Regional differences in life expectancy at birth in Mexican municipalities, 1990-2000

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Resumen

El propósito de este estudio es proporcionar estimaciones de la esperanza de vida al nacer para los estados y los agregados de municipios por tamaño de población dentro de las regiones de México. Una técnica basada en regresión es utilizada para estimar la esperanza de vida de estas poblaciones de 1990 a 2000. Los hallazgos sugieren que el mayor incremento en la esperanza de vida entre los grupos de tamaño de población se produjo en los municipios rurales "extendidos" (aquellos con una población de 2.500 a 14,999), con un promedio de 7 años. La región de la capital mostro el mayor aumento en la esperanza de vida entre todas las regiones, con aumentos considerables en los municipios rurales "extendidos". Nuestras estimaciones son consistentes con las expectativas de acuerdo a las ventajas urbanas de la esperanza de vida, que probablemente son el resultado de los servicios de salud pública, así como la concentración de la atención médica primaria, secundaria y terciaria. Este análisis puede ser útil en la evaluación de las políticas de salud pública de las autoridades mexicanas, que se han centrado en la disminución de las desigualdades en salud entre bien y mal servidas poblaciones. En general, las esperanzas de vida obtenidas por este método de regresión son bastante similares a las preparados a partir de las tasas de mortalidad específicas por edad, además nuestros resultados muestran la utilidad de este método de acceso directo, en comparación con las expectativas de vida estimadas a partir de la serie completa de tasas de mortalidad específicas por edad.

Palabras clave: disparidades de salud, tasas de mortalidad, esperanza de vida, municipios mexicanos

Abstract

The purpose of this study is to provide life expectancy estimates at birth for states and aggregates of municipalities by population size within regions of Mexico. A regression-based technique is used to estimate life expectancy for these populations from 1990 to 2000. Our findings suggest that the greatest increase in life expectancy among population size groups occurred in "extended-rural" municipalities (those with a population of 2,500 to 14,999) with an average of 7 years. The capital region showed the highest increase in life expectancy among all the regions, with considerable increases in extended-rural municipalities. Our estimates are consistent with expectations with respect to urban advantages in life expectancy, which probably reflect the concentration of public health services, as well as primary, secondary and tertiary medical care. This analysis may be useful in evaluating the public health policies of the Mexican authorities that have focused on diminishing health inequalities between well and poorly served populations. In general, the life expectancies prepared by the regression method are quite close to those prepared from age-specific mortality rates, and our results show the utility of this shortcut method compared with life expectancies estimated from complete sets of age-specific mortality rates.

Keywords: Health disparities, mortality rates, life expectancy, Mexican municipalities

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1. Introduction

Scholars and public health practitioners have long been interested in health indicators linked to different geographies. Life expectancy is one of the most important indicators of health status and level of mortality experienced by general population. Life expectancy may vary over time and among geographic regions and individual localities within a particular country. The factors associated with such differences include population health, medical care access, socioeconomic characteristics such as education, income and housing, and access to clean water. It has been well documented that variations in life expectancy exist among geographic divisions in the United States, as well as individual states (James & Cossman, 2006; Hoque et al., 2012). According to Hoque et al. (2012), change in life expectancy has not been evenly distributed in the United States where, in different areas, life expectancy has grown rapidly or slowly, whereas in others it has declined. As a result, rural-urban life expectancy differentials tended to increase during the period from 1970 to 1990. According to Griffiths and Fitzpatrick (2001), life expectancy for males between Chiltern and Glasgow in the United Kingdom varies by 10 years (78.4 and 68.4, respectively). The objective of this study is to examine life expectancy at birth in Mexican municipalities and determine whether there is any variation of it among them.

Life expectancy is calculated through the construction of either a complete or an abridged life table, both of which have rigorous data requirements that are difficult to meet for small areas. As explained by Bravo and Malta (2010), in theory several methods have been proposed for the estimation of life expectancy in small population areas. Some of the methods are based on stable population concepts (Coale, 1984), others on biological theories of aging (Siler, 1979), and a few of them on the estimation of population by age (Irwin, 1980), abridged life table models (Chiang, 1984) or Brass-type methods for smoothing small area estimates (Brass, 1971).

