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THE DISTRIBUTION DYNAMICS OF HUMAN DEVELOPMENT IN MEXICO 1990–2010

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Based on census data linked to household surveys, we analyze the univariate and joint distribution of income, health and education at the municipality level in Mexico from 1990 to 2010 using Gaussian mixture models. The univariate analysis finds an emergence of a low-income cluster in 2000, which disappears again by 2010. Our trivariate estimation shows an education-led human development convergence over time while dynamics are mainly affected by fluctuations in health and income. Changes in development clusters have a clear spatial pattern and are closely related to the relative size of the agricultural sector and the proportion of indigenous population groups.

JEL Codes: I00, O15, I15, I25

Keywords: human development, Mexico, mixture models

1. INTRODUCTION

After the import-substitution industrialization period (ISI) that persisted until the early 1980s, Mexico opened up its economy by signing the General Agreement on Tariffs and Trade (GATT) in 1986 and by acceding to form the North American Free Trade Agreement (NAFTA) in 1994. Many studies suggest that the income disequalization that started in the mid-1980s can be linked to these changes in trade policy. For instance, Juan-Ramon and Rivera-Batiz (1996) attribute the regional divergence between the mid-1980s and 1990s to GATT accession. Sánchez-Reaza and Rodríguez-Pose (2002), Fuentes Flores and Mendoza Cota (2003) and Chiquiar (2005) similarly argue regarding NAFTA's impact on income inequality. Gómez-Zaldívar and Ventosa-Santulária (2012) argue that the liberalization accelerated the process of convergence between the border provinces and the capital during the period 1990–2010, which then increased the divergence between these provinces and the poorer Southern ones.

In December of 1994 an important economic crisis hit Mexico. The crisis was related to a highly overvalued currency and a resulting current account and foreign debt problem. Despite a recovery, survey data on real household per-capita income shows that the levels in 2010 are still below the levels of 1990, although

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national accounts data point to a more optimistic picture (see below).[1] Despite the crisis, however, there has been continued progress in health and education outcomes. The mean years of education improved from 3.53 years in 1990 to 4.16 in 2000 and 5.24 in 2010, and there were some improvements in health outcomes as well, details on these trends and data sources are provided below.

In this paper, we aim to shed light on the distributional dynamics of household per-capita income, health and education at the municipality level over the past two decades. Our study contributes to a better understanding of the association between the different dimensions of human development and how these associations develop across space and time (e.g. Dreze and Sen, 1989; UNDP, 2010; Suri *et al.*, 2011). Here, we focus on these linkages at the highly disaggregated municipal level, whereas most other studies use nationally aggregated data. We also provide a characterization of the dynamics in the inequality of human development across space and time, which is neglected in aggregate studies. A related study is by Permanyer (2013) who also assesses and decomposes the Human Development Index (HDI) at the municipal level in Mexico and finds that human development has increased over time, inequality between municipalities has fallen and is increasingly linked to income differentials. While this paper is a very useful contribution on trends and drivers of the HDI at a sub-national level, this approach relies on the construction of an index and the associated (arbitrary) assumptions about weights, which are also held fixed over time. It also relies on an asset index to proxy income, which may lead to biases when relative prices, preferences or availability of assets change over time (Harttgen *et al.*, 2013). We differ by flexibly examining the development of the joint distribution of household per capita income, health and education over time and by relying on income data generated through the poverty mapping methodology.

The joint distribution of income, health and education is of central importance as it broadly determines human welfare (Sen, 1999). In this regard, our approach recognizes the interdependency of these dimensions (see Barro, 1991; Pritchett and Summers, 1994; Suri *et al.*, 2011). In particular, we look at the number of clusters in the data graphically using a non-parametric kernel density estimator and also test formally for the number of clusters. In other words, our analysis recognizes that joint changes in all mentioned dimensions do not vary monotonically with changes in single dimensions. Moreover, our approach does not rely on arbitrary thresholds to define which municipalities fit into predefined groups of high, intermediate or low human development. Instead it uses Bayesian posterior probabilities to classify municipalities into different categories of human development given the observed association between health, schooling and income achievements.

[1]National accounts data on GDP/capita, GNI/capita, or household private consumption per capita suggest increases of about 25 percent during this time period. While these indicators all capture slightly different concepts to household per capita income that is calculated from surveys, this discrepancy points to a growing mismatch between national accounts data and survey data, which is also a problem in many other parts of the developing world (see Deaton and Kozel, 2005); while underreporting of incomes at the household level might be an important driver, there could also be reporting errors in the national accounts. While this discrepancy is notable and of concern, it would affect our analysis only if our household surveys were underreporting incomes in ways that have a systematic spatial pattern.

Our work also relates to studies by Quah (1993, 1996) which introduced a conceptual framework for the analysis of income distributions. He argued that the cross-country distribution of GDP per capita can be characterized by "twin peaks" with a rich and a poor cluster of countries. Vollmer *et al.* (2013b) focus on human development by studying the joint distribution of income, health and education across the countries of the world. They find that there were two clusters of countries in 1960, one with high levels in all three dimensions and one with lower levels in all three dimensions. Over time they identify the emergence of a third group of countries between these two clusters.

The major advantage in analysing the joint distribution of income, health and education is that we do not have to limit our analysis to an index of human development that is based on an arbitrary weighting framework (See Cherchye *et al.*, 2008; Foster *et al.*, 2009; Permanyer, 2013). Moreover, in contrast to UNDP's Human Development Index and related aggregate measures, we can explicitly study the distribution of achievements (see Grimm *et al.*, 2008) and geographically characterize the municipal development process and its transitions over the last two decades.

In our univariate analysis, we find a group of 260 agricultural municipalities converging to a very low-income level in 2000, due to a sharp income decline during the 1990s, arguably due to effects of NAFTA, GATT accession, overvaluation, and the 1994 economic crisis on the agricultural sector. We show that in those municipalities incomes fell but inequality also fell, while in more diversified agricultural districts, sectoral shifts reduced those income losses but were associated with rising inequality.

In the trivariate analysis, we find four, four, and three human development clusters in 1990, 2000, and 2010, respectively. In general there is an education-led transition from low to high development levels, and the human development dynamics are closely associated with the relative size of the agricultural sector and the share of indigenous population.

