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Spatial inequality and place mobility in Mexico: 2000 –2015

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ABSTRACT

In this paper we examine the relationship between spatial inequality, place mobility, and spatial polarization in Mexico. We use data for 2457 Mexican municipios from 2000 to 2015. We apply classical and spatial Markov chains to measure spatial income dynamics and we employ a decomposition of spatial inequality to measure spatial polarization. In doing so, we ask the following questions: Has spatial inequality increased across Mexican municipios since 2000? What has been the role of place mobility in any changes in overall spatial inequality? Finally, we examine what the main components of place mobility have been over this period. We find evidence of a strong spatial dependency between municipios that has increased over time but we find no clear pattern at the state scale. Intra-state municipal inequality has relatively declined while Inter-state municipal inequality polarization has increased. We also find clear evidence that transitional dynamics of municipio incomes are influenced by spatial context. Substantial evidence shows that municipio income mobility is driven by a growth component that could be likely reflecting the devaluation of the peso over this period. Exchange mobility is found to be a more important component of overall place mobility than dispersion (inequality) mobility.

1. Introduction

Long-standing spatial inequalities within national systems have been identified as leading to a rise in political populism with strong territorial as opposed to social foundations (Rodríguez-Pose, 2018). The recent history of Mexico serves as an exemplar of this dynamic. In 2018, for the second time in history, a political party other than the PRI (Institutional Revolutionary Party) had won the Mexican Presidential election. Andres Manuel Lopez Obrador (AMLO) accomplished what he had initially envisioned in 2006, taking away power from corrupt political parties and institutions. AMLO's victory was no small feat. With his newly formed political party National Regeneration Movement (MORENA), he had accomplished a landslide victory over rival political parties PRI and PAN by winning thirty-one out of the thirty-two Mexican states.

Fig. 1 shows the presidential election results from 2012 to 2018. The staggering contrast in the results shows how AMLO leveraged the outrage from those who had suffered the most. His victory was backed by the social unrest born out of increased corruption, poverty, and violence that had plagued the country.

The case of Mexico offers an opportunity to unpack the spatial inequality dynamics during a period of unprecedented political transformation. In this paper, we examine the relationships between spatial inequality, place mobility, and spatial polarization within Mexico during the 2000 –2015 period. We explore the following questions: Have spatial inequality and spatial polarization increased across Mexican municipios since 2000? What has been the role of place mobility in any changes in overall spatial inequality? What have been the main components of place mobility over this period?

We build on previous research that has focused on spatial inequality in the Mexican space economy (Esquivel & Cruces, 2011; García-Verdú, 2005; Mallick & Carayannis, 1994; Rey and Sastré Gutiérrez, 2015; Rey & Sastré-Gutiérrez, 2010; Sastr é Guti érrez and Rey, 2013). This paper contributes to the literature on spatial inequality dynamics in three respects. First, it provides updates to the literature on the spatial dynamics of Mexico with a focus on the period 2000 –2015. The second contribution is a tighter integration between questions of inequality, polarization, and place mobility. As we develop more fully in what follows, place mobility pertains to the movement of places (regions, cities) within the spatial income distribution over time. Third, it responds to the call by Wei et al. (2020) for additional techniques to analyze place mobility introducing a new approach to decomposing the sources of place mobility within a multiregional context. This place mobility

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framework offers a formal lens on the question of whether regional economic growth leaves some places behind.

We begin by examining the context of personal and regional income inequality in Mexico (Section 2). In Section 3, we discuss the regional data sets and our methods used to measure spatial clustering, polarization, spatial dynamics, and place mobility. Section 4 applies these methods to the case study of 2457 municipios in Mexico over the 2000–2015 period. We provide a discussion of the findings, their implications for policy, and identify future areas of research in Section 5.

2. Context

2.1. Personal income inequality in M éxico

In 2018 Mexico's GDP reached 1.07 trillion dollars(World Bank, 2022a), making it the 15th largest economy. However, from 2012 to 2018, Mexico ranked among the top countries with the highest income inequality based on the Organization for Economic Co-operation and Development (OECD) classification, behind countries like Chile and Costa Rica (OECD, 2022). Based on previous work, income inequality in Mexico can be characterized as follows: income inequality increased in the 1980s to early 1990s, decreased between mid 1990s and mid 2000s, and increased once again from 2006 until 2014 (Campos-Vázquez, 2013; Campos-Vazquez et al., 2014; Bouillon et al., 2003; Bourguignon et al., 2004).

In the 1980s, the Mexican economy had a negative growth trend (World Bank, 2022a) due to the devaluation of the peso and the economic crisis in the early 1980s. (Sanchez & Luna, 2014). Following the need to break out of this crisis, the Mexican government opted for a neoliberal economic approach and formally declared their intention to join the General Agreement on Tariffs and Trade (GATT) in 1985 after a failed attempt in 1979 (McCartney, 1985). Unions and manufacturers argued that an influx of foreign goods and investment could cripple local production and critical industries as they would not be able to keep up with the foreign competition (McCartney, 1985). Nonetheless, this decision signaled the begging of trade liberalization in Mexico.

Trade liberalization opened the door for the Mexican economy to relieve pressure from its financial problems; however, this move also increased inequality. Bourguignon et al. (2004) found that between 1984 and 1994, returns to education and divergence between rural and urban areas were responsible for the overall increase in inequality. Trade liberalization and skill-based technologies innovation were behind the increase in inequality. Bourguignon et al. (2004) argues that although most children in Mexico are enrolled in primary schools, a significant number living in poor regions are falling behind. This issue created an unbalanced educated population where those falling behind on education missed the skills needed for jobs that were created due to trade openness. Similarly, Bouillon et al. (2003) found that during the same period of time, there was a decrease in returns to those with lower levels of education and an increase in returns for those with high education. Leading to an overall increase in inequality. Moreover, Lopez-Acevedo (2006) found that education accounted for the largest share of earnings inequalities. As inequality in education rose, so did the inequality in earning distribution.

Trade liberalization thus opened the door for higher wages, but not for all industries and not all levels of education, with agriculture being one of the most affected (Bourguignon et al., 2004). This was one of the issues that was discussed when Mexico originally attempted to join GATT because the agriculture industry could be significantly impacted by the trade openness (McCartney, 1985).

Similarly, Campos-Vazquez et al. (2014) found that between 1989 and 1994, a rise in labor income inequality as a result of higher returns to skilled workers, was driving overall inequality in Mexico. Rapid changes due to trade, such as new technologies, widened wage inequalities in Mexico (Esquivel & Rodríguez-López, 2003). However, Esquivel and Rodríguez-López (2003) argues that absent these new technologies, wage inequality should have been reduced with trade liberalization. Others like Cortez (2001) found that labor mobility, rather than the rate of returns of higher education, was responsible for the rise in wage inequality. Cortez (2001) argues that labor market institutions, coupled with a decline of unionization rates and minimum wages, increased inequality.