Stable population methods may be unsuitable for small area estimates due to the rigid assumptions of mortality, fertility and migration rates stability. Biological theories are not well suited for small areas as rigorous data requirements often cannot be met. Likewise, construction of life tables is often not feasible due to the extensive data requirements, and because age-specific death rates for small areas are often unstable. As a result of their various assumptions and data requirements, none of these methods for estimating life expectancy at birth are suitable for small areas (Swanson, 1989).

In recent years several methods have been developed to estimate life expectancy for small areas, such as the Chiang, Silcocks, and Monte Carlo simulation method (NHS, 2005). Both the Chiang and Silcocks methodologies are based on the construction of a life table with the same data requirements and same associated problems with zero deaths in certain age intervals. On the other hand, Monte Carlo techniques are based on a hypothetical population which requires 10,000 or more for the simulation procedure. Toson and Baker (2003) used Monte Carlo simulation techniques to estimate life expectancy for males and females concluding that reliable estimates cannot be made for a population of less than 5,000.

Swanson (1989) developed a regression-based technique to estimate life expectancy at birth which has less data requirements and produces reliable estimates for small areas in the United States. The application of the regression method to Mexico in this study is useful because it does not require assumptions of population stability or quasi-stability (Swanson & Palmore, 1976). This is an important attribute as historical and recent patterns of internal and international migration have modified demographic profiles, particularly in local communities and municipalities.

An additional advantage of applying this method in Mexico is that the age compositions of the states, regions, and municipalities of Mexico are quite similar and none of them have exceptionally high average ages or unusually large concentrations of elderly persons. The weighted average of the index of dissimilarity in age composition for both sexes for the 32 states is about 3.7 percent (calculated from population by 5-year age intervals). The index goes from 1.0 percent for Sinaloa to 8.6 percent for Distrito Federal the Federal District (Mexico City). While some regions within Mexico have historically experienced higher emigration to the United States, such as rural municipalities in the central-western region, other areas, such as metropolitan areas in the northern border states have gained large numbers of internal migrants. These patterns have caused direct effects on the population size of such areas, but have not had much effect on age composition.

Few studies have focused on estimating Mexican urban-rural life expectancy at birth. Among them, Nunez and Moreno (1986) estimated levels of life expectancy for the early 1970s and late 1980s reporting a national average of 63 and 67 years respectively. The estimated life expectancy for rural areas during 1970-1975 was 61 years and for 1985-1989 approximately 65 years. For urban areas, considering the same sub-periods, they estimated a life expectancy at birth of 65 and 68 years. This accounts for an increase of 6.5 percent and 4.6 percent for rural and urban areas, respectively.

Official state estimates (CONAPO, 2007) indicate that life expectancy in 1980 for both sexes was 67 years, but by 2005 this value reached 74.6 years. Regarding gender differences, women show a higher life expectancy than men in all states. Nationally, life expectancy for females in 1980 was 70 years while for men it was 64 years. This gender gap in years of life expectancy continues over time but is decreasing. In 2005, female life expectancy at birth reached 77 years, while men's reached 72.2 years, indicating that gain in life expectancy at birth from 1980-2005 was greater for males (8.2 years) than for females (6.9 years). For both sexes there is a gain of approximately 7.6 years. Thus, the advantage in life expectancy of females over males decreased somewhat during the 25-year period.