This paper is structured as follows. Section 2 presents and describes the data. Section 3 briefly summarizes the methodology applied in our study. Results and an analysis on the income inequality and human development dynamics are presented in Section 4. Section 5 concludes.

2. Data and Methodology

Mexico is composed of 32 states, which are divided into 2,456 municipalities. We consider 2,372 municipalities (covering more than 98 percent of the total population) for which we have comparable data for the years of 1990, 2000, and 2010.[2] For income, we use a data set provided by the World Bank's Poverty, Equity and Gender Unit, PREM-LAC that provides average incomes and measures of inequality for each of our 2372 municipalities. For average income we use the average household per capita income at constant prices of August of 2010 on

[2]Since a small number of municipalities were created after 1990 from other existent municipalities, we decided to exclude such entities from our analysis and perform our analysis based on a balanced panel, avoiding the comparison between differently sized distributions.

a logarithmic scale (with a base of 10). Additionally, we use the 90th/10th percentile income ratio at the same level of aggregation. The income variable consists of all monetary and non-monetary income, including consumption from own production, imputed rent, and income transfers.[3]

These income and inequality data are based on data from the Household Income and Expenditure Survey data (ENIGH) of 1992, 2000, and 2010 and on the population census of 1990, 2000, and 2010.The small-area estimation strategy proposed by Elbers *et al.* (2003) is employed to estimate income and income inequality at the level of each municipality using the census data. The procedure considers the household survey to be a random sample of the underlying population. Then variables which are correlated with income and which are included in both the household survey as well as the census sources are chosen. Only variables in which the sample mean is statistically equivalent to the population average are included in a generalized least-squares regression income model to be estimated using household survey data. Finally, the parameters of the income model are used to predict household incomes and to generate the household income distribution based on the household covariates from the census data. The estimations of income and inequality are calculated at the municipal level by matching the census to ENIGH for the same year (or the closest available one).[4]

Health is measured by the logarithm (with a base of 10) of the number of deaths of children per 1,000 live births.[5] Education is measured by the average years of schooling of the full population. Alternatively, in a robustness check, we also calculated the education variable based on the population aged 25 or older.[6] The health and education variables were generated based on random samples of the censuses of 1990, 2000, and 2010, reaching 10 percent, 10.6 percent and 10 percent of the census population sizes, respectively. This data was provided by the integrated international public use Microdata Series by the Minnesota Population Center (IPUMS International, Version 6.2. as of 2013 by the University of Minnesota). The same source is used to compute variables used later in this study such as the total municipal population, the share of the indigenous population, the proportions of agricultural employment, the share of the illiterate population in

[3]Income figures were deflated using Mexican CPI (Índice Nacional de Precios al Consumidor [INPC]). This income figure is smaller than GDP per capita income level and, as already discussed above, this discrepancy has been rising over time. We do not adjust incomes in the survey to match the national accounts. Thus our estimate strictly corresponds to an estimation based on household survey information only. For a discussion of these issues, see Deaton and Kozel (2005) and Lakner and Milanovic (2014).

[4]For 2000 and 2010, census and survey data are from the same year. To project incomes into the 1990 census, the 1992 household survey was used. This will not present a problem unless the correlation between assets and income has shifted a lot (and differentially across municipalities) in those two years, which is unlikely.

[5]More specifically, the mortality variable considers the questions asked to mothers aged 12 or more, how many of their children have already died. Those who died could have died in previous years as well so that the mortality measures the cumulative mortality of children independently of their age (as a proportion of children born). We believe that this is an appropriate indicator for longer-term child mortality and overall health conditions in a municipality.

[6]This alternative education variable is considered in order to assess whether differences in the age distribution by municipality could potentially bias our results, as low mean education could be just the result of a younger population that is still going to school. However, this alternative education variable comes at the cost of dropping 55 percent, 51 percent and 46 percent of the underlying populations in 1990, 2000, and 2010, respectively.

1990 and the share of employment in the public sector in the same year. To describe the rurality of a municipality, we also generate a variable which measures the proportion of the population living in rural localities (defined as villages and towns with less than 2500 inhabitants).

To model the distribution dynamics, we consider a multivariate finite mixture model. More specifically, we assume a Gaussian mixture model

$$\sum_{k=1}^{G} \tau_k \prod_{i=1}^{n} \phi_k (X_i | \mu_k, \Sigma_k) \tag{1}$$

where $\phi_k(.|\mu_k, \Sigma_k)$ is the density of the d-variate normal distribution with mean $\mu_k = (\mu_{k1} \ldots \mu_{kd})'$ and covariance $\Sigma_k = (\sigma_{kij})_{1 \le i,j \le d}$ $1 \le i \le j \le d$ and $1 \le k \le G$. τ_k are positive mixing weights adding to one and G is the number of components. In the univariate case, the formula simplifies to

$$\sum_{k=1}^{G} \tau_k \phi_k (X_i | \mu_k, \sigma_k) \tag{2}$$

with $\phi_k(X_i|\mu_k, \sigma_k)$ being a univariate normal distribution. In the univariate case, we employ the Expectation-Maximization (EM) algorithm to determine the number of components and to estimate the parameters of the mixture model (see Vollmer *et al.* 2013b for a detailed description of the method). In the multivariate case, we use the Bayesian Information Criterion (BIC) to determine the number of components and estimate the parameters of the mixture model using maximum likelihood techniques (see Vollmer *et al.* 2013b for more details on this).

Once we have fitted a finite mixture model with an appropriate number of components to the data, each observation can be assigned posterior probabilities of belonging to each of the components in the mixture model given the data. This allows us to assign observations to the component that it most likely belongs to according to the highest posterior probability. For the estimation of the model-based clustering, classification and density we used the R package *mclust* (see Fraley *et al.*, 2012).

