics (Table 3) with the non-oil 29 states in the long run (1960–2003), the industrial group's human capital grows faster than the non-industrial group, while L, K and per capita output grow faster in the non-industrial states, suggesting extensive growth. In the closed era with little foreign investment, the relatively higher capital stock growth in

[1] Although Chiapas is a non-oil state there are two reasons to exclude it as a source of potential bias. First, mining and natural gas production are quite important. Second, some economic data were overestimated in the censuses.

Table 3: Aggregate industry descriptive statistics (in logarithms)

Variable	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
	Overall sample 1960–2003 ($N=288$)				Industrialized states only 1960–2003 ($N=126$)			
Labor	0.048	0.062	−0.131	0.401	0.046	0.054	−0.131	0.193
Capital stock	0.036	0.082	−0.204	0.512	0.029	0.066	−0.119	0.205
Human capital	0.022	0.061	−0.218	0.222	0.023	0.049	−0.140	0.164
Per capita product	0.013	0.075	−0.211	0.616	0.008	0.054	−0.125	0.146
	1960–1985 ($N=160$)				1960–1985 ($N=70$)			
Labor	0.064	0.067	0.025	0.120	0.062	0.050	−0.023	0.193
Capital stock	0.048	0.088	−0.204	0.512	0.031	0.062	−0.109	0.166
Human capital	0.007	0.066	−0.218	0.222	0.007	0.048	−0.140	0.137
Per capita product	0.014	0.082	−0.211	0.616	0.003	0.057	−0.125	0.135
	1988–2003 ($N=128$)				1988–2003 ($N=56$)			
Labor	0.028	0.000	0.011	0.011	0.025	0.051	−0.131	0.169
Capital stock	0.021	0.070	−0.200	0.205	0.025	0.071	−0.119	0.205
Human capital	0.040	0.048	−0.134	0.188	0.044	0.042	−0.058	0.164
Per capita product	0.012	0.066	−0.176	0.348	0.014	0.050	−0.123	0.146
Variable	Non-oil states only 1960–2003 ($N=261$)				Non-industrialized states only 1960–2003 ($N=135$)			
Labor	0.047	0.055	−0.131	0.318	0.048	0.057	−0.083	0.318
Capital stock	0.033	0.069	−0.204	0.205	0.037	0.072	−0.204	0.191
Human capital	0.021	0.056	−0.165	0.188	0.018	0.063	−0.165	0.188
Per capita product	0.011	0.054	−0.125	0.152	0.013	0.053	−0.109	0.152
	1960–1985 ($N=145$)				1960–1985 ($N=75$)			
Labor	0.063	0.059	−0.083	0.318	0.063	0.067	−0.083	0.318
Capital stock	0.039	0.071	−0.204	0.191	0.046	0.078	−0.204	0.191
Human capital	0.006	0.058	−0.165	0.157	0.005	0.066	−0.165	0.157
Per capita product	0.010	0.060	−0.125	0.152	0.016	0.061	−0.109	0.152
	1988–2003 ($N=116$)				1988–2003 ($N=70$)			
Labor	0.027	0.043	−0.131	0.169	0.030	0.034	−0.055	0.102
Capital stock	0.025	0.066	−0.119	0.205	0.026	0.062	−0.103	0.188
Human capital	0.039	0.049	−0.134	0.188	0.035	0.054	−0.134	0.188
Per capita product	0.012	0.045	−0.123	0.146	0.010	0.040	−0.064	0.099

Source: Author's own calculations

the non-industrial sample suggests an industrial policy of investment spread across all states and not just the industrial core. In the open era, capital and labor growth slowed while human capital growth increased in both groups. However, the increase in human capital was not enough to stop relatively slower output growth in the non-industrialized states. Also, foreign investment did not stop a slowing of the capital stock growth rate in general. So, the open era, unlike either the closed or overall period, is characterized by relatively faster output growth in the industrial states supported by relatively strong human capital growth, while the non-industrial output growth is the slowest of the three eras.

As our model explicitly analyzes spatial autocorrelation, we also include a set of descriptive maps (Figure 1) to illustrate the importance of spatial issues. The 1960 levels of *Y*, *K*, *H* and *N* illustrate a lot of spatial heterogeneity across the country. The south has relatively less capital and labor while the Northern Tier has relatively more. Tabasco is an important outlier in terms of per capita output in this initial year, but in the next years Campeche and Chiapas also joined increasing their per capita product due to oil production. Some southern states as Michoacán, Puebla, Tlaxcala and Yucatán have lower levels of income. In the case of physical capital, the spatial heterogeneity is even more illustrative. From Figure 1 it is evident that darker colors are concentrated in the Northern Tier and some central states, while in the south predominate the lightest colors. Private investments tend to highlight the importance of spatial issues in the Mexican regional system.