From 1989 until 1996, inequality in Mexico rose from 50.6 to 53.6, as measured by the Gini coefficient. After 1996 however, inequality in Mexico followed a downward trend (World Bank, 2022b). Esquivel and Cruces (2011) used national household surveys and found that inequality had a downward trend. Based on a Gini decomposition method, the authors found that labor income, public transfers, and remittances played an essential role in stabilizing inequality when measured by the Gini index. Increased education rates also had an effect post-NAFTA in reducing inequality. According to Campos-V ázquez (2013), based on a Bound and Johnson decomposition of the supply and demand on relative wages, the rise in educational enrollment in college and high school caused a decline in wage inequality after 1996. Between 1996 and 2006, Esquivel et al. (2010) found that higher wages at the bottom of the distribution reduced the skill premium of the upper decile. In addition, a more progressive approach to education spending increased the availability of secondary schools in rural areas, and it reduced constraints on the demand for education (i.e., higher attendance costs for secondary schools). Lastly, government transfer programs such as Procampo and Progresa (later called Oportunidades) targeted poor segments of the population to reduce inequality and poverty. However, although well intended, inequality was only reduced 9.3% when compared to advanced countries that also implemented government transfers and had an inequality reduction of 30%50%. Moreover, remittances played an essential role in reducing inequality between rural and urban household per capita income in the early 2000s (Lustig et al., 2013; Mejía-Guevara, 2015). From 2006 until 2010 (Campos-Vazquez et al., 2014), saw a increase in inequality that sparked from a decrease in wages from low-wage workers. Iniguez-Montiel and Kurosaki (2018) looked at the relationship between growth, inequality, and poverty between 1992 and 2014 and found that Mexican states displayed both income and inequality convergence patterns. Where lower levels of inequality led towards growth periods and that poverty

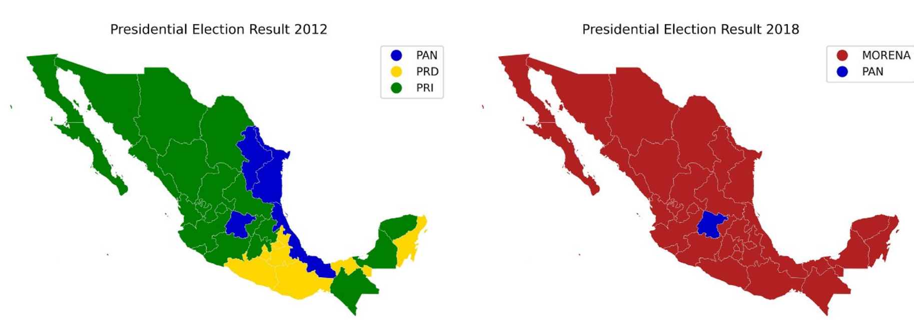

Fig. 1. Presidential Election Results 2012 & 2018.

reduction at the state level is highly determined by inequality levels. The authors conclude that adopting pro-poor policies can help reduce inequality.

2.2. Regional income inequality in Mexico

Historically, infrastructure investment in the south of Mexico has been lower than in the north and center. Once trade liberalization occurred and opened access to the U.S. market, this benefited wealthier states with better infrastructure that were, for the most part, in the north, exacerbating regional inequalities between the North and South (González Rivas, 2007). Others have pointed out that although there was a strong convergence of poor states in the south, there was not a clear convergence of higher income states along the border because of higher income variance in the northern part of the country (Aroca et al., 2003).

Baylis et al. (2012) found that NAFTA increased regional polarization within Mexico. Municipios closer to the border benefited by receiving higher production and incomes due to NAFTA. Compared to Municipios in the South, municipios along the border saw an 8% increase in their economic activity. Nevertheless, regions that lacked the infrastructure increased their economic growth. González Rivas (2007) argues that improving states' infrastructure in the south could open up the dispersion of economic activities that can reduce regional inequalities created by NAFTA. Moreover (Baylis et al., 2012), found evidence that regions with high percentages of lower-skill workers (workers without a high school education) benefited after NAFTA. However, poor regions with already high illiteracy rates were still negatively affected. Others, such as (González Rivas, 2007), argue that trade benefited regions with a lower level of education, which historically had been concentrated in the south. At the same time, however, states along the U.S. border benefited more from trade liberalization than those in the south, widening the gap between north and south. Similarly, Rodríguez-Pose and Sánchez-Reaza (2003) found that with the introduction of trade liberalization, economic divergence and polarization between the wealthier north and poor south was exacerbated. States in the south that historically depended on agriculture and natural resources were affected the most by introducing the Mexican economy to the world markets through trade liberalization. States closer to the U. S. border benefited from the trade liberalization, changing their position from "falling behind" prior to trade openness to "winners". However, states in the southern region were a mix of "catching up" prior to the trade openness and became "losers" with the trade liberalization (Rodríguez-Oreggia, 2005).

3. Materials and methods

3.1. Study area and data

We use municipios in Mexico as our geographical units of analysis (n = 2457). With the exception of Chiapas, that is missing four municipios due to their creation and incorporation date, the remainder of states contain all known municipios based on 2015 data. For this study, we use annual per capita income series at municipal level. For years 2000 and 2005, the estimated per capita income is expressed in purchasing power parity (PPP) in 2005 U.S. dollars. For 2010 and 2015, per capita income is also expressed in PPP, but in 2015 U.S. dollars. The data was obtained from the United Nations Development Program (UNDP) in Mexico. UNDP leverages three main surveys from the Instituto Nacional de Estadística, Geografía e Informática (INEGI)to formulate the estimated per capita income at the municipal level:the National Survey of Income and Expenditure of Households (Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH)); the Censo General de Población y Vivienda; and Conteo de Población y Vivienda.

For observations where data was missing as a result of newly created municipios or municipios where data was not collected by the INEGI at the specific point in time, we used a nearest-neighbor interpolation approach to fill in the income series. This allows us to have full income series across the four time period of our data (2000–2015).[2]

3.2. Methods

3.2.1. Measuring multiscale spatial clustering

The spatial distribution of incomes in Mexico is explored at the state and municipio scales. Choropleth maps based on quintile classifications for each year are developed. We then explore spatial clustering within these spatial distributions. Global Moran'I statistics are adopted using Queen contiguity to define the spatial weights matrix. Weights are row-normalized in each analysis. All analysis is done with PySAL (Rey et al., 2022).

3.2.2. Measuring polarization

Spatial polarization is measured using a decomposition of overall spatial inequality into inequality between and within regions, following (Rey & Sastré-Gutiérrez, 2010; Shorrocks & Wan, 2005) We rely on the states (Fig. 2) to play the role of regions and consider inequality between municipios belonging to different states, and inequality between municipios belonging to the same state. Our measure of spatial polarization is the ratio of between-region inequality over total inequality.

3.2.3. Measuring spatial dynamics

For the analysis of the dynamics of spatial income inequality we adopt classical and spatial Markov chain analysis (Rey, 2001). In each case, the states of the chain are based on local quintiles for the income values in a given period. More specifically, the Markov models are estimated using:

$$r_{i,t} = \frac{y_{i,t}}{\bar{y}_t} \quad (1)$$

where $y_{i,t}$ is per capita income in municipio i in period t, and $\bar{y}_t$ is the mean municipio per capita income for period t. This means that the dynamics are relative in the sense that overall shifts in the income distribution mean are normalized out of the series, allowing for the analysis of exchange dynamics that occur when economies move up or down the income distribution.

We also consider whether the dynamics of the income distribution exhibit spatial conditioning, by testing if the estimated transition probability matrices differ across groups of observations defined on their spatial lag. That is, is the movement of a municipio up or down the income distribution independent of the level of incomes in its neighboring muncipio at the beginning of the interval?

To complement the conditional analysis, we also consider the question of whether muncipios co-move with their neighbors over time within the income distribution by adopting a LISA Markov (Rey, 2001), and we test for directionality in the joint movements of municipios and neighbors using circular histograms of the LISA vectors (Rey et al., 2011).

3.2.4. Measuring place mobility

The final analytical framework we employ is used to formalize the components of place mobility. By place mobility, we mean the evolution over time of the economic well-being of a place in the larger national system. Place mobility is an analog to the concept of inter-generational income mobility. High levels of inter-generational mobility hold when an individual's socioeconomic well-being, relative to others in their generation, is less dependent on the socioeconomic well-being of the individual's parents. For place mobility, the comparison is between the

[2] Because of different conventions used in the development of the two sets of data (2000–2005 and 2010–2015) the data from the two periods are not directly comparable. In what follows, we discuss the precautions adopted when carrying out analyses that span the entire 2000–2015 period.