3. Results

We start by considering the distribution of the individual variables before considering their joint distribution. The first panel in Figure 1 shows a significant income loss in 2000 (for black and white printing solid line) when compared to 1990 (for black and white printing dotted line). The observed income loss reported in the household surveys is probably a consequence of the deep economic crisis of 1994 (see Lustig, 1998; Esquivel *et al.*, 2010; Ortiz-Juárez and Pérez-García, 2013); but note that per capita income figures using national accounts paint a more positive picture (see above). Interestingly, a group of municipalities became very poor in 2000, showing evidence of the possible formation of a disadvantaged convergence club with per capita incomes around 467 Mexican pesos (see the left-hand bulge in the kernel density); this poor group seems to disappear in 2010 (dashed line).

Regarding education, there has been a continuous improvement in the years of schooling over time. With respect to health, the distribution of child mortality

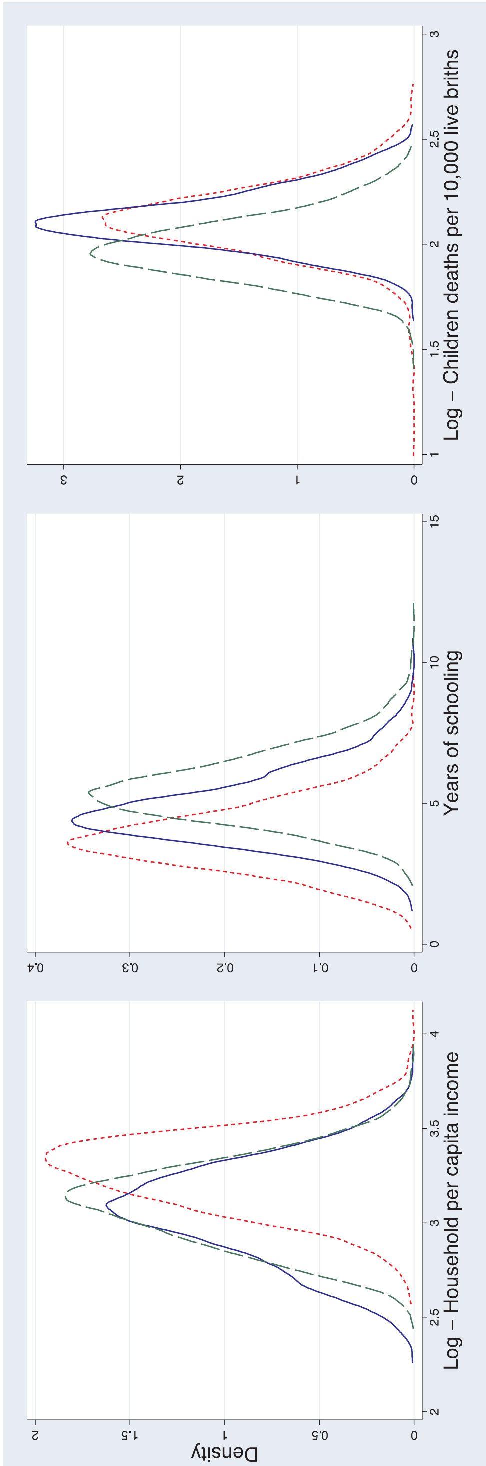

Figure 1. Kernel Densities of the income, education and health variables for the years 1990, 2000 and 2010

Source: Poverty, Equity and Gender Unit, PREM-LAC, The World Bank (income variable) and the Minnesota Population Center (health and education variables). The dotted line refers to 1990, the solid line to 2000, and the dashed line to 2010.

rates shows stagnation during the 1990s and accelerated improvement during the 2000s. In 2000, the distribution has shorter tails, but it is centred at approximately the same mean as in 1990.

3.1. *Univariate Gaussian Mixture Distributions*

In Figure 2, we show the Gaussian mixtures of the univariate distributions of income, health and education. In 2000, the distribution of income is characterized by the emergence of a statistically significant poorer sub-group whereas the same distributions in 1990 and 2010 only consist of one group. This is true at the country level and robust to the exclusion of the municipalities belonging to the states bordering the USA, and to the exclusion of those from the oil-states of Campeche and Tabasco who might experience a different dynamic (Sánchez-Reaza and Rodríguez-Pose, 2002). The clusters in the year 2000 show a mean of 472 and 1291 Mexican pesos. The difference in means represents an income gap between clusters equivalent to 819 pesos (in prices of 2010, see Appendix Table A.1).

Over the last two decades, we find two statistically significant components shaping the health distribution. However, in 1990, the mixture does not indicate the existence of two convergence clubs, but instead the two components have a similar mean achievement but different distributional characteristics. In contrast, for 2000 and 2010, the mixtures indeed represent the coexistence of two clusters of municipalities. In 2000, the new and smaller cluster, made up of 357 municipalities shows on average child mortality rates almost twice as high as those observed in the main cluster (188 versus 119 child deaths per 1000 live births). In 2010, the disadvantaged cluster shrinks to 316 municipalities and the mortality gap declines (137 versus 87 deaths of child deaths per 1000 live births). Moreover, Table 1 shows that 125 out of 357 municipalities escaped from the disadvantaged cluster between 2000 and 2010 showings that in a 10-year period, significant improvements in health outcomes are possible (see Appendix Table A.1). Conversely, during the same period 84 municipalities moved backwards in their health cluster classification due to the fact that they did not experience any statistically significant child mortality reduction.

In the case of education, there are always two clusters, a large group and a small one showing substantially higher levels of education. Both of these clusters move to the right over time, showing significantly improved education outcomes for both groups (see below Table 2 and Appendix Table A.1). The use of the alternative education variable shows the same behavior in terms of clusters and trends as the original variable. Note also that transitions between the clusters in education are also much less frequent than those that happened in the health dimension, suggesting greater stability in education than in health conditions.