RESULTS

Mexican states have consistently converged in all three time periods. The faster convergence rates for relatively poor regions and per capita output elasticities of 1/3 suggested by theory are supported by our results. For example, in the non-oil states sample, the physical capital shares range between 30% and 36% and the human capital share is near to 46%. In the overall period, industrial and non-industrial states averaged 1.8% and 2.02%, respectively, while they are 1.8% and 3.1% in the open era. Human capital is a key factor in the relatively higher non-industrial rate. Mexico is therefore demonstrating diversity in regional convergence in the open era.

We use the overall sample to examine the degree of spatial autocorrelation suggested in the recent literature cited above. Using the Moran *I* index, both the dependent (output) and independent variables (physical capital, human capital and labor) are found to exhibit substantial spatial autocorrelation (Table 4).

Spatial autocorrelation is especially large for *Y*, *H* and *N*. The right side of the Table 4 shows that filtering successfully eliminates the spatial autocorrelation. The gap between the two sides constitutes a ‘pure’ spatial autocorrelation for each state.

Over the entire sample period (1960–2003) the results with spatially filtered data for the unrestricted and restricted equation 5 are shown in

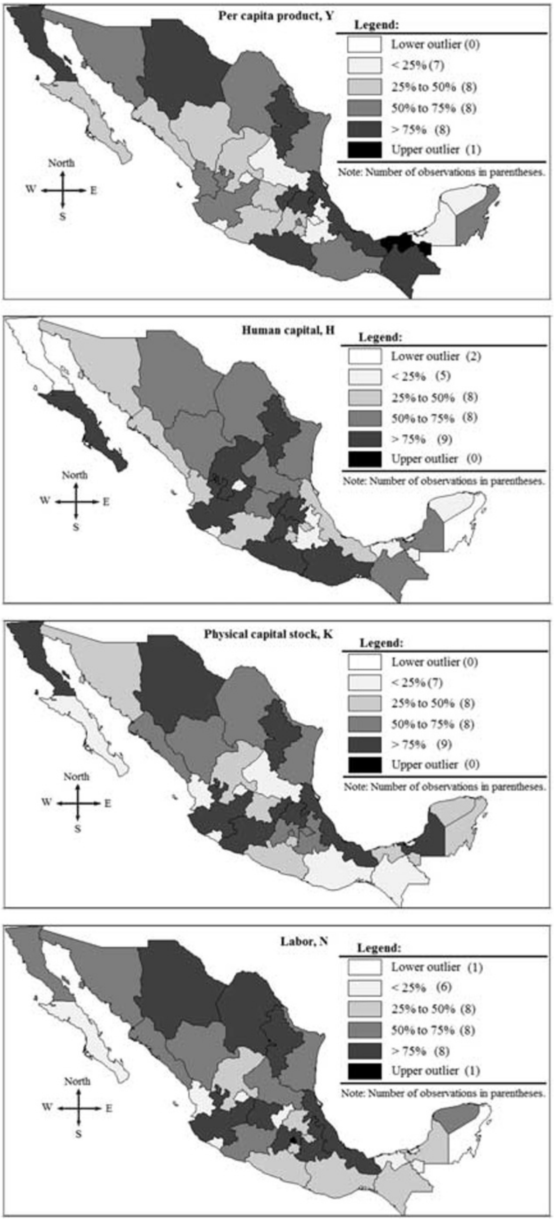

Figure 1: 1960: Spatial distributions of core input/output variables
Source: Author's own calculation using GeoDa software