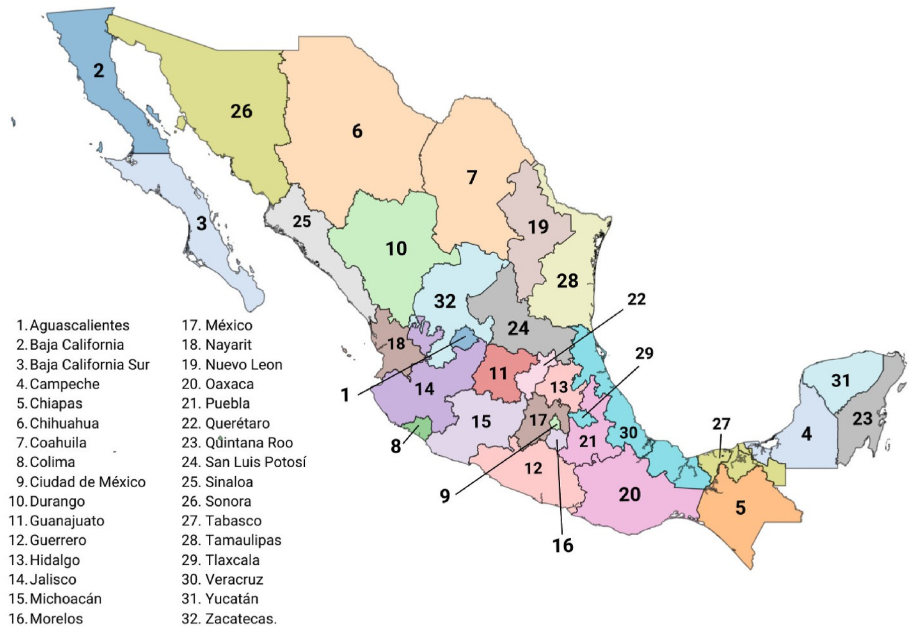

Fig. 2. Overview of States in Mexico.

current rank of a region in the distribution of regional incomes relative to the rank it held in a previous period. Here we tie place mobility to income movement of municipios in the Mexican system. Income changes experienced by individual municpios reflect the combined effects of the growth in the system as a whole, or so called structural mobility, and the changes of the position of individual municipios within the income distribution, or so called exchange mobility which reflects the evolution of the status of a municipio within the system. Adopting the framework proposed by Van Kerm (2004), we can further unpack structural mobility into changes due the growth effects and dispersion effects. The latter would reflect changes in the share of system income held by the individual municipios.

An overall scalar measure of place mobility in Mexico is obtained as:

$$M(y_t, y_{t+k}) = \frac{1}{n}\sum_{i=1}^{n}\left|log\left(y_{i,t+k}\right) - log\left(y_{i,t}\right)\right| \tag{2}$$

where y_t is the vector of municipio incomes in period t. This measure of mobility has the attractive property of being decomposible in a number of ways. We first decompose overall mobility into growth, exchange, and dispersion mobility:

$$M = f(M^G, M^E, M^D) \tag{3}$$

To operationalize this, we need to generate counterfactual income vectors for the second period, for each of these three components that leave the other two components unchanged. Growth mobility (M^G) represents the change in municipio incomes that was due to overall growth in the distribution. This can be thought of as a shift in the municipio income distribution rightwards or leftwards, without any changes in the relative positions of the individual municipios, or changes in the level of dispersion in the distribution over the period $t \rightarrow t+k$. The estimate of the growth mobility component is developed by developing a counterfactual income vector y^G_{t+k} which sorts the observed vector y_{t+k} based on the ranks in y_t. More specifically for a given element i of the vector we have $y^G_{i,t+k} = y_{Rank(y_{i,t}),t+k}$ Note that $\bar{y}^G_{t+k} = \bar{y}_{t+k}$, and that the two vectors differ only in the permutation of their elements. The counterfactual y^G_{t+k} reflects the growth element but maintains the same Lorenz curve as y_t and also preserves the ranks of the municipios from period t. This counterfactual vector is then used to estimate the growth mobility component:

$$M^G = M(y_t, y^G_{t+k}) \tag{4}$$

The counterfactual vector for exchange mobility is obtained as:

$$y^E_{t+k} = P' y_t \tag{5}$$

where P is a permutation matrix that sorts incomes of municipios from period t in the order of period $t + k$ incomes. As was done for growth mobility, we can substitute the exchange counterfactual to form:

$$M^E = M(y_t, y^E_{t+k}) \tag{6}$$

Finally, the dispersion counterfactual is defined as:

$$y^D_{t+k} = \frac{\bar{y}_t}{\bar{y}_{t+k}} L y_t \tag{7}$$

where L is a diagonal matrix with elements:

$$L_{i,i} = \frac{y_{Rank(y_{i,t}),t+k}}{y_{i,t}} \tag{8}$$

which then gives us:

$$M^D = M(y_t, y^D_{t+k}) \tag{9}$$

One complication of the general decomposition in (3) is that there are multiple permutations of the ordering of the three components that can be considered. To see this, consider trying to factor out the growth component:

$$M - M^G = M^E + M^D \tag{10}$$

The difference consists of the two terms M^E and M^D. We could first estimate M^E and solve for M^D as the remaining component, or estimate M^D and obtain M^E as a complement. In the first case, our sequence involved G, E, D and in the second case, G, D, E. In these two sequences, the estimates of the growth component will be identical, however, the two estimates of the exchange component may differ as may the two estimates of the dispersion components.

Similar complications arise if we first started with M^E and left the combined $M^G + M^D$ components for further decomposition, or if we started with factoring out M^D and moved onto $M^G + M^E$. Moreover, the estimates of M^G from these sequences may differ from the estimates where M^G is estimated first.

To resolve this issue, a Shapley value of the decomposition is used as follows. The estimate of the marginal effect of component j (with $j \in \{G, E, D\}$) we form:

$$\hat{M}^j = \frac{1}{3!} \sum_{s \in S^{(3)}} M^{j,s}, \tag{11}$$

where $M^{j,s}$ is the marginal effect of component j in the sequence s, and $S^{(3)}$ is the set of all possible sequences of the three components. The results in an exact decomposition:

$$M(y_t, y_{t+k}) = \hat{M}^G + \hat{M}^E + \hat{M}^D. \tag{12}$$

4. Results

4.1. Spatial distribution of municipio incomes

We begin with an examination of the spatial distribution of municipio incomes summarized by state (Table 1). Fig. 3 portrays the average muncipio income within each of the 32 states for each of the four years in our sample. The classification scheme is based on quintiles determined for the incomes in each of the years. Fig. 4 shows the spatial distribution of incomes at the municipio scale.

The historic north-south divide is clearly evident across the years, and at both spatial scales. More specifically, this pattern reflects significant spatial autocorrelation in incomes across municipios. The dependence is evident at two different spatial scales as reported in Table 2. As comparison of the I values from the different scales is inappropriate, we use the standard normal approximations of the two values for comparison. Doing so reveals stronger dependence at the level of the municipios than at the more aggregate state scale. Moreover, the spatial dependence is strengthening over time at the municipio scale, while no clear pattern holds for dependence at the state scale. At the same time, there is much heterogeneity evident at the finer spatial scale with pockets of high income municipios found throughout all the regions, including the south.

4.2. Intra-state and inter-state inequality

The heterogeneity in the level of incomes across the nation leads to the question of how that heterogeneity may be related to the state context. Fig. 5 portrays the relationship between the level of inequality between municipios belonging to a state, and the per capita income of that state. In each of the periods, there is a negative association between the level of inequality between municipios in a state, and the average income of municipios in the state. The intersectionality of the level of income and disparities is a key signature of the Mexican space economy. At the same time, these dispersion and level measurements do not reveal insights as to the internal dynamics of the municipio income distribution, nor the spatial articulation of the dynamics.