3.2. *Determinants of the Poor Income Cluster in 2000*

We now turn to characterizing and explaining the emergence of the low-income cluster in 2000. Our univariate income mixture model shows that there are 260 municipalities for which the loss of income was much more pronounced. The geographic distribution of this poor group is depicted in Figure A.1 in the appendix. All municipalities in the low-income cluster are rural (i.e. 100 percent of their

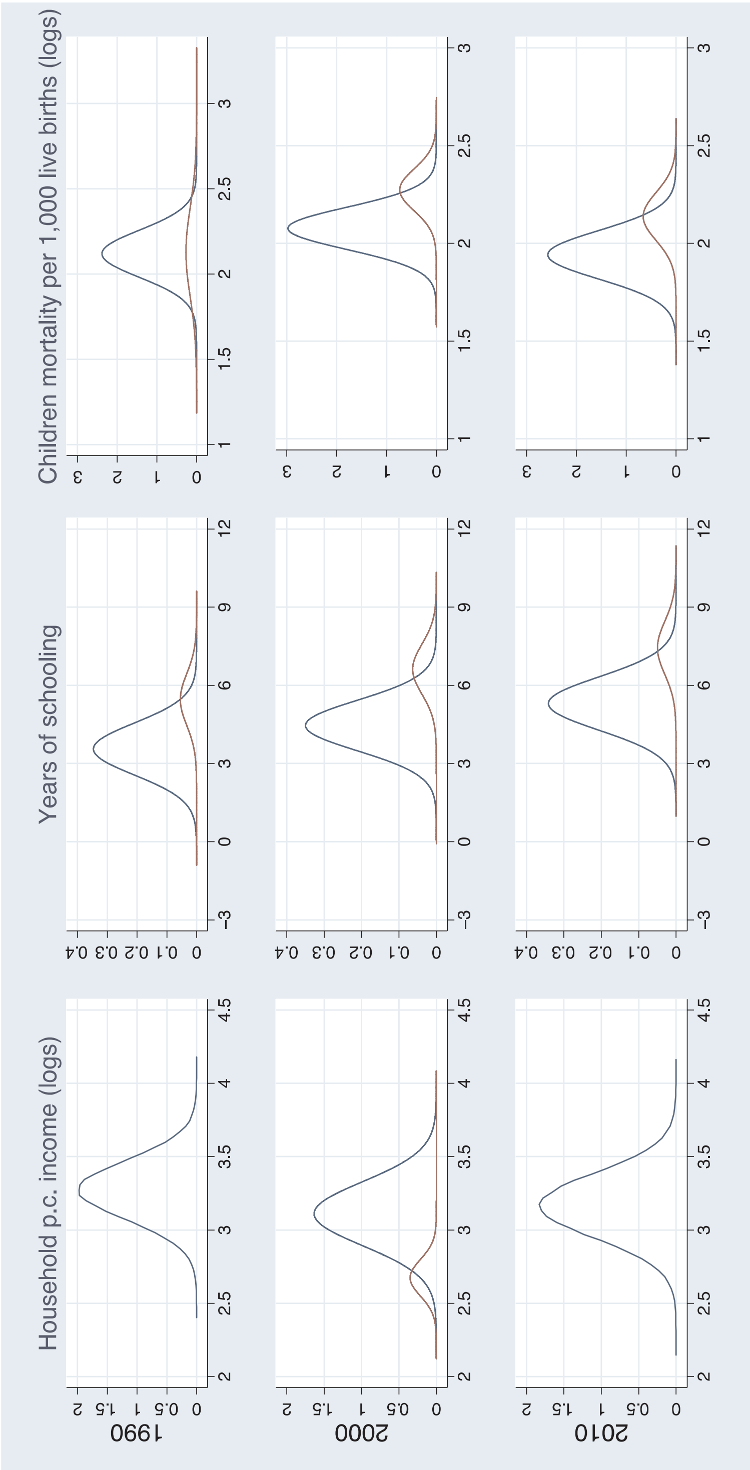

Figure 2. The univariate mixture of the human development components in 1990, 2000 and 2010

Source: Own elaboration based on data provided by The Poverty, Equity and Gender Unit, PREM-LAC (income variable) and the Minnesota Population Center (schooling and health variables).

TABLE 1

Health Transitions Matrix for 2000–2010

		2010		
		Disadvantaged cluster	Main Cluster	Total
2000	Disadvantaged Cluster	232 (9.87%)	125 (5.27%)	357
	Main Cluster	84 (3.54%)	1931 (74.37%)	2015
	Total	316	2056	2372

Source: Own elaboration based on the univariate-clustering. Figures in brackets refer to the proportion of all municipalities in that particular cell of the transition matrix.

TABLE 2

Education Transition Matrix for 1990–2000 and 2000–2010

		2000		
		Main Cluster	Leading Cluster	Total
1990	Main Cluster	2062 (86.93%)	100 (4.22%)	2162
	Leading Cluster	19 (0.80%)	191 (8.05%)	210
	Total	2081	291	2372
		2010		
		Main Cluster	Leading Cluster	Total
2000	Main Cluster	2065 (87.06%)	16 (0.67%)	2081
	Leading Cluster	94 (3.96%)	197 (8.31%)	291
	Total	2159	213	2372

Source: Own elaboration based on the univariate-clustering. Figures in brackets refer to the proportion of all municipalities in that particular cell of the transition matrix.

populations live in localities with less than 2,500 inhabitants) and mostly located within the states of Oaxaca, Chiapas, Veracruz, and Puebla (see Appendix Table A.2).

This emergence of the poor cluster is consistent with the literature on the impact of GATT accession, NAFTA, and the 1994 economic crisis on incomes in poor agricultural communities. Associated with the trade liberalization reforms of the 1980s and 1990s was the emergence of a trade deficit in the agricultural sector. Additionally, GATT and NAFTA shifted the farm imports to US producers of basic staples (including particularly maize). This problem of intensified foreign competition was exacerbated by an overvalued real exchange rate. Urrutia and Meza (2010) argue that financial and trade liberalization accounts for a significant real exchange rate appreciation. Here, sizeable capital inflows contributed to the currency overvaluation (Ibarra, 2011), causing particular competitiveness problems for tradable products such as agricultural goods. The combination of trade liberalization and an overvalued exchange rate caused particular problems for the traditional agricultural sector, causing job losses in this sector (Polaski, 2004) and declining wages in the primary sector in the 1990s, when compared to the rest of the economy, and also in absolute terms (Scott, 2010). Our evidence is consistent with these explanations and suggests that agricultural-based municipal economies (mostly in the southern part of the country) were more likely to suffer from an income reduction due to changes in the trade regime. But note that most rural southern municipalities did not experience such an enormous income decline. We hypothesise that many of these municipalities were able to shift towards the expanding non-farm (dynamic) sector (see also Araujo *et al.*, 2004).