Table 4: Spatial autocorrelation using Moran's *I* test

	Unfiltered variables				Filtered variables			
	Y	*K*	*H*	*N*	*FY*	*FK*	*FH*	*FN*
I_{1960}	0.348*	0.075	0.004	0.106**	−0.054	0.072	−0.203	0.079
I_{1965}	0.305*	0.094	0.270*	0.132**	−0.073	0.084	0.014	0.108
I_{1970}	0.324*	0.136**	0.277*	0.173*	−0.116	0.128	0.181	0.148
I_{1975}	0.405*	0.077	0.256*	0.247*	−0.062	0.077	0.118	0.219
I_{1980}	0.425*	−0.095	0.044	0.161*	−0.095	−0.121	−0.031	0.145
I_{1985}	0.044**	0.115**	0.241*	0.165*	0.032	0.079	0.065	0.146
I_{1988}	−0.069	−0.073	0.137**	0.164*	−0.025	−0.099	−0.031	0.147
I_{1993}	−0.074	−0.089	0.061	0.175*	−0.033	−0.117	0.006	0.156
I_{1998}	−0.074	0.047	−0.158	0.195*	−0.033	0.015	−0.178	0.175
I_{2003}	0.195*	−0.010	−0.100	0.160*	0.140	−0.034	−0.214	0.149

Note: * and ** indicate significance of spatial autocorrelation at 5% and 10%, respectively.
Moran's *I* test is calculated with a weight matrix based on square inverse distance.
Source: Author's own calculations

Table 5. Some diagnostics such as tests of second order serial correlation (m_1 and m_2), speed of convergence (λ), output elasticity (α and β), a measure of fit (R^2) and the Wald test statistic also are shown. In all regressions, the Wald null hypothesis that all the estimated coefficients are all 0 is rejected. The restricted regression results have a speed of convergence closest to what theory predicts.[2] Therefore, we focus on the restricted results as the preferred version, with the unrestricted one serving as a sensitivity test.

The input/output growth model has a poor performance both in terms of the overall fit and the elasticities when all 32 regions are considered, so we focus on the regional sub-samples. Serial correlation appears not to be significant.[3] Once the three oil states are excluded, the model fits quite well with a much higher R^2. Direct elasticities and the speed of convergence are statistically significant in all sub-samples. Over the long 43 year period, the hypothesis of convergence is supported as the initially richer states grew more slowly than others. The similarity of the speed of convergence in non-oil

[2] The literature on rates of convergence around 2% is overwhelming. For a comprehensive listing see De la Fuente (1997). For the Mexican case there are not antecedents allowing a reliable comparison because an input/output growth model had not been tested until now. However, some studies on absolute convergence establish a rate of convergence between 0.9% and 3.3% depending on the period and method used (Esquivel, 1999). Using a more recent period, some have even found divergence (Sánchez-Reaza and Rodríguez-Pose, 2002; Chiquiar, 2005 among others).

[3] When serial correlation is not a serious problem the m_1 test rejects the null hypothesis of AR(1) in first differences, while the m_2 test accepts it when there is no AR(2) in first differences (no AR in levels) (see Arellano and Bond, 1998).

Table 5: Long-run equation 5 results [dependent variable: ln(*yt*)−ln(*yt*−1)]

Sample	Overall	Non-oil	Industrialized	Non-industrialized		Overall	Non-oil	Industrialized	Non-industrialized
Observations	288	261	126	135		288	261	126	135
	Unrestricted regression					Restricted regression			
$\ln(y_{i,t-1})$	−0.066***	−0.105***	−0.083***	−0.096***	$\ln(y_{i,\,t-1})$	−0.085***	−0.102***	−0.089***	−0.096***
	(0.007)	(0.008)	(0.009)	(0.014)		(0.007)	(0.010)	(0.011)	(0.015)
$\ln(\Delta k)$	0.043	−0.022	0.079	−0.030	$\ln(\Delta k)-\ln(n+g+\delta)$	0.073	0.162***	0.271***	0.132***
	(0.029)	(0.054)	(0.094)	(0.061)		(0.051)	(0.045)	(0.066)	(0.033)
$\ln(\Delta h)$	0.104	0.168***	−0.005	0.185***	$\ln(\Delta h)-\ln(n+g+\delta)$	0.114	0.225***	0.130**	0.228***
	(0.119)	(0.053)	(0.072)	(0.064)		(0.091)	(0.042)	(0.060)	(0.054)
$\ln(n+g+\delta)$	−0.273**	−0.616***	−0.689***	−0.552***					
	(0.128)	(0.060)	(0.065)	(0.082)					
R^2	0.24	0.58	0.71	0.56	R^2	0.16	0.59	0.70	0.57
$m-1$	−1.413	−3.436	−1.919	−2.792	$m-1$	−1.482	−3.560	−2.197	−2.715
	(0.158)	(0.001)	(0.055)	(0.005)		(0.138)	(0.000)	(0.028)	(0.007)
$m-2$	−1.186	0.190	0.470	−0.797	$m-2$	−1.349	−0.504	0.902	−1.663
	(0.235)	(0.849)	(0.638)	(0.425)		(0.177)	(0.614)	(0.367)	(0.096)
Implied λ	0.013***	0.022***	0.017***	0.020***	*Implied* λ	0.017***	0.021***	0.018***	0.020***
	(0.001)	(0.001)	(0.001)	(0.003)		(0.001)	(0.002)	(0.002)	(0.003)
Implied α	0.203	0.075	0.469	0.098	*Implied* α	0.268	0.330***	0.552***	0.290***
	(0.138)	(0.183)	(0.561)	(0.197)		(0.188)	(0.091)	(0.134)	(0.072)
Implied β	0.486	0.568***	0.034	0.592***	*Implied* β	0.419	0.460***	0.265**	0.499***
	(0.553)	(0.181)	(0.427)	(0.207)		(0.333)	(0.085)	(0.122)	(0.120)
					Wald test of joint significance				
p-value	0.000	0.000	0.000	0.000	*p*-value	0.000	0.000	0.000	0.000
$\chi 2$	157.3	427.6	463.6	123.2	$\chi 2$	139.3	287.2	107.5	132.0