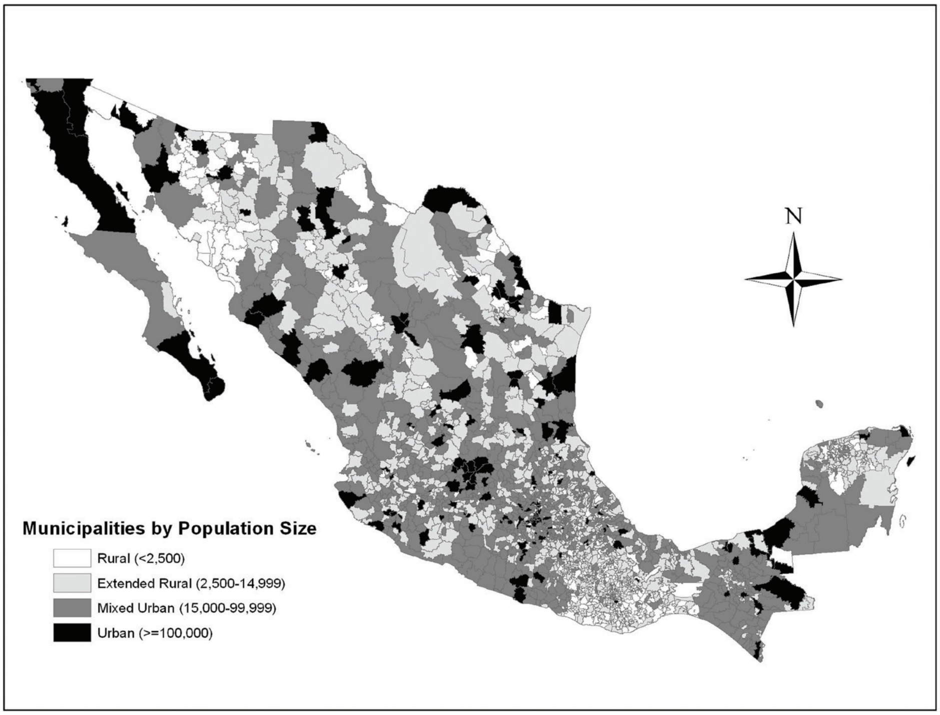
The purpose of this study is to estimate life expectancy at birth for various populations in Mexico. Specifically, a regression-based technique is used to estimate life expectancy at birth in states, regions and aggregates of municipalities, according to population size within regions, for 1990 and 2000. Municipalities are the smallest geographic unit of analysis for which demographic data is available in Mexican official sources. While some municipalities—i.e., those with large cities--have very large populations, most are quite small, and indeed too small in size for life expectancy estimations. While aggregating municipalities by size may obscure some variation, aggregation provides a practical mean to explore trends in life expectancy at birth between 1990 and 2000, and investigate to some extent urban-rural gradients within and between regions. All previous studies of life expectancy in Mexico have used the conventional life tables to calculate life expectancy for the country as a whole or at state level. As far as we can determine, no previous study has estimated life expectancy for aggregates of municipalities by population size in Mexico. Thus, this paper is unique because it represents the first attempt to estimate life expectancy for small areas in Mexico.

This paper is structured in four sections. The first section introduces the aspects of past and recent theoretical and empirical methods in the estimation of life expectancy at birth. The introduction also discusses the appropriateness of the regression model for the case of Mexico, and then a detailed description of this method is offered in Section II. The results obtained from the empirical analysis are shown and discussed in Section III. Finally, the limitations and policy implications drawn from this study are evaluated in Section IV.

2. Methodology

The regression method technique to estimate life expectancy at birth was developed by Mazur (1969, 1972), who first used it to estimate life expectancy of ethnic groups in the Soviet Union. The method was later refined by Swanson (1976) and Gunasekaran et al. (1981). It has been evaluated at state and sub-state levels in the United States, and has proven to be a useful and accurate alternative in the estimation of life

Figure 1 Distribution of Municipalities by Population Size



Source: Author's own.

expectancy for small areas (Swanson et al., 1992, 2009). The regression based method requires only two items of information about a population: the crude death rate and the percentage of persons aged 65 and over. A detailed theoretical and mathematical description of the model can be found in Swanson et al. (1977). The data requirements for the empirical estimation consist of: a) total deaths, b) total population (estimated or enumerated), and c) the population aged 65 years and over (estimated or enumerated).
The regression equation model for estimating life expectancy is specified as follows:

$$e_0 = \beta_0 + \beta_1 CDR + \beta_2 \ln\left(P65+\right) + \beta_3 CDR^2 + \beta_4 \ln(P65+)^2 + \beta_5\left[\left(CDR\right)*\left(\ln\left(P65+\right)\right)\right] \quad [1]$$

where CDR corresponds to crude death rate ((total deaths/total population)*1000) and P65+ denotes the percentage of the population aged 65 and over.