The relationship between overall inequality between municipios and spatial polarization is displayed in Fig. 6. Here we define spatial polarization as inequality between the states. In the initial interval in the sample, both inequality and polarization decline. This is followed by a turn around in 2005, which is more pronounced for polarization than for inequality, with polarization exceeding the value at the start of the sample. In the third interval, polarization remains high, while overall inequality slightly declines. Overall the entire period, we see that while inequality has declined, spatial polarization has increased. In other words, the relative difference between incomes of municipios from the same state have declined whereas the inequality between municipios from different states has increased. [3]

4.3. Spatial dynamics: Markov

A different lens on the spatial dynamics underlying Fig. 4 is afforded by the application of Markov-based methods. The results of applying a discrete Markov chain with the classes being based on period-specific quintiles are summarized in Table 3. The table contains the conditional probabilities of moving between the five quintiles based on 7371 transitions (2457 municipios over 3 intervals). There is clear heterogeneity in the relative mobility within different parts of the income distribution. Municipios in the middle three quintiles move out of their respective classes in 50 percent of the intervals. For example, an area that is in the third quintile (Q2: 40-60th percentile) has a greater than 53 percent chance of moving to a different quintile in the next period. Moreover, the conditional transition probabilities are directionally symmetric with regard to whether the move is downward into Q1 or upward into Q3. In contrast, in the tail quintiles, Q0 (0-20th percentile) and Q4 (80-100th percentile), there is much less mobility. At the bottom of the distribution, municipios remain with a probability of 0.72, while at the top of the distribution the wealthiest municipios hold their position with a slightly higher probality (0.73).

4.4. Spatial dynamics: Spatial Markov

Recall from the previous discussion that the classical transition probabilities from Table 3 are based on the assumptions of independence and homogeneity. Relaxing this, the spatial Markov results reported in Fig. 7 estimate five different transition kernels based on the quintile of the spatial lag for a municipio at the beginning of the transition period. There is clear evidence that spatial context matters to the transitional dynamics. Municipios in the bottom quintile have higher probabilities of remaining in that quintile if there neighbors are also in the bottom quintile (0.761) versus equally poor minicipios with neighbors that fall in say the middle quintile (0.593). A similar neighbor conditioning can be seen at the top end of the distribution where muncipios in the fifth quintile remain at the top with a probability of 0.771 if their neighbors are also in the top quintile, while equally rich municipios with neighbors in the middle quintile remain in the top quintile with a probability of 0.681. Formal tests for homogeneity of transition dynamics across different spatial lags are rejected in both tests as reported in Table 4.

4.5. Spatial dynamics: LISA Markov

Turning to the question of co-movement of a municipio and its neighbors in the income distribution, Fig. 8 reports the rose diagram for the LISA vectors, standardized to the origin. Each observation represents the move of a municipio and its neighbors over the 2000 –2015 period. The color signifies the mean relative incomes of the municipio. Were the moves of a municipio and its neighbors independent, we would expect a roughly circular distribution of these observations. There are two departures from this expectation. First, the distribution is not spherical, rather it is stretched out in a positive orientation, reflecting co-movement of the focal unit and its neighbors. Second, there is a differentiation between the direction of movement for the low income and high income municipios, with the former moving together with their neighbors upwards in the income distribution, while the latter move

[3] All analyses at the state and municipio scales use unweighted observations. We agree with Gluschenko (2018) that in the study of *spatial* inequality, the proper unit of observation is the region, not individuals, and thus we do not weight the observations by population.

Table 1
Overview of States in Mexico.

State	Population 2000	Per Capita Income 2000	Population 2015	Per Capita Income 2015	Municipios
Aguascalientes	944,285	5,427	1,292,901	2,626	11
Baja California	2,487,367	12,153	3,499,474	3,775	5
Baja California Sur	424,041	10,754	770,210	3,887	5
Campeche	690,689	4,805	911,785	2,576	11
Chiapas	3,920,892	3,060	5,272,391	1,215	118
Chihuahua	3,052,907	8,338	3,720,540	2,280	67
Ciudad de México	8,605,239	14,634	8,846,359	4,939	16
Coahuila	2,298,070	7,453	2,970,077	3,543	38
Colima	542,627	6,716	727,540	3,158	10
Durango	1,448,661	5,145	1,769,414	2,067	39
Guanajuato	4,663,032	6,359	5,831,176	2,259	46
Guerrero	3,079,649	3,282	3,574,221	1,543	81
Hidalgo	2,235,591	5,259	2,888,597	2,064	84
Jalisco	6,322,002	5,814	7,954,903	2,651	125
Michoacán	3,985,667	5,333	4,605,970	1,886	113
Morelos	1,555,296	7,099	1,927,187	2,434	33
México	13,096,686	5,891	16,938,897	2,281	125
Nayarit	920,185	5,744	1,230,233	2,475	20
Nuevo León	3,834,141	9,715	5,107,027	3,820	51
Oaxaca	3,438,765	2,735	4,019,821	1,200	570
Puebla	5,076,686	3,925	6,210,963	1,462	217
Querétaro	1,404,306	6,936	2,013,394	2,630	18
Quintana Roo	874,963	6,898	1,587,251	3,155	10
San Luis Potosí	2,299,360	4,451	2,760,851	1,840	58
Sinaloa	2,536,844	6,793	2,992,355	2,745	18
Sonora	2,216,969	6,565	2,944,627	3,543	72
Tabasco	1,891,829	5,420	2,390,920	2,487	17
Tamaulipas	2,753,222	5,605	3,554,993	2,241	43
Tlaxcala	962,646	6,483	1,283,343	2,143	60
Veracruz	6,908,975	4,077	8,065,135	1,810	212
Yucatán	1,658,210	3,114	2,126,176	2,097	106
Zacatecas	1,353,610	5,998	1,580,020	1,962	58

*Ciudad de México, formerly known as Distrito Federal (D.F.), became part of the 32 federal entities in Mexico after a Constitutional Reform in 2016. Rather than having municipios, it cointains alcaldías (boroughs).
*Per Capita Income is expressed in Purchasing Power Parity (PPP).

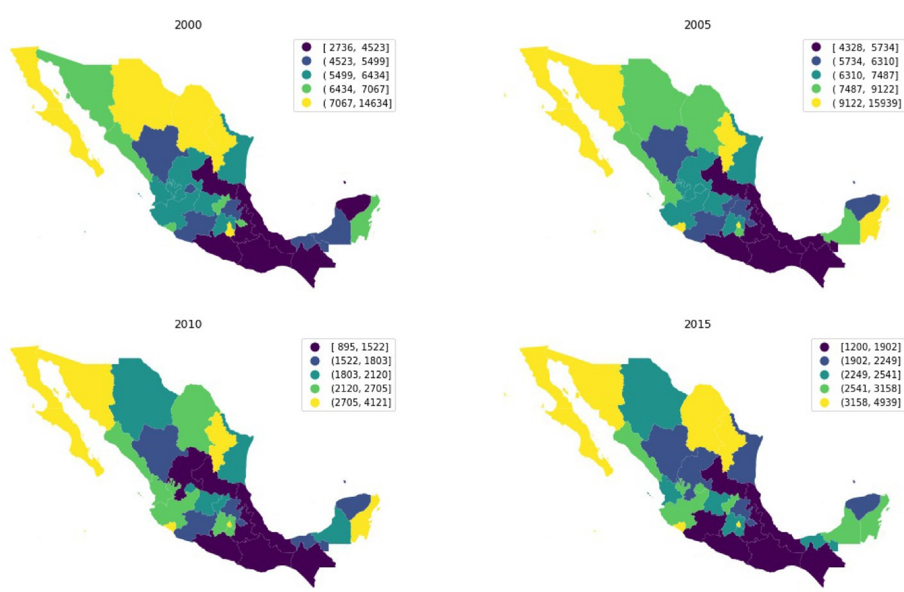

Fig. 3. Average municipio per capita income by state and year (Quintiles).

jointly downward in the distribution over this period.