Notes: One-step system-GMM based on first differences and levels equations. The first lagged difference of each variable is used as an IV. Standard errors are in parentheses. Results of the $m-1$ and $m-2$ tests are the *p*-values for the null of no serial autocorrelation. All estimates include time specific effects and were done using DPD GAUSS software. ***, ** indicate significance at the 1% and 5% level.

Source: Author's own calculations

(2.1%), industrialized (1.8%) and non-industrialized (2.0%) sub-samples suggests approximately 2% convergence for Mexican regions as a reasonable figure that can be compared with regional convergence abroad, such as in the EU where convergence is faster (7%). The slightly higher rate for non-industrialized states also suggests less inequality over time.

The estimated input/output elasticities (α and β) are theoretically reasonable and statistically significant. Once the non-oil states sample is separated into industrialized and non-industrialized, the higher elasticity of human capital relative to physical capital for the 29 states is driven by the large difference between these two different samples. While the relatively higher physical capital elasticity in the industrialized states is to be expected given the well-documented greater share of capital investment over 43 years, the under-studied relatively higher human capital accumulation outside the industrialized states appears to be a largely ignored factor in Mexican regional convergence over the long run.

Economic theory suggests many gains from opening an economy to the world, and Mexico is believed to be no exception. Like the overall period, the closed era exhibits a poor fit when all 32 regions are considered, but supports the underlying model once the non-oil states are excluded (Table 6).

The overall convergence of 2% is the same, but now the industrialized states converge slightly faster (2.2%) than the non-industrialized ones (1.7%). Public domestic investment, with little FDI during the closed era, increased the physical capital stock enough to support faster convergence in the industrial states than in the non-industrialized ones. The same reversal of the relative importance of physical and human capital between the two sub-samples, industrialized and non-industrialized states, is found with theoretically reasonable coefficient values. Therefore, human capital stands out as a key factor of convergence in the closed era as well as over the long run.

While NAFTA was signed in 1993, the open era began earlier when Mexico joined GATT in the mid-1980s. Physical capital investment in non-industrialized states slowed as new FDI and domestic investment flowed into the industrialized states to a much greater degree than in the closed era. Unfortunately, the fit of the non-industrialized sub-sample is quite poor (Table 7) leaving only the non-oil and industrialized sub-samples with theoretically reasonable results.

Although the human capital coefficient is not significantly different from 0 for industrialized states, the physical capital coefficient is similar to the other time periods. While the non-industrialized states results are weak, we can use the logic of the overall non-oil group compared with the industrialized states group to show convergence is faster in the non-industrialized states relative to the industrialized ones, with human capital as a key factor. Though neglected in

Table 6: Closed era results. [dependent variable: ln(*yt*)−ln(*yt*−1)]