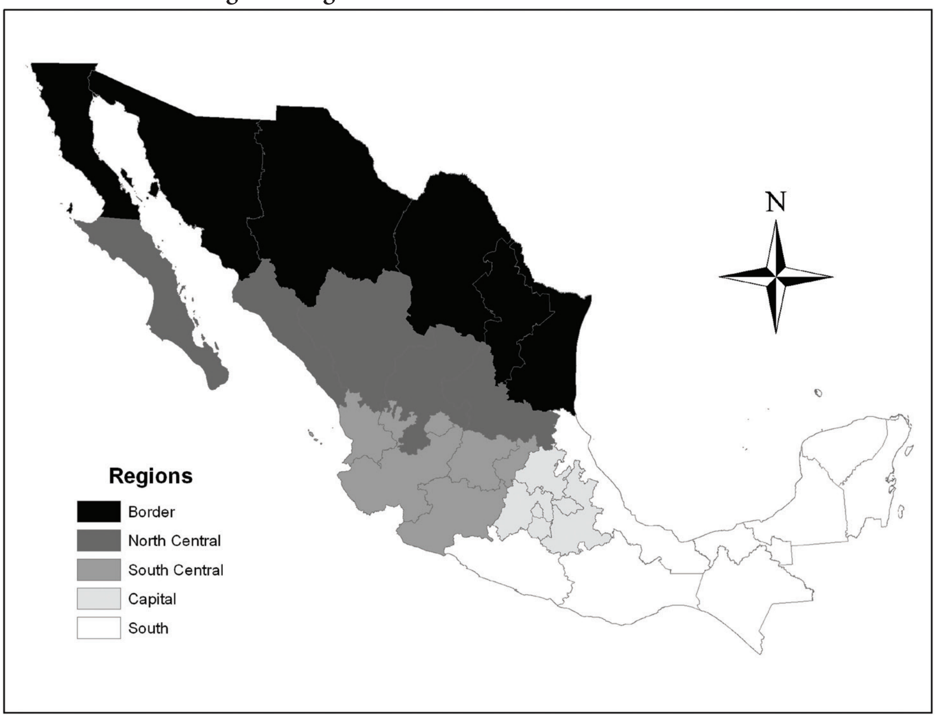
The model also includes a term for the square of each of these variables as well as an interaction term between them. In estimating Equation (1), fitting Mexican data for the year 2000, total deaths and population data were obtained from vital statistics and the 2000 General Mexican Census, respectively (Instituto Nacional de Estadística y Geografía, INEGI, www.inegi.org.mx). In order to calculate the crude death rates, total deaths were averaged for the period 1999-2001.

Heterogeneity in population size and age composition among municipalities could make the comparison of municipalities within and among states difficult. Therefore, we further categorized municipalities according to population size by adopting the classification suggested by INEGI (2005): a) Urban municipalities with a population of 100,000 or greater; b) Mixed-urban municipalities with population sizes within the range 15,000-99,999; c) "Extended-rural" municipalities with a population size of 2,500-14,999; and d) Rural municipalities with a population of less than 2,500. This classification has also been employed in population surveys such as the Mexican Health and Aging Study (MHAS) (Wong, 2004). The distribution of Mexican municipalities by population size can be seen in the map in Figure 1.

Table 1 shows the distribution of municipalities (municipios) according to population size, population aged 65 and older, and total deaths, which are the variables used for life expectancy estimates. As of 2000, approximately 16 percent of municipalities are rural (<2,500 inhabitants), comprising about 15 percent of the all municipalities; however, inhabitants of rural municipalities accounted for less than one percent of the total national population. Approximately 60 percent of Mexico's population lived in the 186 urban municipalities (>= 100,000 inhabitants). The population aged 65 and older likewise tends to be concentrated in large municipalities. Total deaths follow the same pattern, as approximately 59 percent occurred in the largest populated municipalities with just 1 percent in rural municipalities.

