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Interregional Inequality Dynamics in Mexico

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ABSTRACT *This paper examines 60 years of regional income inequality dynamics across the states of Mexico. Drawing on recent developments in exploratory spatial data analysis (ESDA) we examine the role of spatial clustering and heterogeneity in the evolution of regional inequality. We pay particular attention to the choice of the regionalization scheme that has been applied in previous work and we suggest a number of new approaches to evaluate the sensitivity of inferential conclusions to this choice. We also investigate if temporal shifts in equality are reflected in the NAFTA era.*

Dynamique de l'inégalité interrégionale au Mexique

RÉSUMÉ *la présente communication se penche sur la dynamique des inégalités régionales entre les revenus pendant 60 ans dans les états du Mexique. Sur la base de développements récents dans les analyses exploratoires des données spatiales (ESDA), nous examinons le rôle du groupage et de l'hétérogénéité spatiaux dans l'évolution des inégalités régionales, en nous penchant tout particulièrement sur le choix du plan de régionalisation appliqué à des travaux précédents, et en proposant un certain nombre de méthodes nouvelles pour évaluer la sensibilité de conclusions déductives sur ce choix. En outre, nous tentons d'établir si des changements temporels dans les inégalités sont reflétés dans l'ère de NAFTA.*

Dinámica de la desigualdad interregional en Méjico

EXTRACTO *Este trabajo examina 60 años en la dinámica de la desigualdad regional de ingresos a través de los estados de Méjico. Haciendo uso de desarrollos recientes en el análisis exploratorio de datos espaciales (ESDA) examinamos la función del agrupamiento espacial y la heterogeneidad en la evolución de la desigualad regional. Prestamos particular atención a la elección del esquema de regionalización que se ha aplicado en trabajo anterior y sugerimos varios planteamientos nuevos para evaluar la sensibilidad de conclusiones inferenciales de esta elección. También investigamos si los cambios temporales en igualdad se reflejan en la era NAFTA (Tratado de Libre Comercio de América del Norte).*

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墨西哥的区域不平等变化

摘要：本文研究了墨西哥各州60年来的地区收入不平等变化。笔者根据近来解释性空间数据分析（ESDA）上的发展，研究了空间群集和差异性在区域不平等的演变中的作用。本文特别注意了以前工作中选择的地区化方案，建议了几种新的方法评估这种选择的推论的敏感度。本文还研究了平等性的时间偏移是否在NAFTA时代反映出来。

Keywords: *Regional inequality; spatial effects; Mexico*

JEL classification: C21; N16

1. Introduction

It is a well known descriptive finding that economic inequality among the Mexican states has been present for at least the last six decades. After its highest record levels, during the 1940s, the dispersion in per capita income among the states drastically declined for 20 years, yet since 1960, regional inequality levels have shown little change. These temporal effects have been reported in multiple studies and different periods using the traditional approach to assess absolute β and σ-type convergence among the Mexican states (Mallick & Carayannis, 1994; Esquivel, 1999; Esquivel & Messmacher, 2002; Messmacher, 2002; Rodríguez-Posé & Sánchez-Reaza, 2004; Chiquiar, 2005). Furthermore, an important strand of this literature investigates the role that the trade opening process has had in the apparent accentuation of regional differences in more recent times.

During the 1980s and 1990s, with the emergence of new domestic and international socioeconomic factors, while uneven regional economic conditions seem to have persisted, long-standing concerns have grown in complexity. A set of more puzzling features of the distribution—the so-called north–south spatial pattern, potential spatial inequality traps and, more generally, the apparent self-reinforcement of the spatial structure in the regional system of states—have gained a place in the research agenda. There is the perception that regional heterogeneity has been increasing and this in turn might have the effect of further regional polarization. In addition to the economic dimension, this question acquires, thereby, a social relevance. Substantively, the potential emergence of *hot spots* of social unrest (Esteban, 2002) may be indicative of the alignment of economic and spatial disparities, and vice versa, if spatial interaction is present.

While it is important, examining these phenomena is also methodologically challenging. For years, applied literature on Mexico has focused on a couple of pressing issues, as they become readily available within the well established, yet somehow restrictive, analytical tradition. With the aid of recent theoretical developments, and as new methods and techniques have become available across neighbouring disciplines, these limitations could be overcome. This also opens the possibility of exploring new working hypotheses, which may add to the discussion of substantive socioeconomic issues in the regional context. Studies for many other regions, confronting a variety of regional problems, have already moved in the direction of exploring spatial effects and extending traditional approaches with spatial considerations (Carlino & DeFina, 1995; Rey & Montouri, 1999; Anselin, 2003; Fingleton, 2003, 2004; López-Bazo *et al.*, 2004; Rey, 2004a; Rey & Janikas, 2005; Fingleton & López-Bazo, 2006; Le Gallo & Dall'Erba, 2006).

More recently, the awareness about the spatial nature of the data has increased in the literature for the area, yet a number of methodological questions remain unexplored. In the present study, we maintain that some of the methodological frameworks, commonly used to analyse regional economic inequality in Mexico, are not suited to examine some of the previous concerns, which have a space–time dimension. We further suggest that their proper assessment requires the careful observation of the potential existence of spatial effects in the data and the explicit use of spatial analytical techniques in their evaluation. The aim of the present study is to contribute to this latter task with the application of spatial statistics to the analysis of interregional economic inequality in Mexico for the period of 1940 to 2000. In particular, we will explore the following three related issues:

(1) The evolution of spatial dependence and global inequality *across states*,
(2) the *changes* in heterogeneity *across regions*, and
(3) the sensitivity of inference to the choice of regionalization schemes.

The rest of the paper is organized as follows; in Section 2, we start with a historical overview, followed by a review of some of the features that distinguish the bodies of work that have been addressing regional inequality in Mexico with particular attention given to choice of regionalization schemes. In Section 3 we apply exploratory spatial data analysis to the question of interregional inequality, and the paper closes in Section 4 with a discussion of key findings.

2. Regional Inequality in Mexico: Existing Evidence

2.1. Context

The beginning of the 20th century was a convulsive period in Mexico. Everything points to the fact that economic prosperity during the industrialization process indicated by the dictatorship of Porfirio Diaz (1876–1911) did not reach the vast majority of the population. Indeed, the civil war (1910–1920) has been considered a regional reaction to an extremely centralized regime (Meyer, 1993), and to the social discontent about the wealth distribution (Silva Herzog, 1948; López-Alonso & Condey, 2003). Although it has been just recently systematized, the study of the differences in living standards across social groups and regions of Mexico is a historical issue. Apparently, the seeds of regional differences between the north and Bajío and the centre and south regions can be traced back to the post-revolutionary period (López-Alonso, 2007).