But for municipalities belonging to the poor income cluster, which tend to have very poorly developed non-agricultural sectors (employment shares in agriculture average almost 80 percent), this option was apparently not available. As a result, we suggest that the predominance of the labor force engaged in agriculture ensures that agricultural incomes almost fully determine the income distribution in these municipalities. Consequently, a negative shock to agriculture would affect income across the whole distribution and might even affect the largest agricultural producers proportionately the most, leading to falling incomes but no rise (or even a decline) in income inequality.

In contrast, in municipalities with a more mixed economic structure (dual or multi-sector), there exist inter-sectoral migration (escape) possibilities, mostly for those with relatively high levels of education or ability. Thus, more educated or skilled individuals are more likely to transit from the traditional (declining) sector towards the modern sector. Consequently, in dual or multi-sector municipalities, this dynamic would translate into the emergence of a substantial inter-sectorial labor income-gap expressed as an increasing 90/10-income inequality ratio. As the demand for labor in these municipalities is mainly driven by the expansion of sectors linked to relatively skill-intensive activities, the disequalization of labor earnings, due to increasing returns to skills, is an expected outcome of this transition. This outcome is also consistent with the argument of one-time disequalizing impact of skill-biased technical change in the 1990s correlated to the new liberalized trade regime (López-Calva and Lustig, 2010).

Table A.3 in the appendix shows supporting evidence of this development based on the 1006 rural municipalities in the states of Chiapas, Oaxaca, Veracruz and Puebla. While on average, in rural municipalities classified to be in the non-poor cluster in 2000, the distance between top and bottom incomes increases over the 1990s, in municipalities sorted into the poor group in 2000, income inequality falls as the poor cluster also loses income. The difference is statistically significant for the poor component at the 1 percent level and significant for the non-poor component at the 5 percent level. These trends are consistent with our suggested interpretation of how economic opportunities develop in poor and non-poor clusters in the 1990s.

In order to investigate the relationship between the formation of the low-income group and the different inequality change paths amongst the selected rural municipalities, we also estimate a Gaussian bivariate mixture model of the distribution of the 90/10-income ratio for the period 1990–2000. The sample is restricted to the 1006 rural municipalities of Chiapas, Oaxaca, Veracruz and Puebla which make up the vast majority of the poor cluster in 2000.

Figure 3. Bivariate Gaussian mixture model of the 90/10 income inequality ratio distribution 2000 vs. 1990 (left panel) and the overlaid low-income club of convergence in 2000 on the same bivariate distribution (right panel)

Source: Poverty, Equity and Gender Unit, PREM-LAC, The World Bank (income variable). The left graph shows the four clusters generated by the bivariate mixture model for the relationship between income inequality in 1990 and 2000. The right graph shows the same municipalities but the symbols refer to which income cluster they belong to in 2000 (x refer to poor cluster, circles to non-poor cluster). The black solid line is the 45-degree line showing identic inequality levels in 1990 and 2000.

Figure 3 shows the results. The diagonals in the graphs divide municipalities experiencing disequalizing trends in income over time (above the diagonal) from those experiencing equalizing trends (below the diagonal). The left graph shows the four clusters generated by the bivariate mixture model for the relationship between income inequality in 1990 and 2000.

Clusters 1, 2, and 3 are largely aligned according to their overall level of inequality, while cluster 4 unites municipalities where income inequality is increasing significantly between 1990 and 2000. The right graph shows the same municipalities but the symbols refer to which income cluster they belong to in 2000 (x refer to poor cluster, circles to non-poor cluster). 194 out of 239 municipalities (81 percent) which moved into the emerging low-income cluster in 2000, show decreasing income inequality ratios from 1990 to 2000, while all municipalities that observed large increases in inequality belonged to the non-poor cluster. This supports our hypothesis relating worsening conditions for the tradable sector with differing opportunities for sectoral shifts and associated inequality outcomes in poor and non-poor municipalities (see also Villalobos-Barría, 2012 and Klasen *et al.*, 2014).

TABLE 3

PROBIT MODEL FOR THE INCOME POOR CLUSTER CLASSIFICATION (REGRESSION COEFFICIENTS REPORTED)

Dependent Variable: 1 if belongs to the poor cluster in 2000; 0 otherwise			
	Restricted sample 1	Restricted sample 2	Unrestricted sample
Log income in 1990	23.563*	23.488**	25.018**
	(2.379)	(2.728)	(2.743)
Log income in 1990 (sq.)	–4.159**	–4.168**	–4.418**
	(–2.578)	(–2.963)	(–2.979)
Log child mortality in 1990	0.309*	0.290*	0.331**
	(2.337)	(2.377)	(2.842)
Share of illiterate population in 1990	0.017***	0.019***	0.018***
	(4.028)	(4.662)	(4.457)
Share of indigenous population in 1990	0.566***	0.576***	0.619***
	(3.730)	(3.544)	(4.196)
Share of employment in agriculture in 1990	–0.044***	–0.047***	–0.045***
	(–3.338)	(–3.493)	(–3.529)
Share of employment in agriculture (sq.) in 1990	0.0005***	0.001***	0.001***
	(4.471)	(4.843)	(4.828)
Share of employment in the public sector in 1990	0.052*	0.055*	0.056*
	(2.000)	(2.196)	(2.242)
Coastal municipality	–0.156	–0.192	–0.196
	(–0.505)	(–0.618)	(–0.643)
Constant	–34.953*	–38.909**	–38.202**
	(–2.305)	(–2.960)	(–2.732)
State dummies		Yes	
Observations	1006	2080	2372
Wald chi2 (11, 16, 16)	214.36	632,90	350,15
Prob > chi2	0.0000	0.0000	0.0000
Log pseudolikelihood	–397.67	–438.75	–441.194
Count R^2	0.819	0.907	0.918
Adj Count R^2	0.238	0.258	0.250
Pseudo R^2	0.279	0.440	0.462

Robust bootstrap standard errors in parentheses. Significance levels ***p < 0.01, **p < 0.05, *p < 0.1.