Sample	Overall	Non-oil	Industrialized	Non-industrialized		Overall	Non-oil	Industrialized	Non-industrialized
Observations	160	145	70	75		160	145	70	75
	Unrestricted regression					Restricted regression			
$\ln(y_{i,t-1})$	−0.064**	−0.104***	−0.086***	−0.089***	$\ln(y_{i,t-1})$	−0.112***	−0.096***	−0.102***	−0.082***
	(0.027)	(0.015)	(0.020)	(0.023)		(0.042)	(0.020)	(0.021)	(0.022)
$\ln(\Delta k)$	0.018	−0.031	0.080	−0.058	$\ln(\Delta k)-\ln(n+g+\delta)$	−0.051	0.172***	0.243***	0.191***
	(0.054)	(0.068)	(0.121)	(0.092)		(0.098)	(0.051)	(0.077)	(0.058)
$\ln(\Delta h)$	0.153	0.189***	0.048	0.213***	$\ln(\Delta h)-\ln(n+g+\delta)$	0.102	0.213***	0.112	0.224***
	(0.111)	(0.066)	(0.135)	(0.076)		(0.113)	(0.060)	(0.114)	(0.070)
$\ln(n+g+\delta)$	−0.133	−0.584***	−0.618***	−0.646***					
	(0.127)	(0.073)	(0.103)	(0.084)					
R^2	0.30	0.67	0.75	0.67	R^2	0.05	0.69	0.74	0.69
m−1	−2.873	−3.086	−1.940	−2.139	*m*−1	−1.255	−3.151	−2.081	−2.238
	(0.004)	(0.002)	(0.052)	(0.032)		(0.209)	(0.002)	(0.037)	(0.025)
m−2	−0.858	2.729	0.898	1.829	*m*−2	−0.940	1.897	1.137	1.056
	(0.391)	(0.006)	(0.369)	(0.067)		(0.347)	(0.058)	(0.255)	(0.291)
Implied λ	0.013**	0.022***	0.018***	0.018***	*Implied* λ	0.023***	0.020***	0.021***	0.017***
	(0.005)	(0.003)	(0.004)	(0.004)		(0.009)	(0.004)	(0.004)	(0.004)
Implied α	0.076	−0.121	0.373	−0.240	*Implied* α	−0.314	0.357***	0.531***	0.298***
	(0.231)	(0.260)	(0.565)	(0.378)		(0.599)	(0.106)	(0.168)	(0.090)
Implied β	0.649	0.722***	0.224	0.875***	*Implied* β	0.628	0.442***	0.245	0.514***
	(0.469)	(0.254)	(0.628)	(0.313)		(0.691)	(0.125)	(0.249)	(0.162)
					Wald test of joint significance				
p-value	0.177	0.000	0.000	0.000	*p*-value	0.004	0.000	0.000	0.000
$\chi 2$	6.311	253.0	323.9	137.4	$\chi 2$	13.60	146.4	53.03	115.8

Note: See Table 5.
Source: Author's own calculations

Table 7: Open era results. [dependent variable: ln(*yt*)−ln(*yt*−1)]

Sample	Overall	Non-oil	Industrialized	Non-industrialized		Overall	Non-oil	Industrialized	Non-industrialized
Observations	128	116	56	60		128	116	56	60
	Unrestricted regression					Restricted regression			
$\ln(y_{i,t-1})$	−0.075***	−0.114***	−0.078***	−0.136***	$\ln(y_{i,t-1})$	−0.111***	−0.115***	−0.089***	−0.144***
	(0.018)	(0.021)	(0.014)	(0.022)		(0.030)	(0.024)	(0.018)	(0.025)
$\ln(\Delta k)$	−0.332	−0.058	0.020	−0.043	$\ln(\Delta k)-\ln(n+g+\delta)$	0.093	0.146*	0.289**	0.035
	(0.258)	(0.068)	(0.169)	(0.070)		(0.073)	(0.077)	(0.122)	(0.045)
$\ln(\Delta h)$	−0.085	0.128**	−0.018	0.133*	$\ln(\Delta h)-\ln(n+g+\delta)$	0.001	0.229***	0.156	0.190**
	(0.195)	(0.059)	(0.091)	(0.078)		(0.129)	(0.080)	(0.131)	(0.087)
$\ln(n+g+\delta)$	−0.915***	−0.695***	−0.824***	−0.398***					
	(0.270)	(0.135)	(0.129)	(0.148)					
R^2	0.04	0.34	0.63	0.03	R^2	0.01	0.32	0.61	0.01
m−1	1.907	−2.444	−0.246	−2.152	*m*−1	0.917	−2.611	0.668	−2.570
	(0.057)	(0.015)	(0.806)	(0.031)		(0.359)	(0.009)	(0.504)	(0.010)
m−2	−0.786	−1.319	−0.921	−1.713	*m*−2	−1.242	−1.302	−0.358	−1.907
	(0.432)	(0.187)	(0.357)	(0.087)		(0.214)	(0.193)	(0.721)	(0.057)
Implied λ	0.015***	0.024***	0.016***	0.029***	*Implied* λ	0.023***	0.024***	0.018***	0.031***
	(0.003)	(0.004)	(0.003)	(0.004)		(0.006)	(0.005)	(0.003)	(0.005)
Implied α	0.971	−0.318	0.250	−0.193	*Implied* α	0.452	0.298*	0.540**	0.096
	(0.754)	(0.370)	(2.127)	(0.313)		(0.357)	(0.156)	(0.229)	(0.121)
Implied β	0.250	0.695**	−0.236	0.589*	*Implied* β	0.008	0.466***	0.292	0.514**
	(0.571)	(0.319)	(1.146)	(0.347)		(0.632)	(0.163)	(0.245)	(0.234)
					Wald test of joint significance				
p-value	0.000	0.000	0.000	0.000	*p*-value	0.002	0.000	0.000	0.000
$\chi 2$	62.76	386.3	346.8	123.6	$\chi 2$	14.82	141.6	60.13	118.9