During the 1930s and 1940s, Mexico began to undertake the structural changes that resulted in the 'Mexican miracle' of sustained economic growth in the following three decades. These effects lasted until the 1970s when the development model for industrialization, based on import substitution, could not be sustained anymore and finally collapsed. Meanwhile, from the regional development perspective, Unikel *et al.* (1976) find that regional disparities persisted from the 1940s through to the 1970s. Measured by development indices, regions in the northern border and the Federal District steadily showed better performance than those in the south of the country (Huerta, 2001).

Although the country has experienced dramatic transformations, by far the most drastic has been the transition from a period of import-substitution based industrialization (ISI) to an open economy, and the change from an omnipresent protectionist state to a market-led economy, in about one decade. Through its independent history and along these latter transitions, the desired socioeconomic development has not reached important segments of the population and distributional-related issues, such as inequality, poverty and marginalization have always been a concern at the country and regional levels (Boltvinik, 1982; Hernández Laos, 1984; Stern, 1994).

2.2. Existing Evidence

In order to briefly characterize the main bodies of literature on regional inequality in Mexico, we find it useful to distinguish two questions; the methodological approach and the motivations. On the methodological front, despite the growing interest in spatial effects within the broader convergence literature (Rey & Montouri, 1999; Fingleton, 2003, 2004; Rey, 2004b; Fingleton & López-Bazo, 2006; Rey & Le Gallo, 2009), as well as more generally in analysing regional disparities (Bishop *et al.*, 1994; Levernier *et al.*, 1995; Partridge *et al.*, 1996; Morrill, 2000) in contrast, the predominance of an unidimensional approach in Mexican studies has limited the possibilities of addressing regional phenomena.

Indeed, most studies for Mexico have adopted a convergence approach (Barro & Sala-i-Martin, 1992), in which the main focus is on the question of regional growth. Despite the interest that this approach has awakened, it has also been the focus of many critiques as its theoretical bases and underlying assumptions can be restrictive, for instance, in studying heterogeneous regional systems (Quah, 1993). The simple regression towards the mean, commonly used to operationalize β convergence, will be informative on the *catching-up* of an *average* state, but it is silent on regional specificities. In other words, the approach informs about a very well-defined set of regional dynamics, but it has little to say about spatial change. In an effort to reconcile these questions, a distribution-free approach also has been applied to analyse the convergence issue among Mexican states (García-Verdú, 2005). While this approach has been helpful in broadening the range of phenomena under investigation, the dynamics taking place in space have been overlooked.

Meanwhile, when the focus is purely on inequality (instead of differences in growth) in the Mexican economy, the emphasis has been placed on the interpersonal dimension of the problem and, more occasionally, on the regional question. This is understandable since inevitably some level of detail is lost with the aggregation. Also, the richness of the micro-data has not been fully exploited in the latter case. Nonetheless, confirmatory work sometimes crosses dimensional boundaries to investigate regional effects. For example, Bouillon *et al.* (2003) find that the rising income inequality from 1984–1994 has deteriorated the living conditions in the southern states. Along the same lines, Lustig *et al.* (1998) find that the greatest contribution to inequality may come particularly from the southeast region, i.e. Chiapas, Guerrero and Oaxaca, given the increase in poverty rates this region experienced in the same period (17% to 37%). Despite the fact that these findings shed some light on the regional dimension of inequality, there are important consequences when moving from the inter-personal to the spatial dimension, namely aggregation effects, which remain generally unexplored.

Closely related to these studies are those analysing regional imbalances (Unikel *et al.*, 1976; Hernández Laos, 1984, 1997). In these studies, the focus is not on one specific indicator but usually on a group of variables, or factors, which are used as proxies of the level of regional development. Also common is the use of the per capita regional income or product as a rough approximation to the level of regional development. As in previous studies, a number of regionalization schemes have been proposed under this line of research, but formal spatial considerations are mostly absent.

In terms of the substantive motivation, one can distinguish two driving concerns: political and theoretical. Both have mostly motivated the short-term perspective in the analysis. In the first case, the search for explanations for regional disparities or persistent patterns frequently has a political component. Under discussion is, for instance, the potential consequences of changes in trade policy, with a focus on the *pre* and *post* reform periods. Also, the extent to which regional policies may, or may not, have a role in reversing such patterns. The counterpart is theoretical. It partially resides in the expectations that opening processes have generated. As argued by Fujita *et al.* (2001), a greater openness to world markets may have effects on regional inequality. There is now mounting evidence of countries that, having gone through opening processes, have also experienced regional adjustments (Sheahan, 1997; Haddad *et al.*, 2002; Kanbur & Zhang, 2005). In contrast, long-run analysis usually relies on the analytical tradition of development theories (Myrdal, 1957; Hirschman, 1958; Williamson, 1965; Amos Jr, 1983) in looking for explanations to unequal regional performance.

Drawing from theoretical developments in regional science and methodological research (Anselin, 1988; Krugman, 1999; Fujita *et al.*, 2001) a body of work has more recently approached the question of regional disparities with a different set of questions. Among the testable hypotheses are the role of the regional structure and spatial interactions in explaining uneven regional performance (Oosterhaven *et al.*, 2001; Anselin *et al.*, 2004; Ramajo *et al.*, 2008). Under this approach, disentangling the interacting forces in the regional context might be helpful to the design of regional policies directed to reduce regional disparities. For Mexico, a couple of studies are already using spatial statistics and geocomputation to shed light on the understanding of regional patterns (Aroca *et al.*, 2003, 2005), analyse income mobility at the regional level (Sastré-Gutiérrez & Rey, 2007) and to address methodological issues when dealing with spatial units (Sastré-Gutiérrez & Rey, 2008).

2.3. Regionalization Schemes

We turn now to the studies that have used explicit regionalization schemes as a part of their research design to illustrate a variety of related questions on regional disparities for Mexico (Unikel *et al.*, 1976; Hernández Laos, 1984, 1997; Hanson, 1998a, 1998b, 2003; Esquivel, 1999; Arroyo, 2001; Aroca *et al.*, 2003, 2005; Bouillon *et al.*, 2003; Chiquiar, 2005). Although this should be indicative of an active interest in spatial considerations, in general, there is a lack of agreement in the regional schemes used by these studies. Interestingly, even when the results have shown qualitative changes to slight variations in the partition criteria, the sensitivity of the conclusions regarding the dynamics of inequality, to the choice of partitioning scheme, remains unexamined.