Formal tests of the spatial co-movement for the LISA vectors are reported in Table 5. For each of the eight sectors of the Rose diagram from Fig. 8 (counting from 0 in a counter-clockwise fashion) the observed number of LISA vectors are reported in the Counts column. Based on random spatial permutation of the data, the expected number of counts under the null of independence in the focal-neighbor moves is reported in the Expected column. In all eight sectors, the number of observed counts depart from expectation as reflected in the pseudo p-values. For sectors 0 and 1 (from 0 to 90°), which represent positive co-movement in the distribution, the number observed is significantly larger than expectation. This is also true for sectors 4 and 5 (180 –270) which represent co-movement downwards in the distribution. In contrast, the number of LISA vectors where the municipio moves in a

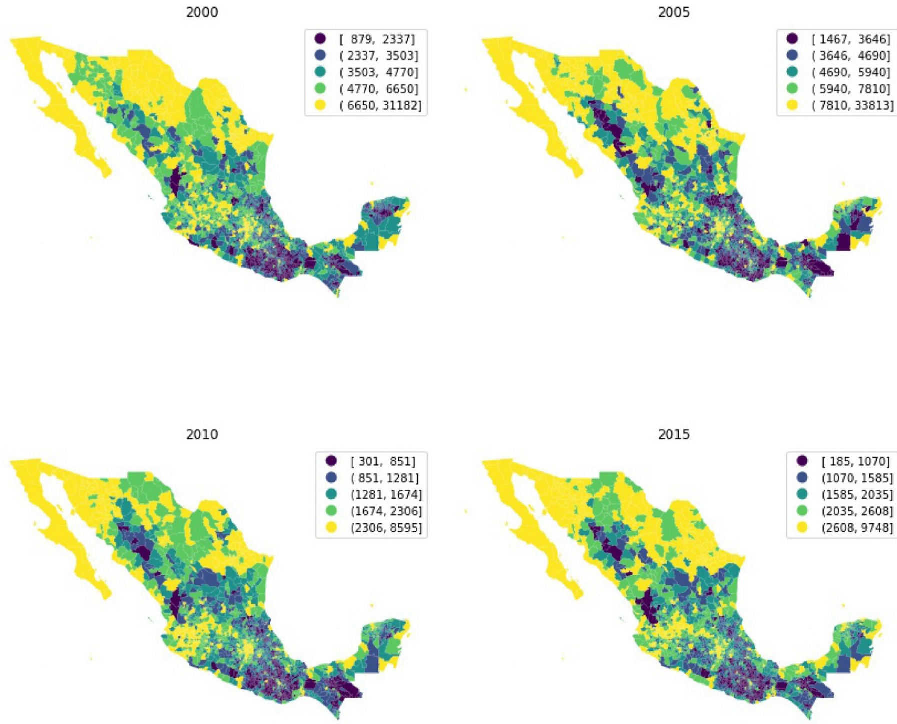

Fig. 4. Average municipio per capita income by year (Quintiles).

Table 2
Global spatial autocorrelation of incomes, State and Municipio scales. *I*: Moran's *I*, *z*(*I*): standard normal approximation, p_sim: pvalue based on random permutations.

	State			Municipio		
	I	z(I)	p_sim	I	z(I)	p_sim
2000	0.41	3.10	0.01	0.62	49.73	0.00
2005	0.51	3.84	0.00	0.58	46.45	0.00
2015	0.48	3.61	0.00	0.67	53.36	0.00
2020	0.34	2.62	0.01	0.67	53.12	0.00

different direction of its neighbors are significantly fewer than expected, with roughly equivalent number of cases where the municipio moves upwards but it neighbors move downwards (sectors 6 and 7) and cases where the neighbors move upwards but the municipio moves downwards in the income distribution (sectors 2 and 3).

4.6. *Place mobility decomposition*

Table 6 summarizes the decomposition of overall municipio income into the growth, exchange and dispersion components over the 2000–2015 period. The first column reports the estimate of the mobility component, with associated standard errors in parentheses, while the

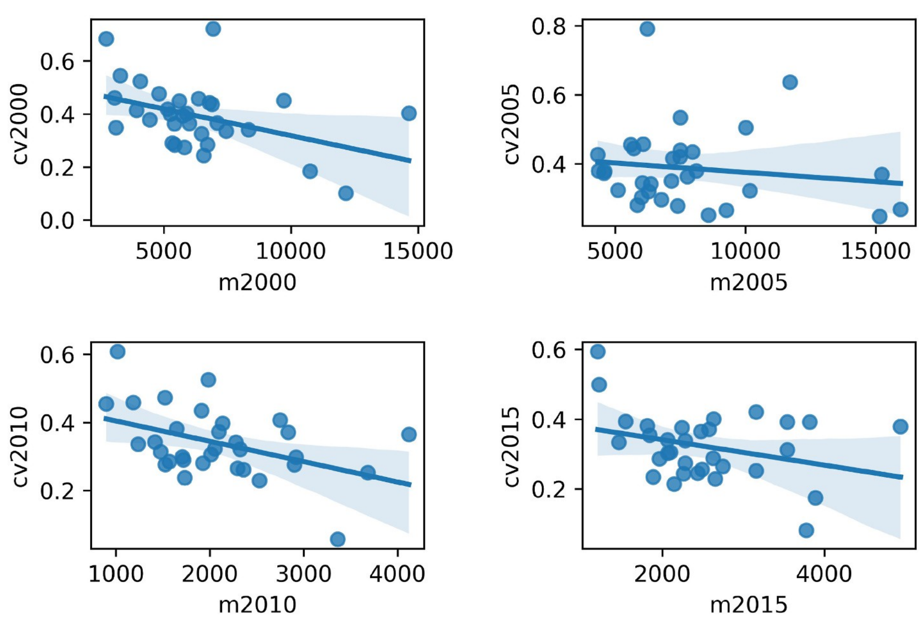

Fig. 5. Intrastate spatial inequality (Coefficient of variation in municipio incomes) and mean municipio income by state.

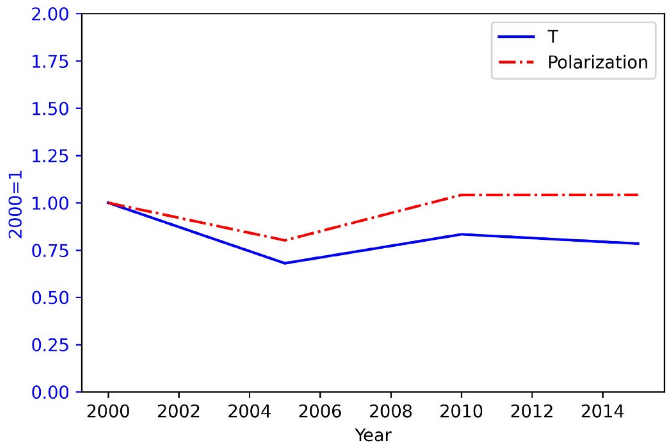

Fig. 6. Spatial inequality T (intermunicipio inequality) and spatial polarization (between state inequality).

Table 3
Discrete Markov chain transition probabilities. Quintiles of Municipio incomes.

	Q0	Q1	Q2	Q3	Q4
Q0	0.72	0.23	0.04	0.01	0.00
Q1	0.21	0.49	0.24	0.05	0.01
Q2	0.05	0.22	0.47	0.22	0.04
Q3	0.01	0.05	0.21	0.50	0.23
Q4	0.00	0.01	0.04	0.22	0.73

second column contains the share of overall mobility each component accounts for. Nationwide, the growth component accounts for 85.9% of overall municipio income mobility over this period, indicating that, on average, secular moves in the distribution as a whole have been the driving force behind the changes in municipio incomes in Mexico. At the same time, internal mixing, or exchange mobility, accounted for 13.2% of municipio income mobility. Dispersion mobility reflecting changes in the share of national income held by each municipio plays a much more

Table 4
Spatial Markov Homogeneity tests.