While the regression method for estimating life expectancy is broadly useful, there are two conditions under which the method may not be suitable: a) a substantial "special" population, such as is found in a retirement community with an exceptionally high percentage of persons aged 65 and older; and b) a small population with very few deaths, so that the crude death rate can fluctuate substantially from year to year (Swanson et al. 2009). A very large difference between the percent aged 65 and over at state level compared with a given small area would warrant further examination. In relation to the second condition, the use of the regression method is generally not recommended where the number of deaths is less than 50. We therefore restrict the analysis to those municipalities with more than 50 deaths during the years of study as well as

Figure 2 Regional Classification of Mexican States



Source: Author's own

Table 1. Total Municipalities, Total Population, Population 65+, according to Municipality Size, 1990 and 2000

Size of population (INEGI classification)	Number of municipalities	Percentage of all municipalities	Total population	Percentage of national population	Population age 65 & over	Percentage of national population age 65 & over	Percentage 65 & over	Total deaths	Percentage of national deaths	Crude death rate
					1990					
<2,500	399	16.6	573,433	0.7	39,557	1.2	6.9	4,459	1.1	7.8
2,500-14,999	1,051	43.7	7,911,034	9.7	409,157	12.1	5.2	48,419	11.8	6.1
15,000-99,999	810	33.7	27,925,719	34.4	1,214,112	36.0	4.3	146,617	35.7	5.3
100,000	143	6.0	44,839,459	55.2	1,714,015	50.8	3.8	210,889	51.4	4.7
Mexico	2,403	100.0	81,249,645	100.0	3,376,841	100.0	4.2	410,384	100	5.1
					2000					
<2,500	382	15.6	521,560	0.5	48,587	1.0	9.3	3,384	0.8	6.5
2,500-14,999	1,015	41.6	7,767,104	8.0	500,874	10.5	6.4	38,947	8.9	5.0
15,000-99,999	860	35.2	31,300,265	32.1	1,631,403	34.3	5.2	139,419	31.8	4.5
100,000	186	7.6	57,894,483	59.4	2,569,447	54.1	4.4	257,231	58.6	4.4
Mexico	2,443	100.0	97,483,412	100.0	4,750,311	100.0	4.9	438,981	100	4.5

Source: Own calculations with data from the Censo de Poblacion y Vivienda, years 1990 and 2000.

to municipalities where the percentage of population 65 and older is no greater than 20 percent of the total population. Within the regions of Mexico these two conditions exclude from the analysis at least the aggregates of municipalities with a population size of less than 2,500 inhabitants and some extended rural municipalities; however, an estimate for the national aggregate of rural municipalities is included.

Although the population of Mexico in general is quite young, with only about 5 percent of the total population over age 65, there are some variations in the distribution of the elderly population according to population size across municipalities. In 2000, urban municipalities included approximately 54 percent of the elderly population while only 1 percent lived in rural municipalities. As would be expected from these differences in age composition, the crude death rate in rural municipalities is somewhat higher than in the urban areas (6.5 and 4.4 per 1,000 total population, respectively).

To control for differences in the socioeconomic composition of municipalities that may be associated with health outcomes and life expectancy, we divided the Mexican geography into five regions (Figure 2). The regions are Border: Baja California, Sonora, Chihuahua, Coahuila, Nuevo León, Tamaulipas; North Central: Baja California Sur, Sinaloa, San Luis Potosí, Zacatecas, Durango; South Central: Querétaro, Nayarit, Jalisco, Guanajuato, Morelos, Puebla, Tlaxcala; and South: Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz, and Yucatán.

3. Results

Our findings are as follows: First, from the estimation of equation (1) the coefficients obtained are applied to the respective data in order to calculate life expectancy at state level; second, our life expectancy estimates are compared with the official estimates provided by Consejo Nacional de Población (CONAPO)[2]; third, we estimate life expectancy for aggregates of municipalities by population size.

The calibrated model (equation 1) was carried out through standard OLS regression with the results shown in Table 2. These are consist with the expectations of a positive relationship of the quadratic term related to the population aged 65 years and over, and the measure of overall mortality, which is later specified by crude death rates, upon overall life expectancy.

Table 2. Estimated Coefficients from the Regression-Based Model for Mexican States, 2000

Variable	Regression coefficient
Constant	72.25
CDR	4.08
ln(P65+)	-8.87
CDR^2	0.40
ln(P65+)^2	8.74
[CDR* ln(P65+)]	-4.67
R2	0.38
N	32

Source: Own calculations.