In Aroca *et al.* (2003), a regionalization scheme of five groups of states is used to analyse polarization for the period 1970 to 2000.[1] The study uses spatial statistics and distributional dynamics to analyse spatial patterns in levels and growth rates of income per capita. The spatial structure of levels of income per capita is clearly pronounced in the south of the country, but no such structure is found at the centre or the north part of the country. Interestingly, when the northern region is reconstructed to exclusively include the border states, strong evidence of spatial clustering is found.

Using the same regionalization scheme, Aroca *et al.* (2005) investigate spatial patterns and the presence of so-called *convergence clubs*, for the periods of *pre* and *post* reforms. Three regional criteria are applied, the first one is based on simple contiguity, the second on geographic bands and the third one on distance from the United States. Spatial dependence is found statistically significant for the three regional definitions and two clusters are identified. The first one composed of the group of states that share a border with the United States and the second one is a group of southern states. The study also uses decomposition techniques to analyse regional inequality and finds that between-group inequality accounts for 50% of overall inequality from 1970–1985 and 72% of the increase in total inequality from 1985–2002. This indicates an increase of interregional inequality throughout the period. While the divergent paths between the north and south of the country seem to have underpinned the reversal of convergence in Mexico, most of the increase in inequality (94%) is found to occur in the period 1985–1993, prior to NAFTA.

Esquivel (1999) analyses regional convergence during 1940–1995 using seven groups of states. According to this study, inequality across states decreased at a speed of 1.2% per year during the period, and two distinct periods are identified in that process. From 1940 to 1960 inequality decreased rapidly followed by a longer period in which regional inequalities have remained relatively stable. In addition to the standard absolute β- and σ-convergence specifications, the study includes dummy variables to investigate regional effects within the same framework. States in the north, Pacific, Gulf and capital regions, are found to grow faster than those in the south, centre and centre-north. No signs of interregional convergence are found and instead rigidity is the clear feature of the distribution in the study period. Arroyo (2001) analyses regional convergence for the period 1980–1999 using five regions, finding that regional inequality increased during this period together with persistence in the income ranking of the states.

Hanson (1998b) examines wage inequality and tests the predictions of the New Economic Geography (NEG) for the Mexican case, using five regions to identify geographic patterns. The sample period (1980–1993) is split into the *pre*- and *post*-trade reform periods. Evidence of changes in regional wages, consistent with NEG predictions are found. In particular, regional disparities exist as a result of the wage premium paid to skilled workers located in the border region. Employment growth after the liberalization is higher in regions that are relatively close to the United States and also higher in regional industries that are located near their upstream and downstream industries. Therefore, location-specific factors, beyond proximity to the United States are also relevant in explaining how regional industries have adjusted to trade. In a subsequent study, Hanson (2003) classifies the states into six regions. Again, evidence of spatial disparities is found. Young, highly educated workers living in the border region have had higher wage gains than less-educated workers living in the southern region.

Bouillon *et al.* (2003) use eight groups of states to investigate regional effects of rising household income inequality during 1984–1994. One of the hypotheses tested is uneven regional development (such as the lagging southern region) as an explanatory variable for the increase in inequality. The results show that the fixed effect of the southern region alone can explain 9% of the increase in income inequality. Income in the southern rural areas fell 14% during the study period, while rural income nationwide fell only 0.5%.

Other studies have used regionalizations to analyse indicators of regional development as well. For instance, Hernández Laos (1984) follows Unikel *et al.* (1976) in the regionalization criteria, using eight regions to define the regional structure. Although reference is made to possible modifications in the results to the change of regional definition, this possibility was not explored. In a subsequent paper, the same author uses 10 regions to describe the regional structure of Mexico in analysing regional development (Hernández Laos, 1997).

3. Mexican Regional Inequality Revisited

While the previous section reveals a growing number of studies have turned a spatial lens to the question of Mexican economic development, the specific regionalization schemes adopted have varied across these studies. To date, the question of the sensitivity of inferences about regional inequality dynamics to this choice remains unexamined. Here we take up this issue by explicitly considering these alternative definitions, comparing their aggregation profiles and contrasting inequality decompositions derived from the different schemes.

The data set we use in the empirical exercise was originally constructed by Esquivel (1999) using different sources. It covers the period 1940–1995 and is one of the longest and most reliable data series constructed for Mexico with decadal per capita gross state product (GSP). The details about the construction of the original data series are found in Esquivel (1999). We partially reconstructed the series with official data sources from the Instituto Nacional de Geografía e Informática (INEGI), Banco de México (BANXICO) and the Consejo Nacional de Población (CONAPO) and used that information to extend the original data series up to 2000.[2]

We begin from a slightly different perspective from those in previous studies, in that we feel both the spatial and temporal dimensions of the data need to be considered jointly. Figure 1 contains quintile maps for the relative per capita state gross domestic product for the first (1940) and last (2000) decade in our sample. Here relative is defined as a percentage of the mean value. At first glance a comparison of the two maps suggests a familiar north–south pattern to relative incomes with the richer states typically found in the north and the poorer states in the southern portion of the country.

The snapshots provided by the quintile maps, while revealing, are silent on the intervening periods. The quintile classification does not speak to the question of polarization or multimodality in the distribution at a given point in time (since a histogram of the quintile distribution would be roughly flat). At the same time, the degree of inequality in the distribution is difficult to ascertain from the map. More specifically, we see that the upper bound on the richest quintile has decreased from 3.581 in 1940 to 2.550—indicating that the ratio of per capita GSP for the richest

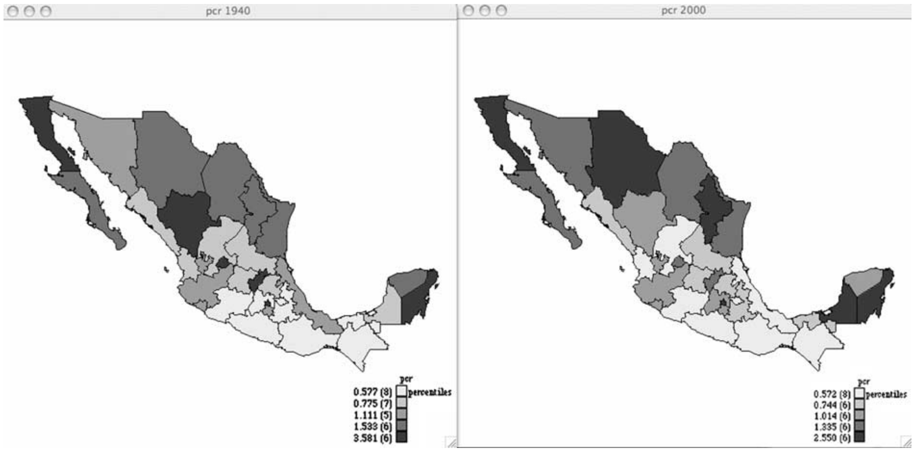

Figure 1. Relative GRP 1940 and 2000.

to poorest state has declined, yet we do not know anything about the distribution of values within each quintile class, or the degree of mobility of individual states across these classes over time.