Source: Own elaboration based on data by The Poverty, Equity and Gender Unit, PREM-LAC, The World Bank.

To further probe the correlates of ending up in the low cluster in 2000, we exploit our available data at the municipal level and implement a parsimonious probit model of cluster membership in Table 3. The explanatory variables consist of the initial values (in 1990) of variables representing human development dimensions. Additionally, to test our hypothesis of the role of agriculture and intersectoral labor mobility in affecting the transition, we include the share of employment in agriculture and the share of indigenous population (expected to show lower mobility levels). The share of employment working in the public sector is included as a rough proxy for the scale of non-traditional activities. Finally, state and coastal municipalities dummies are also considered. The equation is estimated on our unrestricted sample made up of the 2372 municipalities; on a restricted sample consisting only of the 1006 rural municipalities within the states of Chiapas, Oaxaca, Veracruz and Puebla including 92 percent of all poor municipalities (restricted sample 1); and on 2080 municipalities having more than 50 percent of their population living in rural areas (restricted sample 2).

As expected, municipalities with higher levels of education and health in 1990 are less likely to end up in the poor income cluster in 2000. Supporting our hypothesis, after controlling for income convergence, the shares of indigenous population as well as the proportion of agricultural employment are strongly correlated with the formation of the new poor component. Our results show an increasing association between the share of indigenous population and the probability of being in the poor cluster in 2000 (see the top panel in Figure A.2 in the appendix).

Regarding the proportion of employment in agriculture, we find a strong U-shape correlation with the observed clustering in 2000. The turning point situated in agricultural shares about 50 percent. However, as the majority of municipalities in our restricted sample show higher employment shares in this sector, we conclude that rising agricultural employment share is associated with an increased probability of income decline during the 1990s (see the bottom panel in Figure A.2 in the appendix).

This analysis supports our hypothesis that in agricultural municipalities with high structural barriers (related to a high indigenous share), the negative shocks to agriculture in the 1990s (NAFTA, GATT, overvaluation, and the 1994 economic crisis) caused these economies to converge on a low-income level in 2000, while the structural barriers prevented a mitigation of these changes through outmigration.

A catch-up process among municipalities that were previously sorted into the disadvantaged component characterizes income dynamics during the period 2000–10. Municipalities belonging to this group grew faster than the rest (71 vs. 18 percent respectively). Beta convergence is also found during the period 2000–10 with slopes of –2.11 and –0.75 respectively. As a result, a significant proportion of the municipalities in the low-income cluster improved their income rank in 2010. Figure A.3 in the appendix shows that on average, municipalities in the low-income cluster grew faster than the rest during the period 2000–10 (left panel). This beta-convergence ensures that a significant proportion of the municipalities moved upwards in the income distribution in 2010 (right panel).

But, what can explain such a dynamic? For one, it may well be the case that the end of the crises that had generated the low-income cluster has disappeared, allowing these poor municipalities to catch up. In particular, favorable external conditions and domestic price stability encouraged investments in agriculture. Thus, improved production enhanced incomes of relatively poor rural households in the poorest agricultural municipalities (Esquivel *et al.*, 2010). In addition, a substantial increase in government transfers targeted to the poor helped promote incomes in poor municipalities. For instance, the *Progresa* (later known as *Oportunidades*) conditional-cash transfer program started in 1997 has played a role in the equalization of incomes between 1997 and 2010 particularly in rural areas (see López-Calva *et al.* (2012) and Lustig *et al.* 2013). At the beginning of the program in 1997, participation was restricted to those areas that already had an elementary school and/or health services. Consequently, the poorest communities were excluded at the beginning of the implementation of the program but were included progressively in the 2000s (Sariego-Rodríguez, 2008).

3.3. *Trivariate Distribution of Income, Health and Education*

We now turn to the analysis of the joint distribution of per-capita income, health, and education. Our mixture model classifies municipalities into different human development clusters based on posterior probabilities. We find four, four, and three human development clusters in 1990, 2000, and 2010 respectively. Descriptive statistics of these clusters are displayed in Table 4.

The distribution of human development across municipalities shows an education-led convergence of human development over the past two decades. The reason for this development can be found in our univariate analysis as we show that the education distribution monotonically improves over time. Because such improvement has an upper limit in the case of schooling years, improvements are then associated with convergence in this dimension as education progress in those municipalities at the top of the distributions occurs at a slower rate compared with municipalities at the bottom of the education distributions. See Grosse *et al.* (2008) for a related analysis of pro-poor progress in education where the boundedness of education affects the distributional pattern of progress. In health, there is divergence between 1990 and 2000 driven by one cluster of particularly high mortality in 2000.

In income, there is a larger disparity among clusters in 2000, supporting our finding of the univariate discussion above, which becomes smaller in 2010 as four clusters merge into three and the mean gap between them shrinks. Figure A.4 in the appendix displays the same clustering using two-dimensional graphs. The centers and the lengths of the box sizes represent the mean value and standard deviations of the human development dimensions, respectively. This figure shows that the joint distribution of education and income explains the four clusters found in 1990. In 2000, the appearance of a low-income/high-children-mortality cluster canceled out the convergence in education observed during the 1990s. Further education convergence as well, the income convergence of the 2000s contributes to the reduction in the number of clusters (from 4 clusters in 2000 to 3 clusters in 2010). Figures A.6, A.7 and A.8 in the appendix show the geographic distribution of the development clusters in 1990, 2000, and 2010 respectively.

For the period 2000–10, the time-variant number of human development clusters does not allow us to directly determine whether a municipality transited from a less to a more developed stadium using the resulting non-square transition matrix.

To overcome this difficulty, we grouped municipalities according to a narrow criterion of human development improvement/deterioration. We define an improvement (deterioration) to have taken place only if a municipality moved to higher (lower) cluster *and* improved (worsened) its overall ranking.[7] Although this definition of transition is strict and conservative, pronounced changes in human development at municipal level using this definition seem to be much more common than transitions found in cross-country studies such as Vollmer *et al.* (2013a). Here, the proportion of municipalities improving or deteriorating ranges

[7]This conservative approach is useful to assess the dynamics in human development since it excludes municipalities transiting from a less to a more developed cluster (and vice versa) that could even worsen (improve) their ranking position within their original distribution of human development.