Table 3 shows our estimated life expectancy for 2000 for each of the Mexican States, the official estimates reported from CONAPO and the difference between them. As a way to measure accuracy of our life

2 CONAPO. Indicadores demográficos básicos 1990-2030. www.conapo.gob.mx.

Table 3. Estimated Life Expectancy in Mexican States, 2000

State	Estimated	Official	Difference
BORDER	73.84	73.73	0.11
Baja California	75.18	74.81	0.37
Coahuila	73.46	71.62	1.84
Chihuahua	74.12	73.86	0.26
Nuevo León	73.35	74.41	-1.06
Sonora	73.62	73.92	-0.30
Tamaulipas	73.31	73.75	-0.44
NORTH CENTRAL	73.40	73.54	-0.14
Baja California Sur	73.77	74.25	-0.48
Durango	73.36	73.38	-0.02
San Luis Potosí	73.29	73.20	0.09
Sinaloa	73.33	73.59	-0.26
Zacatecas	73.23	73.26	-0.03
SOUTH CENTRAL	73.39	73.60	-0.21
Aguascalientes	73.44	74.20	-0.76
Colima	73.34	74.22	-0.88
Guanajuato	73.35	73.77	-0.42
Jalisco	73.30	72.82	0.48
Michoacán	73.22	73.24	-0.02
Nayarit	73.31	73.66	-0.35
Querétaro	73.75	73.26	0.49
CAPITAL	73.44	73.94	-0.50
Distrito Federal	73.12	74.69	-1.57
Hidalgo	73.29	74.75	-1.46
México	74.13	73.88	0.25
Morelos	73.28	73.96	-0.68
Puebla	73.51	72.58	0.93
Tlaxcala	73.30	73.78	-0.48
SOUTH	73.55	73.15	0.41
Campeche	73.32	73.02	0.30
Chiapas	74.01	73.96	0.05
Guerrero	73.66	73.52	0.14
Oaxaca	73.10	71.91	1.19
Quintana Roo	74.36	74.18	0.18
Tabasco	73.61	73.10	0.51
Veracruz	73.23	72.43	0.80
Yucatán	73.12	73.05	0.07

Mean difference=0.04

Mean absolute difference=0.54

Number overestimated=16

Number of absolute differences exceeding 1.0 years=5

*Source: Compiled by author. * Official estimates reported by CONAPO, Indicadores demográficos básicos 1990-2030.*

expectancy estimates, this table also includes the mean difference and the mean absolute difference. The results indicate that the regression estimates a national life expectancy of 73.39, compared with the official number of 73.89, a difference of approximately 0.50 years. The resulting average mean absolute difference for the 32 states indicates an underestimation of the life expectancy by the regression method of approximately 0.54 years. A simple t-test for mean differences was performed indicating no significant statistical differences from the regression based on official estimates.

Table 4. Summary Statistics of Estimated Life Expectancy at Birth, 1990 and 2000 by Population Size

	Population Size									
	Mexico		100,000 or more		15,000-99,999		2,500-14,999		less than 14,999*	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
Mean	69.1	73.71	71.15	73.77	70.35	73.67	65.71	73.08	64.7	73.39
Stdev	4.08	1.52	2.42	0.95	2.42	1.17	4.67	2.62	8.26	2.81
N	1346	1298	143	183	788	845	380	270	1445	1396

Source: Own calculations. * Non-adjusted results for municipalities with less than 50 deaths during the period of study.

The next step consists of applying the calibrated model, fitting the required cross-sectional data for the years 1990 and 2000 using aggregates of municipalities as units of analysis. The estimated life expectancy at birth by population size of municipalities is shown in Table 4. The mean life expectancy at birth in 1990 is approximately 69.1 years while the estimated life expectancy in 2000 is 73.7 years, indicating approximately a 4.6-year increase in average length of life during the decade. Comparing the estimates by population size, municipalities of 100,000 or more showed the highest life expectancy compared to semi-urban and extended rural municipalities. Nonetheless, the gap between expanded-rural and urban municipalities experienced a considerable reduction as in 1990 it was approximately 5.4 years while in 2000 only 0.7 years.