3.1. Changes in Interregional Inequality

Figure 2 portrays the dynamics of inequality (left panel) and spatial clustering (right panel). Our inequality measure is based on the adaptation of the Theil Index to regional analysis as follows:

$$T^t = \sum_{i=1}^{n} s_i^t \log(ns_i^t) \tag{1}$$

and

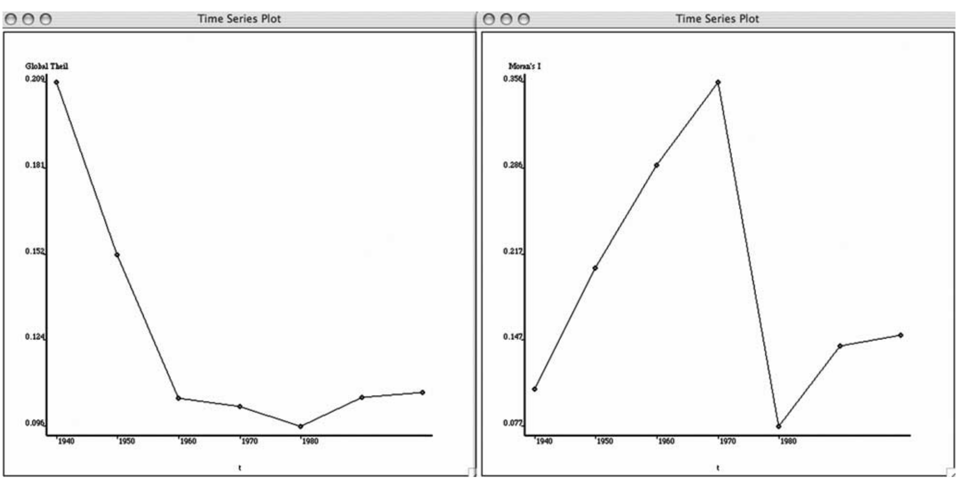

Figure 2. Inequality and spatial autocorrelation.

$$s_i^t = y_i^t / \sum_{i=1}^{n} y_i^t, \qquad (2)$$

where n is the number of regions and y_i^t is per capita income in region i in period t. The T index is bounded in the interval $[0, \log(n)]$, with 0 meaning perfect equality, and the value of the $\log(n)$ corresponding to income concentration in one single region. T will measure systematic or global inequality of income between the regional observations at one point in time.

The global measure of inequality T is found to drop sharply from its maximum to a relatively flat value since 1960. We also measure the level of global spatial autocorrelation in the series using Moran's I:

$$I = \left(\frac{n}{S_0}\right) \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} z_i z_j}{\sum_{i=1}^{n} z_i^2}, \qquad (3)$$

where $z_i = y_i - \bar{y}$ and

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \qquad (4)$$

with w_{ij} an element of a spatial weights matrix, defined here using simple contiguity. This measure of spatial autocorrelation starts off relatively low but displays a marked increase up through the 1970s. The increase in the value of the statistic is erased in one decade as the value in 1980 falls below the 1940 value. Following 1980 there is a slight increase in spatial clustering.

Although there is substantial variation in the measure of spatial autocorrelation over the 60 years, the statistic is significant in all decades with the exception of 1980. Thus the pattern of relative incomes across Mexican states cannot be considered random in most years. This would bring into question any statistical approach resting on an assumption of random sampling and poses a new stylized fact about the Mexican space economy that needs to be addressed from a theoretical perspective.

As stated in Mills & Zandvakili (1997, p. 1) 'a major shortcoming [of measures of inequality] is the lack of statistical measures of relative size.' This relates to the question of the significance of a computed value of inequality relative to a hypothesized value. As a result, methods in regional inequality have been restricted to a descriptive profile, i.e. reporting the value of an inequality measure at one point in time, tracking the value over time, or using the decomposition properties to identify interregional and intraregional shares of inequality. The application of methods for hypothesis testing about measures of regional inequality is largely absent from the literature (Rey, 2004a). While asymptotic methods are available for some inequality statistics, there are some difficulties in applying them in small samples usually used in regional analysis. Moreover, those methods also rest on the assumption of random samples and observational independence which are at odds with the empirical regularity of spatial autocorrelation in regional income series.

To address these limitations we extend the approach suggested by (Rey, 2004a) to provide an inferential basis for regional inequality statistics. We examine two sets of hypotheses. The first concerns trends in *global inequality*, that is whether inequality has significantly changed for the Theil statistic over the period t to $t+k$:

$$H_0 : T^t - T^{t+k} = 0,$$
$$H_1 : T^t - T^{t+k} \neq 0. \tag{5}$$

Our test statistic in this case is:

$$\delta T = T^t - T^{t+k} \tag{6}$$

and we develop the sampling distribution for this statistic under the null using random labelling in time. Table 1 summarizes the operation of this form of randomization. For each pair of years considered (t and $t+k$) we first calculate the observed levels of inequality for the first and second year, which are represented by the first two columns of the table. To create a realization of a process in which inequality is constant over time, we randomly relabel the time index for each state's income. As reflected in the third and fourth columns of Table 1 this results in a mixing of the income values for each state over the two years in a random fashion. For a given relabelling, we recalculate the global T statistic for each of the years and compute the difference in inequality over the period. We repeat this random labelling a large number of times to build up a distribution of our test statistic. Since there are n states, there are a total of 2^n possible random labellings. In our case $n = 32$ so there are over four billion possible random labellings. We take a random sample of 9,999 random labellings from this set to develop the sampling distribution of our test statistic and to obtain a pseudo-p-value for our test statistic as follows:

$$p(\delta T|H_0) = \frac{1 + \sum_{l=1}^{9,999} \psi_l}{10,000}, \tag{7}$$

where $\psi_l = 1$ if $|\delta T| < |\delta T_l|$, otherwise $\psi_l = 0$, and δT_l is the difference in the global inequality for the lth relabelling.