Note: See Table 5.
Source: Author's own calculations

terms of both domestic and foreign investment, non-industrialized states converge at a relatively faster rate in the open era. However, this convergence by the relatively poor regions is to a lower equilibrium creating the 'two Mexicos' mentioned in other studies of a lagging south diverging from a Northern Tier. Such a polarization of Mexico's economy may not be optimal and suggests a continued need for federal intervention to equalize the disparities between the two regional groups. Continued polarization can result in an overly concentrated industrial sector that has been shown to have a negative impact on productivity in the open era (Salgado Banda and Bernal Verdugo, 2011).

CONCLUSION

Mexico's open economy era is now long enough to allow a regional panel data comparison of the current open era with the prior closed era. Relatively new econometric methods can be combined with spatial analysis to move our understanding of Mexican regional growth to a new level. Often ignored or poorly measured, the human capital can now be explicitly considered as in analyses of regional US and EU growth. The 2% Mexican regional industrial convergence found is much lower than the EU's 7% using the same spatial model.

The physical capital elasticity is also lower than the EU's 0.43 in the non-industrialized states but higher in the industrialized ones, while overall (29 regions) it is lower. This result holds in all time periods. Thus, two Mexico's are found, suggesting the industrial sector is overly concentrated. While an initial policy response may be more capital investment in non-industrialized states, the importance of human capital in that group suggests another policy response: to leave industry as it is and develop the non-industrial part of the Mexican economy with creative human capital investments promoting a service economy. For example, the very recent opening of Mexico's oil sector to foreign investment could be combined with a regional policy of allowing more oil profits to remain in the southern regions near where the oil is located. The decentralized funds could be targeted at early childhood education, which has been a root cause of Mexico's low human capital to date (Arias *et al.*, 2010). Such a policy would directly address the lagging southern region's economic growth, where they appear to have a relative advantage and the program structure *via Oportunidades* may already be in place to carry out such a policy.

New FDI, in general, and oil sector, in particular, can also be targeted to increasing the formal part of the economy, especially in the southern states. For example, the new tax system of President Peña Nieto and the impacts of the retirement program policies on the informal sector will be especially sensible in the south, as the more informal industrial sector there makes the reform harder to accomplish (Deichmann *et al.*, 2004). Recent analysis of informal sector employment and how to 'formalize' more of the economy (Dougherty and Escobar, 2013), along with new types of data to measure progress in reducing informality in southern Mexico (Brock *et al.*, 2014) offer new avenues for research in this area. If the institutional literature is correct, some regions are trapped in a different type of economy over very long periods (Acemoglu and Robinson, 2012, Chapter 1). A policy to decrease inequality would exploit the very different factor endowments of the regions and treat the difference as a strength and not a weakness. For example, Mexico's largest port of Veracruz would receive non-industrial investment to promote transportation and logistics to take advantage of the widening of the Panama Canal while remaining relatively poorly endowed with industrial physical capital. Other models measuring different types of convergence and historical data reflecting institutions (eg, Brock and Ogloblin, 2014) could be applied to deepen our understanding of how well a 'southern strategy' is doing.

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