TABLE 4

Descriptive Statistics for the Human Development Components of the Trivariate Gaussian Mixture Model

	1990		2000		2010	
	Mean	SD	Mean	SD	Mean	SD
HD Dimensions	Full Sample (N = 2372)		Full Sample (N = 2372)		Full Sample (N = 2372)	
Years of schooling	3.82	1.19	4.79	1.24	5.57	1.24
Child mortality	2.12	0.17	2.12	0.13	1.98	0.15
Household pc income	3.27	0.20	3.06	0.25	3.10	0.21
	Bottom cluster (N = 1480)		Bottom cluster (N = 693)		Bottom cluster (N = 602)	
Years of schooling	3.34	0.86	3.79	0.76	4.58	0.77
Child mortality	2.16	0.14	2.25	0.11	2.08	0.13
Household pc income	3.23	0.17	2.82	0.19	2.91	0.15
	Middle bottom cluster (N = 223)		Middle bottom cluster (N = 955)		Middle cluster (N = 472)	
Years of schooling	3.47	1.24	4.56	0.41	5.51	0.86
Child mortality	2.12	0.27	2.09	0.01	1.99	0.16
Household pc income	3.16	0.23	3.09	0.03	3.11	0.21
	Middle cluster (N = 372)		Middle cluster (N = 74)		Upper cluster (N = 1298)	
Years of schooling	4.41	0.80	4.98	1.51	6.15	1.29
Child mortality	2.08	0.11	2.04	0.15	1.92	0.11
Household pc income	3.40	0.08	3.09	0.19	3.21	0.17
	Upper cluster (N = 297)		Upper cluster (N = 650)			
Years of schooling	5.15	1.19	5.87	1.13		
Child mortality	2.03	0.11	2.04	0.10		
Household pc income	3.38	0.22	3.24	0.19		

Source: Own elaboration.
Note: Household per capita income in US dollars of 2010.

TABLE 5
Human Development Transitions, 1990s and 2000s

	Classification in 2000 compared to 1990		Classification in 2010 compared to 2000	
	Frequency	Percentage	Frequency	Percentage
Upward	526	22.18	202	8.52
Stable	872	36.76	1305	55.02
Downward	974	41.06	865	36.47
Total	2372	100	2372	100

Source: Own elaboration based on the trivariate-clustering.

from about 60 percent during the 1990s to 45 percent during the 2000s (See Table 5 above). These human development transitions are displayed in appendix figures A.9 and A.10 respectively.

Noteworthy is the fact that during the 1990s, a considerable portion of the human development dynamics takes place in the south-western state of Oaxaca, which consists of 209 municipalities. This state exhibits one of the highest proportions of indigenous population (58 percent) and the second highest proportion of employment in agriculture (68 percent).[8] Table A.4 in the appendix shows that in Oaxaca, about one fourth of the municipalities improved their Human Development classification. Consequently, in absolute terms, this is the state where the highest number of 139 municipalities experiences improvements (139 municipalities). Simultaneously, Oaxaca also comprises more than one-fourth of all municipalities with declining human development classification (117 municipalities, or 21 percent). However, as a share of total municipalities in a state, improving municipalities are concentrated in the mostly Central and Southern states of Quintana Roo (86 percent), Queretaro (83 percent), Campeche (78 percent) and Yucatan (77 percent), followed by, Michoacán (74 percent) and Guanajuato (74 percent). Losers of the 1990s are mostly located in the states of Baja California (100 percent), Distrito Federal (94 percent), Colima (80 percent), Morelos (64 percent), and Nayarit (55 percent).

During the 2000s, the municipalities of Guanajuato (78 percent), Zacatecas (78 percent), Yucatan (67 percent), Durango (66 percent) and Nayarit (65 percent) made significant progress, while a substantial share of municipalities in the states of San Luis de Potosi (35 percent), Chiapas (28 percent), Guerrero (20 percent), Quintana Roo (14 percent) and Campeche (11 percent) worsened.

The spatial dynamics in human development during the 1990s show that the suggested positive income dynamics in the border regions linked to greater trade integration with the USA in the wake of GATT accession and NAFTA, did not generate broader human development improvements in many municipalities.

The decade of the 2000s shows improvements in human development in municipalities in central and southern regions, which benefit from the recovery of the tradable sector. Despite their economically advantageous location,

[8]Only Chiapas and Yucatán exhibit higher shares of employment in the agriculture and of indigenous population respectively.

border-states continue stagnated in human development terms (as their municipalities were less likely to improve in human development classification even when almost 40 percent of their municipality were classified into the less developed clusters in 2000), which might also be linked to rising mortality associated with the intensifying drug violence in the 2000s. This result can also be linked to the macroeconomic crisis of 2008–09 that originated in the USA, in which Mexico's GDP contracted by 6.6 percent due to their larger dependence on the US market. This was the sharpest economic decline in Latin America in the year of 2009 (Villarreal, 2010).

3.4. *Human Development Clustering*

In order to investigate the factors that are correlated with such positive and negative changes in development, Table 6 shows the outputs of the ordered probability models of (a) the observed clustering in 2000 and 2010 and of (b) the relative change in the classification from 1990 to 2000 and from 2000 to 2010 (dubbed transitions). Appendix Tables A.5 and A.6 show the marginal effects for the ordered probit models in Table 6.

To do this, we control for the initial clustering observed in the previous decade (1990 and 2000, respectively) and include as explanatory variables the initial values of the shares of indigenous population, employment in the agriculture, the share of rural population, the population size as well as controls for border and coastal location. Our result shows that low human development in 2000 seems to be clearly and strongly correlated with the share of employment in agriculture, and with the share of indigenous populations (both in 1990). A significant negative correlation is also found for border regions. Coastal regions do not differ significantly in their human development from the rest.

The clustering observed in 2010 reflects the same negative association of human development with the indigenous population share, and the share of employment in agriculture, although the effects shrink substantially compared with the 2000 clustering. Also, there is now a significant correlation with the share of employment in agriculture. Finally, border municipalities perform worse than the rest while coastal location is uncorrelated with the human development classification.