Table 2 reports the results of applying this framework to the case of global inequality changes over each pair of decades. The diagonal elements of the table report the level of global inequality for that decade (i.e. $T^{1950} = 0.152$), while the above diagonal elements report the difference between inequality associated with the column year and row year. For example, the value in row 1, column 2 is the difference between $T^{1950} - T^{1940} = 0.152 - 0.209 = -0.057$. The p-value for this difference is reported in the corresponding value below the diagonal, with significant p-values in bold. Thus, the drop in regional inequality between 1940 and 1950 is significant at a 5% level.

As with the case of the differences between 1940 and 1950, the rest of the differences between the initial year and the other years in the sample are statistically

Table 1. Cross-period random labelling.

observed		H_0	
t	$t+k$	$t^\star$	$t+k^\star$
$y_{1,t}$	$y_{1,t+k}$	$y_{1,t+k}$	$y_{1,t}$
$y_{2,t}$	$y_{2,t+k}$	$y_{2,t}$	$y_{2,t+k}$
$y_{3,t}$	$y_{3,t+k}$	$y_{3,t}$	$y_{3,t+k}$
$y_{4,t}$	$y_{4,t+k}$	$y_{4,t+k}$	$y_{4,t}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
$y_{n,t}$	$y_{n,t+k}$	$y_{n,t}$	$y_{n,t+k}$

Table 2. Temporal changes in inequality.

	1940	1950	1960	1970	1980	1990	2000
1940	0.209[a]	−0.057[b]	−0.104	−0.107	−0.113	−0.104	−0.102
1950	**0.033**[c,d]	0.152	−0.047	−0.050	−0.057	−0.047	−0.046
1960	**0.012**	0.392	0.105	−0.003	−0.009	0.000	0.002
1970	**0.005**	0.343	0.769	0.102	−0.006	0.003	0.005
1980	**0.001**	0.263	0.610	0.678	0.096	0.010	0.011
1990	**0.029**	0.413	0.992	0.974	0.724	0.105	0.001
2000	**0.008**	0.409	0.893	0.748	0.555	0.969	0.107

[a]Diagonal elements: T_t
[b]Above diagonal elements: $\delta T = T_{t+k} - T_t$
[c]Below diagonal elements: $p(\delta T | H_0 : T_{t+k} = T_k)$
[d]**Bold** indicates significant at $p < 0.05$

significant at the 5% level as well. No other changes in regional inequality in 60 years have been as dramatic as the changes of inequality across Mexican states relative to the 1940s. From this standpoint, neither the decrease in the dispersion during the 1970s nor the reversion of the process during the 1980s, are statistically significant regional inequality changes.

Without reliable data series before 1940 it is not clear if the inequality curve reached its maximum in the 1940s. Nevertheless, a quick look at the post-revolutionary period indicates that the redistributive efforts initiated by the Cardenismo (1934–1940) had no historical precedent. The investment related to the industrialization process and directed to strategic growing centres in the country, apparently implied economic redistribution across states. The initiatives of this period might be showing its first signs at the beginning in the 1940s, but the following presidential term (Manuel Avila Camacho, 1940–1946) continued this industrialization impulse. Therefore, the effect seems to have been magnified in a big wave, with a turning point in the 1940s followed by a large drop of regional inequality in the following decade. By contrast, previous studies have identified increasing interregional differences between 1900 and 1940 (Unikel *et al.*, 1976; Hernández Laos, 1984). It has been suggested that the same redistributive effect of selective allocation of resources might have also had its effects on interregional inequality trends.

3.2. Differences in Interregional Inequality

Our second set of hypotheses concern the issue of the definition of regions in the analysis of interregional inequality in Mexico. In assessing the original concern about spatial heterogeneity across Mexican regions, the focus of the investigation should be directed to a key aspect, which is the aggregation of areas into homogeneous and spatially contiguous regions. As mentioned, methodological aspects in achieving this homogeneity have been mostly ignored in studies for the area and are explored next. Also, as part of the aggregation process, two basic conditions have to be considered; first is that regions must be exhaustive—which in our case implies including all 32 states—and second, they should be mutually exclusive—i.e. each state should be assigned to one single group within a particular scheme.

Table 3. Regional definitions.

	Regionalization Scheme					
State	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
Aguascalientes	4	4	2	2	3	4
Baja California	1	1	1	1	5	2
Baja California Sur	1	1	2	2	6	2
Campeche	5	5	5	6	4	1
Chiapas	5	5	5	5	7	3
Chihuahua	1	2	1	1	5	2
Coahuila	2	2	1	1	5	4
Colima	4	4	3	3	6	4
Distrito Federal	3	3	4	4	1	5
Durango	1	2	2	2	3	4
Guanajuato	4	4	3	3	3	5
Guerrero	5	5	5	5	7	3
Hidalgo	3	3	3	3	2	3
Jalisco	4	4	3	3	6	4
Mexico	3	3	4	4	1	5
Michoacan	4	4	3	3	7	3
Morelos	3	3	3	3	2	5
Nayarit	4	4	2	2	6	1
Nuevo Leon	2	2	1	1	5	4
Oaxaca	5	5	5	5	7	3
Puebla	3	5	3	3	2	3
Quertaro	3	4	3	3	3	5
Quintana Roo	5	5	5	6	4	1
San Luis Potosi	4	4	2	2	3	1
Sinaloa	1	1	2	2	6	2
Sonora	1	1	1	1	5	2
Tabasco	5	5	5	6	4	1
Tamaulipas	2	2	1	1	5	4
Tlaxcala	3	3	3	3	2	3
Veracruz	5	5	3	3	4	1
Yucatan	5	5	5	6	4	1
Zacatecas	4	4	2	2	3	1

In all we consider six different regionalization schemes, the definitions of which are contained in Table 3 with the geographical distributions displayed in Figures 3–8.[3] Three of the regional schemes are adopted from previous studies by Hanson (1998b, 2003) and Esquivel (1999). The criteria for the grouping have not been reported by the authors. What is apparent is the use of geographical bands with contiguity constraints, but the use of some specific algorithm for this definition is not mentioned. Additionally, in order to consider the normative perspective, we have included two synthetic classifications based upon the original official definitions, which groups the states into *mesoregions* and has been used in Mexico for regional policy design by the National Development Plan 2001–2006. The classification in *mesoregions* was made by the National Institute of Statistics, Geography and Informatics (INEGI) from Mexico. A distinctive characteristic in this regionalization is that it lacks the basic criteria of exclusivity of the states. In particular, Chihuahua and Durango pertain to two regions in the same map, Northeast and Northwest; Puebla pertain to Southeast and Center, and Queretaro is assigned to Center-Occident and Center in the same map. In principle, this