Test	LR	Chi-2
Stat.	298.55	367.63
dof	80	80
p-value	0.000	0.000

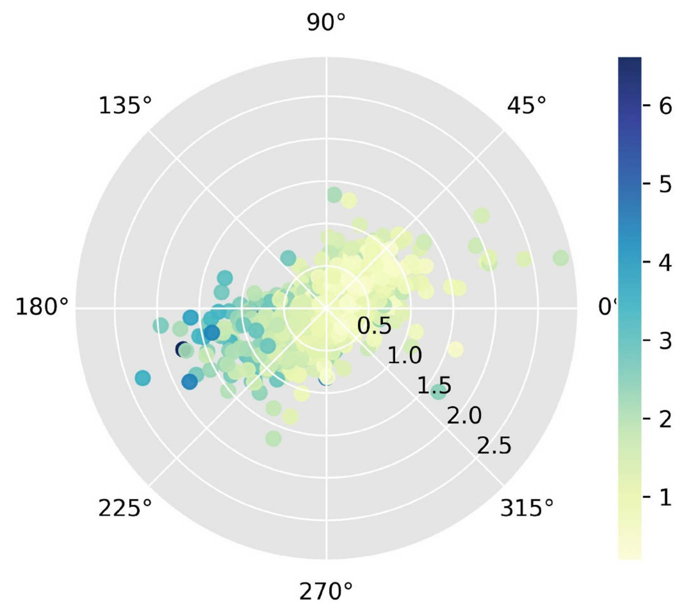

Fig. 8. LISA Vectors standardized to the origin. Each point shows the end-point of a LISA vector reflecting the move of a municipio and its neighbors in the income distribution over 2000–2015. The color bar reflects the level of income of the focal municipio.

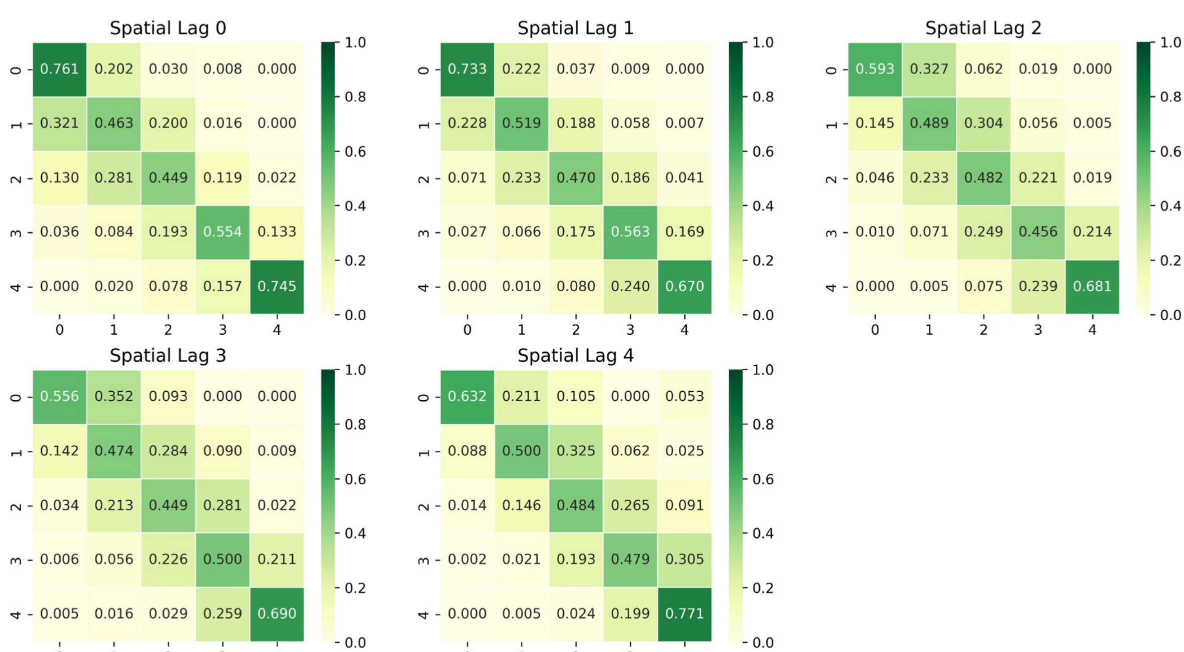

Fig. 7. Spatial Markov transition probabilities. Each matrix reports the estimated transition probabilities for municipios with a spatial lag falling into a specific qunitile of the income distribution. (Spatial Lag 0 contains the transition probabilities for municipios with the poorest neighbors, Spatial Lag 4 contains the transition probabilities for the muncipios with the highest income neighbors.)

Table 5
LISA Markov Vectors.

	Counts	Expected	p-value
Sector			
0	607	465.069	0.002
1	368	236.827	0.002
2	148	187.614	0.000
3	223	383.291	0.000
4	484	349.204	0.002
5	247	181.891	0.002
6	142	231.194	0.000
7	238	421.910	0.000

Table 6
Municipio income mobility decomposition 2000-2015. Jacknife standard errors reported in parentheses below estimates.

Component	Estimate	Share
2000–2015		
Exchange Factor	0.113	[13.2%]
	(0.003)	(0.34%)
Growth Factor	0.738	[85.9%]
	(0.005)	(0.54%)
Dispersion Factor	0.008	[0.9%]
	(0.002)	(0.28%)
2000–2005		
Exchange Factor	0.152	[41.4%]
	(0.004)	(1.16%)
Growth Factor	0.157	[43.0%]
	(0.005)	(1.32%)
Dispersion Factor	0.057	[15.6%]
	(0.003)	(0.88%)
2005–2010		
Exchange Factor	0.086	[6.4%]
	(0.003)	(0.21%)
Growth Factor	1.201	[89.6%]
	(0.004)	(0.31%)
Dispersion Factor	0.054	[4.0%]
	(0.003)	(0.24%)
2010–2015		
Exchange Factor	0.091	[40.6%]
	(0.002)	(1.05%)
Growth Factor	0.117	[52.1%]
	(0.003)	(1.46%)
Dispersion Factor	0.016	[7.3%]
	(0.002)	(1.07%)

limited role over this period.

The contributions of the three components to overall place mobility by state are shown in Fig. 9. The ternary diagram is a triangular array that locates each state in a three dimensional space based on the contributions of growth, exchange, and dispersion mobility to overall mobility. The dominance of the growth component is clear, as it is the main driver of municipio income mobility across all states. There is also a relationship between the relative importance of the exchange component and overall mobility, as exchange tends to become more important in states where overall municipio income mobility is lower.

The dominance of the growth component over the entire period is likely reflecting the pronounced weakening of the peso over this period. It may also reflect the break in the series between the two periods 2000-05 and 2010-15 mentioned previously. To explore this, we repeat the mobility decomposition for each of the three 5-year intervals. The importance of the growth component is substantially different between two intervals before and after the break (2000 –2005 and 2010–2015), and the interval that spans the break (2005-2010). In the latter case, the growth factor dominance is in line with that seen in the analysis over the entire sample period (2000–2015). However, for the other two intervals, the importance of the exchange factor grows to approximate that of the growth factor.

Given that the length of the intervals for the three five-year

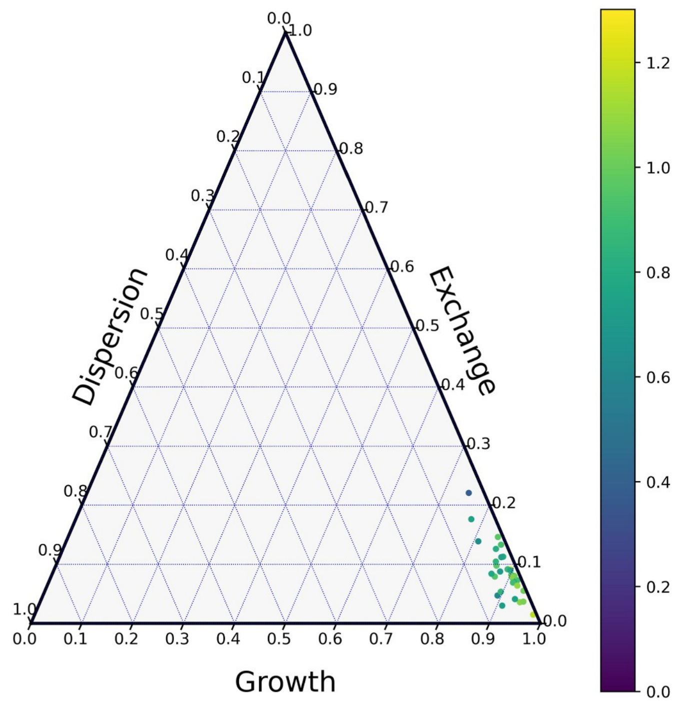

Fig. 9. Ternary scatter plot of municipio income mobility components by state 2000–2015.

decompositions is the same over these periods, we suggest that the outsized estimate of the growth component over the entire sample period is likely a mixture of the peso devaluation and a break in the series between the 2000–2005 and 2010–2015 periods. Thus, we feel more emphasis should be placed on the two five-year sub-samples prior and after the break. In these cases, growth mobility still is the largest component of mobility, yet exchange mobility plays an important role in the dynamics of the municipio income distribution.