Next, we ask whether the patterns of urban-rural differences show regional variations as well. In doing this, we estimated the change in life expectancy between 1990 and 2000 through a dummy regression model that is specified for each population size category and region. This is specified as follows:

$$e_0 = \alpha + \mu(YR) \qquad [2]$$

where e_0 is the estimated life expectancy for each municipality in 1990 and 2000, α is the intercept (1990 mean life expectancy), μ represents the change in mean life expectancy (in years) between 1990 and 2000, and YR is a dummy variable for year (YR=0, in 1990; YR=1, in 2000). Following Swanson et al. (2009) we performed the one-tailed test (p=0.05) to the slope coefficient (μ) for each of the estimated model specifications in order to determine the existence of statistical significance of change in life expectancy.

The results from the estimation of the dummy regression model are shown in Table 5. This table displays, along with the estimated coefficients, the standardized slope coefficient and the T-score as well as its significance level. The slope coefficient in the dummy variable regression equation for each region and population size class shows significance levels (p>.001). These suggest that there is statistical evidence that between 1990 and 2000 population did experience gains in life expectancy. In all regions there is a gradient in the estimated life expectancy according to population size.

Table 5. Dummy Regression Results of Life Expectancy Change by Population Size, 1990-2000

	Urban				
	Border	North Central	South Central	Capital	South
Constant	71.44	72.59	70.52	70.74	71.21
Est. Change Mean in Life Expectancy	2.52	0.82	3.05	3.10	2.47
Standardized (μ)	0.72	0.57	0.70	0.55	0.63
T-score	8.19	3.49	6.70	6.25	7.00
P(b=0)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
R-square	0.51	0.32	0.48	0.31	0.40
	Mixed-Urban				
	Border	North Central	South Central	Capital	South
Constant	71.25	72.04	70.89	67.64	71.17
Est. Change Mean in Life Expectancy	2.47	1.30	2.26	6.14	2.71
Standardized (μ)	0.38	0.37	0.52	0.31	0.49
T-score	4.99	4.97	10.52	13.88	14.36
P(b=0)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
R-square	0.14	0.14	0.28	0.31	0.25
	Extended Rural				
	Border	North Central	South Central	Capital	South
Constant	68.48	70.97	69.01	63.70	64.79
Est. Change Mean in Life Expectancy	5.53	2.37	3.65	10.36	6.30
Standardized (μ)	0.52	0.43	0.34	0.27	0.39
T-score	4.46	3.98	3.09	8.85	6.30
P(b=0)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
R-square	0.28	0.19	0.17	0.27	0.15

Source: Own calculations.

In general, extended rural municipalities tend to have lower life expectancy at birth while urban areas show the highest estimates as compared with the rest of the municipalities within each region, with the exception of the south-central region in which mixed-urban municipalities showed the highest estimated life expectancy.

In analyzing regional differences in life expectancy, we find that the north central region recorded the highest mean life expectancy at birth at the beginning of the period (1990) with 72.59, 72.04, and 70.97 years for urban, mixed-urban, and extended rural municipalities, respectively, while the lowest estimates in life expectancy by population size categories were found in the South region.

When considering changes between 1990 and 2000 in life expectancy by population size and region there are two interesting results to discuss. First, the highest increase in the change of life expectancy among population size groups occurred in extended-rural municipalities with an average increase of 7 years. The other two groups, urban and mixed-urban experienced an estimated increase in life expectancy, on average, of approximately 3.7 and 3.0 years respectively. Second, the capital region showed the highest increase in life expectancy among all regions, with considerable increases of those in extended-rural and mixed-urban municipalities. For these two groups the increase is approximately 10.36 and 6.14 years respectively, while for the urban groups the increase reaches approximately 3 years. Nonetheless, the South region experienced the second highest increases for mixed-urban and extended-rural with 2.7 and 6.3 years respectively. Significant gains in life expectancy are also estimated for the border region particularly in extended-rural municipalities with approximately 5.5 years between 1990 and 2000.

4. Limitations and Final Discussion

The results presented here indicate the usefulness of the regression method for sub-state estimates of life expectancy in Mexico. Our calibrated model and the estimates by population size are within the range of past studies (Nunez et al. (1986)). Our findings indicate that extended rural municipalities have experienced the largest increase in life expectancy at birth during the period 1990 to 2000. Among these, the capital region showed the highest gain compared to other regions. This may indicate urban advantages in life expectancy which probably reflect the concentration of public health services, as well as primary, secondary and tertiary medical care.