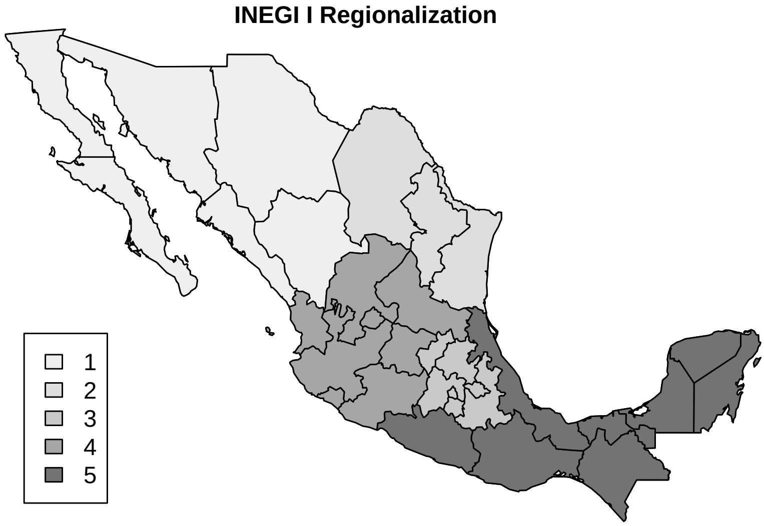

Figure 3. INEGI I regionalization.

feature makes this classification inappropriate for interregional analysis and certainly misleading for policy purposes, since a policy intervention targeted at this state will impact two regions simultaneously and thus cloud the analysis. In order to overcome the technical difficulties, we synthetically constructed two different schemes assigning the states to one single region each time, obtaining two different regional schemes out of the original one. These are reported as INEGI regions(I) and INEGI regions(II) in Table 3.

In addition to the five schemes taken from previous studies, we apply a spatially constrained regionalization algorithm to generate a sixth classification scheme. Specifically we adopt the *max-p* algorithm (Duque *et al.*, 2009) which generates regions by grouping states together to respect a contiguity constraint and to

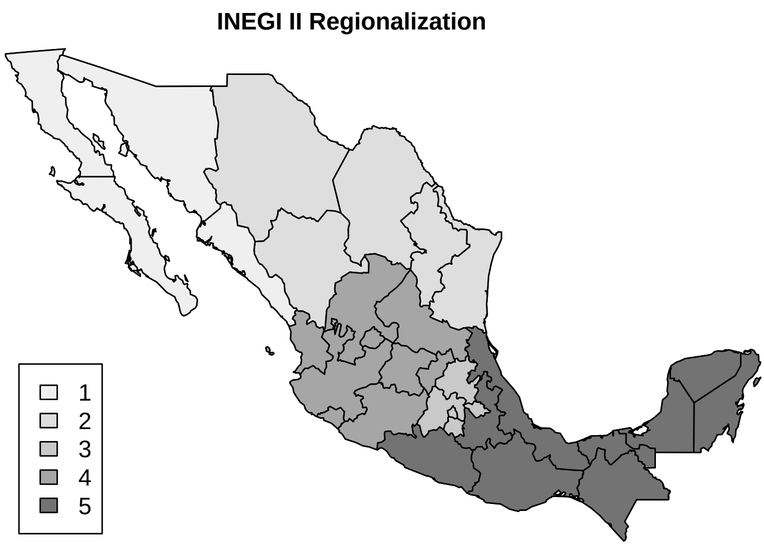

Figure 4. INEGI II regionalization.

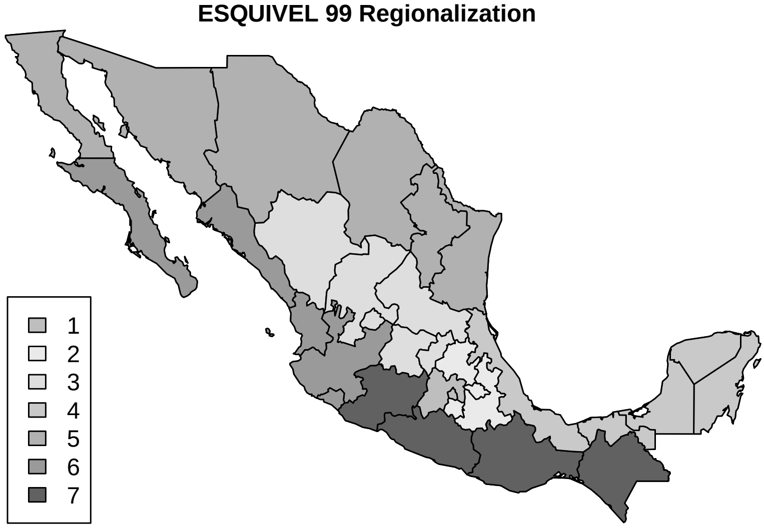

Figure 5. ESQUIVEL regionalization.

maximize intraregional homogeneity with regard to per capita GDP. Additionally the approach uses a base threshold, which as applied here consists of a minimum number of states for a region. In our case we based this threshold on the average number of states observed in the five previous regionalization schemes. Given these constraints, the max-p is distinct from other regionalization algoirthms in that the number of regions to be formed is endogenously determined, rather than having to be specified *a priori*.

As is summarized in Table 4, the six different regionalization schemes vary in a number of dimensions having to do with the cardinality of the regional membership. The two INEGI definitions result in the fewest number of regions (5) while the definition based on Esquivel (1999) has the maximum number of

Figure 6. Hanson98 regionalization.

Figure 7. Hanson03 regionalization.

partitions of the states (7). At first glance this might suggest that the larger number of regions would result in a smaller number of states in each region, on average. While this is true for the case of the six schemes here, the extremes of the cardinalities are not a simple function of the number of regions, as the smallest cardinalities (i.e. regions with only two states) are found in schemes with different number of regions (i.e. 5, 6, and 7), while the same holds for the maximum cardinalities where schemes with 5 and 6 regions result in individual regions composed of 10 states.