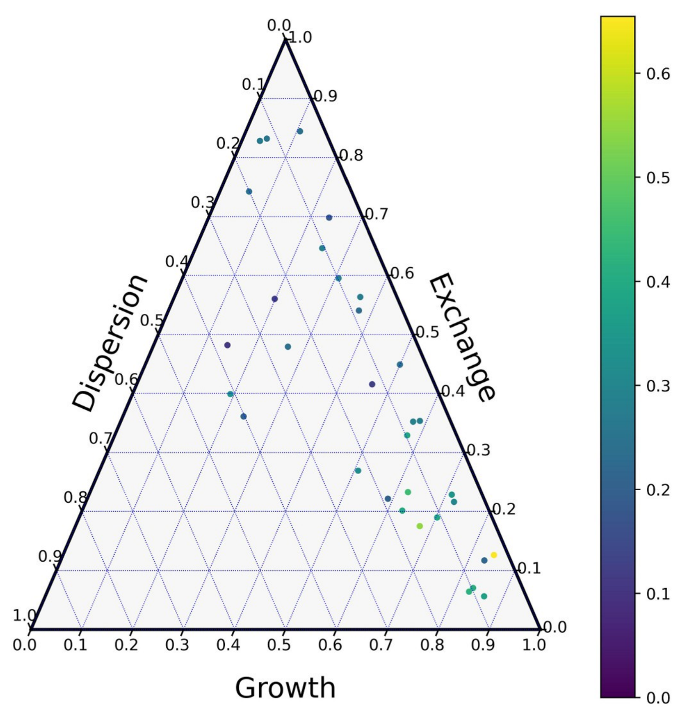

Fig. 10. Ternary scatter plot of municipio income mobility components by state 2000–2005.

Figs. 10 and 11 display the ternary diagrams for the mobility decompositions for these two subperiods. The overall relative balance between the growth and exchange components is reflected in each of the states in both periods. The tendency for the importance of the exchange component to grow as municipio income mobility declines in a state is also seen in both sub-periods.

5. Discussion

The focus of our work has been the multiscalar nature of spatial dependence in and place mobility in Mexican income dynamics. Our findings reveal stronger dependence at the municipio scale which suggests that a focus on state level dynamics only may limit our understanding of spatial income dynamics. We also find much spatial heterogeneity in the form of pockets of high income municipios in the poorer southern states that warrants a more spatially granular view of the Mexican economy.

We find that the relationship between spatial inequality and spatial polarization is complicated. On the one hand, declining inequality in the form of gaps between the wealthiest and poorest municipios in Mexico suggests a positive evolution of the income distribution which may reflect successfully policies implemented to reduce inequality. Alongside the reduction in overall inequality, however, is an increasing amount of spatial polarization reflecting growing inequality between municipios belonging to different states. From a policy perspective, these conflicting patterns raise intriguing questions moving forward. In terms of reducing the discontent that grows from spatial inequality, it is an open question as to whether it is the intrastate municipio inequalities (which have been declining) or the interstate inequalities (which are increasing in a relative sense) that translate into discontent and the rise of political polarization.

The spatial inequality and polarization results are based on snapshots of the income distribution at different points and time. Inequality may be more tolerable when it coexists alongside distribution mobility, since places may be able to improve their relative positions in the distribution over time. We examine the internal dynamics of the municipio distributions using classical and spatial Markov chain approaches. There is much dynamism in the middle of the municipio income distribution, as municipios in the middle three quintiles move into different quintiles over a five year period in roughly half of the intervals. Moreover, they do so in a symmetric fashion as moves upwards or downwards in the distribution have similar probabilities. However, the story is very different in the tails of the distribution as the poorest and richest municipios tend to remain in the same income class at much higher rates than what is seen in the middle of the distribution. Additionally, we find strong evidence of spatial poverty traps, in that poor municipios surrounded by poor municipios have lower upward mobility than do equally poor municipios with better off neighbors.

These results imply that regional development policies need to focus more fully on pro-poor regional growth strategies that also consider the role of spatial spillovers. Previous federal-level government social programs, such as "Oportunidades", have proved helpful in reducing inequality by as much as 11% (Aguilar-Guti érrez, 2016). Based on the framework we adopted of Mexican states being"regions", a similar approach to "Oportunidades" could be taken by states while carefully considering the spatial context of municipios when introducing these strategies.

We also introduced a new approach to measure the concept of place mobility in the study of regional inequality dynamics. This framework allows us to examine the specific drivers of overall mobility that reflect shifts in the overall distribution, mobility due to increasing inequality, and mobility due to exchanges of ranks over time. Low dispersion mobility indicates that over both the long and short-run periods, changes in the share of incomes claimed by the richest and poorest municipios have played a relative minor role in the overall spatial dynamics. More important have been the structural growth component

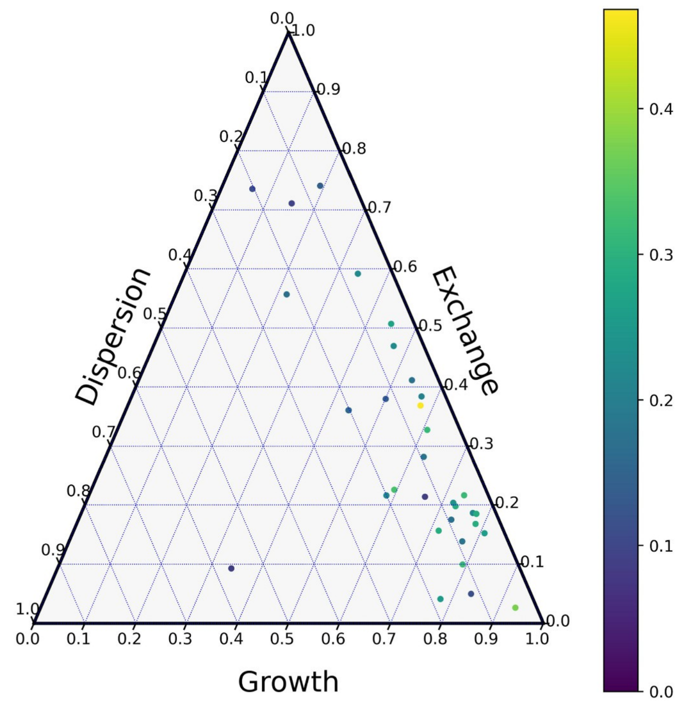

Fig. 11. Ternary scatter plot of municipio income mobility components by state 2010–2015.

whereby all municipios have felt the impact of the devaluation of the peso, and exchange mobility leading to changes in the rankings of municipios in the income distribution.

While our study has shed new light on the spatial dynamics of inequality in Mexico and introduced a new approach to measure place mobility, there are several limitations to note. First, we are combining data from two different governmental reports for the 2000 –2005 and 2010–2015 which involved different conventions for recording income. While we have taken precautions to mitigate the impact of such changes, through the use of normalized incomes in the Markov models, the impacts of changing conventions on the results need to be kept in mind. A second limitation is that this data does not include information on remittances, which have been shown to be important sources of income and have played a role in reducing personal income inequality (Campos-Vázquez & Lustig, 2017). The extent to which remittances impact spatial income inequality remains an open question.