The right-hand panel of Table 6 shows the correlates of transitions. First, we find strong evidence of "conditional convergence" in human development. Municipalities clustered in worse off clusters improve their human development performance between 1990–2000 and even more so between 2000 and 2010. This is to be expected as many processes, including diffusion of policies and best practices, transfers, as well as migration, and roll-out of more generous social policies (including *Progresa/Oportunidades*) would promote such a conditional convergence. Although the US border condition is statistically and negatively correlated with the clustering in 2000 and 2010, it is not correlated with the human development transitions observed between 1990 and 2000. Conversely, coastal municipalities are more likely to improve their human development classification over time, a result which may be related to the upsurge of the tourism industry initiated since the 1970s (Wilson, 2008).

TABLE 6

ORDERED PROBIT MODEL FOR THE DEVELOPMENT CLUSTERING AND THEIR CHANGES

	Clustering		Transitions[a]	
	2000	2010	1990–2000	2000–2010
Very low development in t_{-1}	–1.85***	–1.15***	10.97***	4.60***
	(–10.08)	(–4.94)	(18.41)	(15.70)
Low development in t_{-1}	–1.37***	0.12	6.93***	4.03***
	(–4.98)	(0.51)	(12.23)	(12.89)
Middle development in t_{-1}	–0.45**	0.85***	4.61***	1.27***
	(–2.91)	(3.60)	(10.00)	(4.76)
Share indigenous population in t_{-1}	–2.27***	–0.78***	–2.35***	–0.55**
	(–10.86)	(–4.27)	(–12.75)	(–3.17)
Share emp. agriculture in t_{-1}	–4.06***	–2.59***	–4.44***	–2.85***
	(–12.64)	(–8.45)	(–10.99)	(–8.70)
Total population in t_{-1}	–0.0005	0.007*	–0.002*	–0.0006**
	(–1.85)	(2.12)	(–2.35)	(–2.99)
Share rural population in t_{-1}	0.05	–1.36**	–0.005	0.09
	(0.22)	(–3.17)	(–0.02)	(0.67)
US border	–0.53*	–0.75**	–0.06	–0.19
	(–2.50)	(–2.70)	(–0.18)	(–0.91)
Coastal	0.19	–0.008	10.97***	4.60***
	(1.14)	(–0.03)	(18.41)	(15.70)
Constant—Cut 1	–5.59***	–6.32***	2.67***	–1.94***
	(–24.25)	(–7.09)	(5.53)	(–6.46)
Constant—Cut 2	–2.45***	–4.82***	7.24***	1.88***
	(–13.11)	(–5.45)	(13.54)	(5.97)
Constant—Cut 3	1.29***	–	–	–
	(7.21)	–	–	–
State dummies	Yes		Yes	
Observations	2372	2372	2372	2372
Wald Chi^2	817.77	3989.06	1673.18	756.79
Prob > chi^2	0.0000	0.0000	0.0000	0.0000
Count R^2	0.699	0.690	0.781	0.701
Adj Count R^2	0.497	0.318	0.628	0.339
Pseudo R^2	0.314	0.294	0.513	0.452
Log likelihood	–2819.57	–1667.30	–1230.97	–1729.62

Significance levels ***p < 0.01, **p < 0.05, *p < 0.1; t-values in parenthesis. High development cluster is the excluded category. [a]Transitions refer to the following ordered categories: declining, stable and improving human development clustering in the period of reference.

Source: Authors' calculations.

Our results provide additional support to the idea that the social stress generated along the border could have harmed human development there. The drug war and associated violence that started in the mid-2005s, as well as the human trafficking of Central American migrants to the USA may provide a plausible explanation for the observed lack of development dynamics in the border region (particularly in Sonora and Chihuahua, see Figure A.10 in the Appendix). Further research should address the causal relationship between conflict and human development changes in border regions.

Table 6 also shows that the share of the indigenous population, and the agricultural share are negatively correlated with the human development transition in the 1990s and the 2000s, although the effects of agricultural dependence and the indigenous share are substantially smaller in the 2000. This suggests that the improvements that took place in the 2000s, which are mostly related to a catch-up effect captured by our "conditional convergence" term are also partly explained by improving conditions for agriculture in municipalities with higher proportions of indigenous populations; of course, many of the worst-off clusters remain very agricultural and contain a large indigenous share; in those, the positive "convergence" effect is moderated by the negative coefficients on agricultural and indigenous shares, so that more of these municipalities ended up moving up.

4. Discussion and Concluding Remarks

At highly disaggregated levels, there is a lack of studies addressing the issue of convergence in human development. Most studies only focus on the income dimension. We add to the literature by performing an overall assessment of human development based on the joint distribution of health, education and household per capita income as main determinants of human welfare. Specifically, based on Gaussian mixture modeling, we test formally for the number of clusters in the joint distribution of income, health and education.

Our trivariate Gaussian mixture models show over time an education-led transition from low and quite unequal to higher and somewhat more equal human development levels. But mobility in human development is high, affected particularly by fluctuations in health and income. Between 1990 and 2010, 55 percent of all municipalities transited from higher to lower or from lower to higher development levels. The human development dynamics are associated with the relative size of the agricultural sector and the share of indigenous population in these municipalities; location also matters, with different dynamics close to the US border or in Southern municipalities.

These analyses present a largely descriptive picture on distributional dynamics in Mexico. We suggest that some of these dynamics are likely to be related to fundamental economic changes in the Mexican economy over this time period, in particular trade liberalization, NAFTA, and swings in the real exchange rate. We also suggest that municipalities who benefited from these changes economically did not apparently benefit from it in a broader human development perspective. We suggest that this could be related to social stresses and a rise in violent crime that has affected mortality. While these results are suggestive, further research should address the determinants of these distributional dynamics more thoroughly using decomposition methods or well-identified econometric methods. Of particular interest would be to more clearly link the spatial distributional dynamics of human development in Mexico to the changing trade and exchange rate regimes, specific state policies to reduce poverty and promote human development, violence, and migration. In such an analysis, one could also consider spatially explicit econometric models to assess to what extent location and neighbourhood affects human development levels and transitions.

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Supporting Information

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Appendix: Further descriptive and regression results and maps