Usually, the regional decomposition of inequality is undertaken with one of the entropy indices in Theil (1967, 1972), according to some partition of the units into

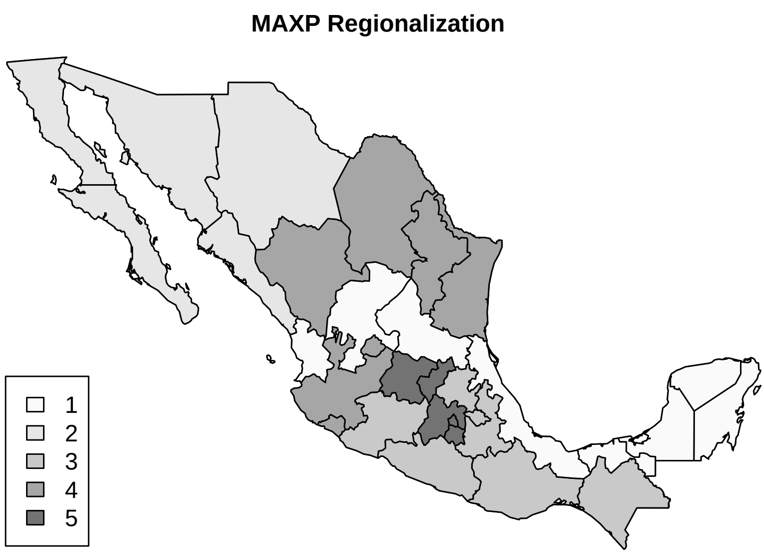

Figure 8. MAXP regionalization.

Table 4. Regionalization cardinalities.

Scheme	Regions	Minimum States	Average states	Maximum states
INEGI I	5	3	6.4	8
INEGI II	5	4	6.4	9
HANSON98	5	2	6.4	10
HANSON03	6	2	5.3	10
ESQUIVEL99	7	2	4.6	6
MAXP	5	5	6.4	8

mutually exclusive and exhaustive regions (Shorrocks & Wan, 2005). The decompositional property of the Theil index has been explored in several studies of regional inequality (Fan & Casetti, 1994; Akita & Kawamura, 2003; Noorbakhsh, 2003; Rey, 2004a; Shorrocks & Wan, 2005). Conceição & Ferreira (2000) define the components of inequality as overall or global inequality, inequality between groups and inequality within groups. From a spatial perspective, the between share corresponds to interregional inequality, and the within share will be referred to as intraregional inequality. When comparing groups, the requirement to obtain equality is that the population share in each group should be equal to the income proportion of that group, this accounting for the interregional share of inequality. The share not considered in this last measure will be that existing within groups, i.e. the intraregional share. To operationalize the interregional and intraregional components, the n spatial observations are placed into ω groups, which are exhaustive and mutually exclusive. From this grouping it follows that the global statistic can be written as follows:

$$T^t = \sum_{g=1}^{\omega} s_g^t \log(n/n_g s_g^t) + \sum_{g=1}^{\omega} s_g^t \sum_{i \in g} s_{i,g}^t \log(n_g s_{i,g}^t), \tag{8}$$

where n_g is the number of observations in group g (and $\Sigma_g n_g = n$), $s_g^t = \Sigma_{i \in g} y_{i,g}^t / \Sigma_i^n y_i^t$ is the share of total income accounted for by group g, and $s_{i,g}^t = y_{i,g}^t / \Sigma_{i=1}^{n_g} y_{i,g}^t$ is region i's share of group g's income.

In a spatial context, the first term at the right of equation (8) is the interregional component or between group, which measures the distance between the average income of the aggregated groups, and the second term will be the intraregional component or within group inequality and measures the distances between the incomes of regions pertaining to the same group or partition (Rey, 2004a). Figure 9 contrasts the interregional component, expressed as a share of inequality across the different regionalization schemes and over time. The trends are generally similar across the different schemes with a broad inverted-U pattern with the maximum relative level of interregional inequality being in 1970.

While the trends appear to be in agreement across the six schemes, the relative importance of interregional inequality is rather more distinct across the definitions. With the exception of 1990, the ESQUIVEL scheme generates the highest share of interregional inequality, while HANSON03 is second highest (they are reversed in 1990), followed closely by MAXP. Also consistent is the lower level of interregional inequality reflected by the two INEGI regional schemes, with the HANSON98 definition falling in the middle.

Figure 9. Interregional inequality dynamics.

Moving beyond a descriptive analysis of these trends, we carry out two sets of inferential tests related to these regional definitions and their implications for interregional inequality measurement. The first is whether each of the regional schemes is capturing a significant level of interregional inequality. In other words, is the interregional inequality share significantly different from what would be expected if incomes were randomly distributed across the states and regions. The second test examines whether the differences *across* the regional schemes are significant. Here we are interested in the question of whether the choice of the specific regionalization scheme matters.

To examine both sets of questions we rely on random spatial permutations following the approach introduced by Rey (2004a). More specifically, for each year in our sample we calculate the interregional inequality decomposition from (8) using each of the six different regional partitions. We then randomly shuffle the states about the actual map, and recalculate the decomposition for the synthetic map. We generate 9,999 such synthetic maps and associated statistics to develop the sampling distributions of our test statistics under the null that incomes are randomly distributed across space in Mexico.

For our first question we are comparing the observed share of interregional inequality against the collection of inequality shares from the synthetic maps for a given year and partition. These results are reported in Table 5 as *p*-values. For example, in 1960 the interregional inequality share generated by the INEGI I scheme was significant, as only 19 of the interregional inequality shares from the 9,999 random maps was as extreme as the observed value from the actual map.

Table 5. Interregional inequality tests over time (*p*-values).

Definition	1940	1950	1960	1970	1980	1990	2000
INEGI I	0.154[a]	0.124	**0.002**[b]	**0.000**	**0.009**	**0.007**	**0.006**
INEGI II	0.107	**0.091**	**0.003**	**0.000**	**0.005**	**0.004**	**0.003**
HANSON98	0.501	0.286	**0.010**	**0.005**	0.301	0.516	0.403
HANSON03	0.373	0.315	**0.002**	**0.000**	**0.028**	**0.079**	**0.030**
ESQUIVEL99	0.435	0.299	**0.018**	**0.006**	0.249	0.461	0.328
MAXP	**0.062**	**0.049**	**0.002**	**0.000**	**0.032**	**0.025**	**0.017**

[a] *p*-value based on random spatial permutations
[b] **Bold** indicates signifcant at $p < 0.10$

Based on this interpretation, the qualitative inference regarding the peak of interregional inequality in 1970 is found to be statistically significant for each of the regionalization schemes. The inferential results are more nuanced however, as the broad agreement in significant interregional inequality is also reflected for 1960 as well.

At the same time, there are some important distinctions across the regional definitions. Most striking is that MAXP is the only scheme that detects significant interregional inequality in each decade. HANSON98 and ESQUIVEL99 only pick up interregional inequality in 1960 and 1970, while the three other schemes show significant interregional inequality from 1960 forward through the remaining decades.

The results in Table 5 are based on marginal tests involving each partition scheme alone against its own distribution under the null of spatial randomness. We also explicitly compare the *differences* between each pair of inequality shares for a given year using the same random permutation strategy. Here we calculate the observed difference in the interregional inequality shares from the two sets of regional definitions, then we repeat that calculation for the random maps. We then compare the observed difference to the expected value of the differences obtained from the random permutations to develop a test of the differences.