We see two key areas for future research. Using the new mobility framework introduced in this paper to support comparative analyses of the components of place mobility across different national systems is a promising direction. Building on prior work comparing Mexico and the United States (Rey and Sasté Gutiérrez, 2015) to extend the set of countries may shed important light on how different national contexts influence spatial inequality and place mobility dynamics. Related to this is the need for a more integrated approach to the literature on personal income inequality dynamics (Piketty & Saez, 2003) and spatial inequality dynamics in these countries. To date, the personal and regional income inequality are largely separate from one another and their is a critical need to explore their connection in future research.

References

Aguilar-Gutiérrez, G. (2016). Why inequality declined in Mexico? Analysis with Gini, Mehran and Piesch Indexes, 2000-2012. *Economía, Sociedad y Territorio, 16*, 557–590.

Aroca, P., Maloney, W. F., & Bosch Mossi, M. (2003). *Is NAFTA polarizing Mexico? Or el sur tambien existe? Spatial dimensions of Mexico 's post-liberalization growth.* https://doi.org/10.2139/ssrn.402440

Baylis, K., Garduño-Rivera, R., & Piras, G. (2012). The distributional effects of NAFTA in Mexico: Evidence from a panel of municipalities. *Regional Science and Urban Economics, 42*, 286–302. https://doi.org/10.1016/j.regsciurbeco.2011.09.006

Bouillon, C. P., Legovini, A., & Lustig, N. (2003). Rising inequality in Mexico: Household characteristics and regional effects. *Journal of Development Studies, 39*, 112 –133. https://doi.org/10.1080/713869428

Bourguignon, F., Ferreira, F. H., & Lustig, N. (2004). *Microeconomics of income distribution dynamics in East Asia and Latin America*. Washington, UNITED STATES: World Bank Publications.

Campos-Vázquez, R. M. (2013). Why did wage inequality decrease in Mexico after NAFTA? Economía mexicana. *Nueva época, 22*, 245–278.

Campos-Vazquez, R., Esquivel, G., & Lustig, N. (2014). The rise and fall of income inequality in Mexico, 1989–2010. In *Falling inequality in Latin America*. Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198701804.003.0007.

Campos-Vázquez, R. M., & Lustig, N. (2017). *Labour income inequality in Mexico*. https://doi.org/10.35188/UNU-WIDER/2017/412-4

Cortez, W. W. (2001). What is behind increasing wage inequality in Mexico? *World Development, 29*, 1905–1922. https://doi.org/10.1016/S0305-750X(01)00068-7

Esquivel, G., & Cruces, G. (2011). The dynamics of income inequality in Mexico since NAFTA [with Comment]. *Economia, 12*, 155 –188.

Esquivel, G., Lustig, N., & Scott, J. (2010). *Declining inequality in Latin America: A decade of progress? United nations development programme*. New York; Washington, D.C: Brookings Institution Press.

Esquivel, G., & Rodríguez-López, J. A. (2003). Technology, trade, and wage inequality in Mexico before and after NAFTA. *Journal of Development Economics, 72*, 543 –565. https://doi.org/10.1016/S0304-3878(03)00119-6

García-Verdú, R. (2005). Income, mortality, and literacy distribution dynamics across states in Mexico: 1940-2000. *Cuadernos de Economía, 42*, 165 –192.

Gluschenko, K. (2018). Measuring regional inequality: To weight or not to weight? *Spatial Economic Analysis, 13*, 36–59. https://doi.org/10.1080/17421772.2017.1343491

González Rivas, M. (2007). The effects of trade openness on regional inequality in Mexico. *The Annals of Regional Science, 41*, 545 –561. https://doi.org/10.1007/s00168-006-0099-x

Iniguez-Montiel, A. J., & Kurosaki, T. (2018). Growth, inequality and poverty dynamics in Mexico. *Latin American Economic Review, 27*, 12. https://doi.org/10.1186/s40503-018-0058-9

Lopez-Acevedo, G. (2006). *Mexico: Two decades of the evolution of education and inequality*.

Lustig, N., Lopez-Calva, L. F., & Ortiz-Juarez, E. (2013). Declining inequality in Latin America in the 2000s: The cases of Argentina, Brazil, and Mexico. *World Development, 44*, 129–141. https://doi.org/10.1016/j.worlddev.2012.09.013

Mallick, R., & Carayannis, E. (1994). Regional economic convergence in Mexico. *Growth and Change, 25*, 325–334.

McCartney, R. J. (1985). *Mexico to lower trade barriers*. Washington Post: Join GATT.

Mejía-Guevara, I. (2015). Economic inequality and intergenerational transfers: Evidence from Mexico. *The Journal of the Economics of Ageing, 5*, 23 –32. https://doi.org/10.1016/j.jeoa.2014.09.012

OECD. (2022). Inequality - income inequality - OECD data. http://data.oecd.org/inequality/income-inequality.htm.

Piketty, T., & Saez, E. (2003). Income inequality in the United States, 1913-1998. *Quarterly Journal of Economics, 118*, 1 –39.

Rey, S. J. (2001). Spatial empirics for economic growth and convergence. *Geographical Analysis, 33*, 195–214. https://doi.org/10.1111/j.1538-4632.2001.tb00444.x

Rey, S. J., Anselin, L., Amaral, P., Arribas-Bel, D., Cortes, R. X., Gaboardi, J. D., Kang, W., Knaap, E., Li, Z., Lumnitz, S., Oshan, T. M., Shao, H., & Wolf, L. J. (2022). The PySAL ecosystem: Philosophy and implementation. *Geographical Analysis*. https://doi.org/10.1111/gean.12276

Rey, S. J., Murray, A. T., & Anselin, L. (2011). Visualizing regional income distribution dynamics. *Letters in Spatial and Resource Sciences, 4*, 81 –90.

Rey, S. J., & Sastré Gutiérrez, M. L. (2015). Comparative spatial inequality dynamics: The case of Mexico and the United States. *Applied Geography, 61*, 70-80. https://doi.org/10.1016/j.apgeog.2015.01.012

Rey, S. J., & Sastré-Gutiérrez, M. L. (2010). Interregional inequality dynamics in Mexico. *Spatial Economic Analysis, 5*, 277–298.

Rodríguez-Oreggia, E. (2005). Regional disparities and determinants of growth in Mexico. *The Annals of Regional Science, 39*, 207 –220. https://doi.org/10.1007/s00168-004-0218-5

Rodríguez-Pose, A. (2018). The revenge of the places that don't matter (and what to do about it). *Cambridge Journal of Regions, Economy and Society, 11*, 189 –209. https://doi.org/10.1093/cjres/rsx024

Rodríguez-Pose, A., & Sánchez-Reaza, J. (2003). *Economic polarization through trade: Trade liberalization and regional growth in Mexico*. Working Paper 2003/60. WIDER Discussion Paper.

Sanchez, G. V., & Luna, A. (2014). Slow growth in the Mexican economy. *Journal of Post Keynesian Economics, 37*, 115–133.

Sastré Gutiérrez, M. L., & Rey, S. J. (2013). Space-time income distribution dynamics in Mexico. *Annals of GIS, 19*, 195–207. https://doi.org/10.1080/19475683.2013.806354

Shorrocks, A., & Wan, G. (2005). Spatial decomposition of inequality. *Journal of Economic Geography, 5*, 59–81. https://doi.org/10.1093/jnlecg/lbh054

Van Kerm, P. (2004). What lies behind income mobility? Reranking and distributional change in Belgium, Western Germany and the USA. *Economica, 71*, 223 –239. https://doi.org/10.1111/j.0013-0427.2004.00367.x

Wei, Y. D., Wu, Y., Liao, F. H., & Zhang, L. (2020). Regional inequality, spatial polarization and place mobility in provincial China: A case study of Jiangsu province. *Applied Geography, 124*, Article 102296. https://doi.org/10.1016/j.apgeog.2020.102296

World Bank. (2022a). *GDP (current US$) | World Bank national accounts data, and OECD National Accounts data files*.

World Bank. (2022b). Gini index - Mexico | data. https://data.worldbank.org/indicator/SI.POV.GINI?locations=MX.