The results of these tests are reported by decade in Table 6. For each decade-block, the values on the diagonal of the matrix are the share of interregional inequality for that year and regional systems. Above the diagonal are reported the differences in the interregional share between the system on the column and row. Thus we see that the interregional share for the HANSON03 (0.065) system is higher than that from the HANSON98 scheme (0.035) for 1940. Finally, the values below the diagonal are the *p*-values for the difference between the inequality shares from the row system and column system. Continuing on with this example, the difference between the HANSON98 and HANSON03 schemes is found to be significant in 1940 (p-value $= 0.041$).

There is clear evidence that the choice of regionalization scheme matters particularly in the latter three decades as the HANSON03, ESQUIVEL99, and MAXP schemes are found to be significantly different from the INEGI I and HANSON98 schemes in most comparisons. Interestingly, however, we find no significant differences between the HANSON03, ESQUIVEL99, or MAXP schemes in any of the years. By the same token, the tests do not distinguish between HANSON98, and the two INEGI schemes. Thus, there appear to be differences between two sets of regionalization schemes, with the first consisting of HANSON03, ESQUIVEL99, and MAXP, and the second HANSON98, INEGI I and INEGI II. While the temptation exists to recommend one approach to regionalization over the others, we do not do so here as our purpose is to examine the sensitivity to inferences about interregional inequality dynamics to the choice of regionalization scheme. Moreover, such a choice is not straightforward as the regionalizations differ in their cardinalities.

4. Conclusion

This paper has examined interregional inequality dynamics over a 60 year period for the states of Mexico. Two broad sets of questions were central to the investigation of these dynamics: first, did the amount of interregional inequality

Table 6. Interregional inequality differences.

1940	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.032	−0.003	0.003	0.033	0.037	0.033
INEGI II	0.809	0.029	0.006	0.036	0.040	0.036
HANSON98	0.874	0.744	0.035	0.030	0.034	0.030
HANSON03	0.133	0.122	**0.041**	0.065	0.004	−0.001
ESQUIVEL99	0.172	0.126	0.166	0.813	0.069	−0.004
MAXP	0.111	0.083	0.174	0.985	0.894	0.065

1950	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.029	0.001	−0.001	0.021	0.024	0.020
INEGI II	0.927	0.030	−0.002	0.020	0.024	0.020
HANSON98	0.947	0.913	0.028	0.022	0.025	0.021
HANSON03	0.229	0.220	**0.046**	0.050	0.003	−0.001
ESQUIVEL99	0.243	0.219	0.149	0.802	0.053	−0.004
MAXP	0.180	0.197	0.204	0.967	0.846	0.049

1960	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.038	0.004	0.014	0.019	0.024	0.015
INEGI II	0.523	0.043	0.010	0.015	0.019	0.011
HANSON98	0.157	0.307	0.053	0.005	0.009	0.000
HANSON03	0.106	0.199	0.284	0.057	0.005	−0.004
ESQUIVEL99	0.098	0.140	0.426	0.569	0.062	−0.009
MAXP	0.153	0.302	0.968	0.701	0.469	0.053

1970	INEGII	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.042	0.002	0.018	0.025	0.032	0.024
INEGI II	0.762	0.044	0.016	0.023	0.030	0.022
HANSON98	0.059	0.123	0.059	0.007	0.014	0.006
HANSON03	**0.027**	0.051	0.158	0.066	0.007	−0.001
ESQUIVEL99	**0.013**	0.030	0.206	0.386	0.074	−0.008
MAXP	**0.017**	0.031	0.528	0.940	0.514	0.065

1980	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.018	−0.002	0.014	0.028	0.030	0.013
INEGI II	0.745	0.017	0.015	0.029	0.031	0.015
HANSON98	0.109	0.096	0.032	0.014	0.016	−0.000
HANSON03	**0.016**	**0.009**	**0.029**	0.046	0.002	−0.014
ESQUIVEL99	**0.016**	**0.012**	0.130	0.794	0.048	−0.016
MAXP	0.152	0.093	0.975	0.173	0.167	0.032

1990	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.015	−0.001	0.015	0.040	0.039	0.023
INEGI II	0.796	0.013	0.016	0.042	0.041	0.024
HANSON98	0.112	0.112	0.030	0.025	0.024	0.008
HANSON03	**0.004**	**0.002**	**0.011**	0.055	−0.001	−0.017
ESQUIVEL99	**0.008**	**0.006**	0.060	0.919	0.054	−0.016
MAXP	**0.034**	**0.031**	0.444	0.152	0.218	0.038

2000	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
INEGI I	0.018	−0.002	0.018	0.036	0.036	0.022
INEGI II	0.743	0.016	0.021	0.038	0.038	0.024
HANSON98	0.079	0.056	0.036	0.017	0.017	0.004
HANSON03	**0.003**	**0.005**	**0.032**	0.054	0.000	−0.014

Table 6 (*Continued*)

1940	INEGI I	INEGI II	HANSON98	HANSON03	ESQUIVEL99	MAXP
ESQUIVEL99	**0.008**	**0.008**	0.164	1.001	0.054	−0.014
MAXP	**0.036**	**0.026**	0.766	0.228	0.308	0.040

[a]Diagonal elements: IR_r.
[b]Above diagonal elements: $\delta = IR_c - IR_r$
[c]Below diagonal elements: $p(\delta|H_0 : IR_c = IR_r)$
[d]**Bold** indicates signifcant at $p < 0.05$

significantly *change* over this period; and second: does the choice of regionalization system matter in terms of measuring the amount of interregional inequality?

In order to address these questions we extend approaches to inequality decomposition to incorporate computationally based approaches to inference that allow us to move beyond a descriptive analysis of inequality patterns. In doing so we find that with respect to the first question there have been significant drops in overall income inequality between Mexican states since 1940, but that the drops are concentrated in the first two decades and further reductions in inequality have not been achieved since the 1960s.

Regarding the question of interregional inequality we find the choice of regionalization scheme matters both qualitatively and quantitatively. The share of global inequality attributed to the interregional component is sensitive to regional compositions as there are consistent differences in the relative magnitudes of interregional inequality across different regional definitions and these differences are found to be statistically significant in the majority of cases.

Notes

1. We return to a detailed analysis of the regionalization schemes in our empirical analysis below.
2. More details on the data preparation are available upon request.
3. The region identifiers in the legends of Figures 3 to 8 are linked to the states in Table 3.

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