Overall, the results are in line with recent studies indicating that the greatest gains in life expectancy over the past decades have been achieved in women in the poorest states of the country (Frenk et al. 2003). This pattern of the decreasing gap in health inequalities between urban and rural areas would represent, to some extent, successful public health interventions for the uninsured population that have been targeted by policy programs. As pointed out by Frenk et al. (2003; pp. 1669), the second-generation reforms facilitated to improve and extend the health service to the uninsured population of the poorest states (Chiapas, Guerrero, Hidalgo, and Oaxaca) and areas of Mexico City and to improve the managerial infrastructure and abilities of state and federal health offices. An evaluation of the Mexican health system and its impact on the population's well-being is out of the scope of this analysis and a more conclusive inference would entail further analysis, which is left for further research. Nonetheless, this study leads to several policy implications.

The aging process of a country entails different economic and social implications. From the economic perspective, the 'macro' effects asociated with the country's saving rates, fiscal sustainability, and in general the social security system have been heavily explored. This is where the role of designing a pension (retirement) system can arise as a crucial policy tool to mediate these effects. This often conveys the projection of demographic indicators such as old-age dependency ratio and life expectancy, whose unreliable baseline estimates would necessarily distort the resources dedicated to cover the financial provisions. For Mexico, this statement is also relevant at the sub-national level, such as states, as they have decentralized pension systems.

Furthermore, an accurate analysis of the trends and disparities of the aging process in terms of life expectancy is expected to provide appropriate interventions to the local health and social care needs, particularly for the older population. This, in turn, should benefit the application of more efficient public policies and, even more relevant, of limited resources by local governments.

Some limitations, however, arise from this study. At this stage of the research we are unable to provide more conclusive inferences about those municipalities excluded from the analysis given that the methodology applied here, was limited to those with more than 50 deaths. In order to provide stable estimates, this analysis excludes most of the rural and some extended-rural municipalities. Although more work needs to be done, we advise that the regression method would be useful for small area populations higher than 2,500. The application of standard methods in the calculation of life expectancy, such as life

Table 6. Percentage of "Ill-defined" deaths in Mexican States, 1990-2001

State	Ill-defined deaths	Total deaths	% Ill-defined deaths
BORDER	2,071	221,119	0.94
Baja California	226	32,586	0.69
Coahuila	290	30,162	0.96
Chihuahua	617	45,496	1.36
Nuevo León	475	47,220	1.01
Sonora	192	31,627	0.61
Tamaulipas	271	34,388	0.79
NORTH CENTRAL	1,758	100,439	1.75
Baja California Sur	28	4,995	0.56
Durango	466	17,456	2.67
San Luis Potosí	536	29,415	1.82
Sinaloa	388	30,029	1.29
Zacatecas	340	18,544	1.83
SOUTH CENTRAL	2,008	252,730	0.79
Aguascalientes	93	11,059	0.84
Colima	53	7,054	0.75
Guanajuato	435	60,952	0.71
Jalisco	490	90,537	0.54
Michoacán	587	53,825	1.09
Nayarit	153	12,134	1.26
Querétaro	197	17,169	1.15
CAPITAL	2,538	422,331	0.60
Distrito Federal	87	135,934	0.06
Hidalgo	212	27,945	0.76
México	424	150,942	0.28
Morelos	152	19,849	0.77
Puebla	1,457	75,076	1.94
Tlaxcala	206	12,585	1.64
SOUTH	4,796	281,257	1.71
Campeche	112	7,353	1.52
Chiapas	1,195	44,733	2.67
Guerrero	689	31,033	2.22
Oaxaca	1,081	50,816	2.13
Quintana Roo	82	6,846	1.20
Tabasco	259	21,231	1.22
Veracruz	1,019	95,320	1.07
Yucatán	359	23,835	1.51
Total	1,371	1,277,876	0.11

Source: Own calculations with data from INEGI.

tables, are in general suggested for populations above 5,000 (Eayres and Williams, 2004; Toson et al. 2003). For municipalities with a lower population, one might follow a strategy proposed by Kulkarni et al. (2011) consisting of aggregating contiguous municipalities in the same state until the cluster meets the appropriate population threshold[3].

There are also anomalous results in the estimation of state-level life expectancy which require caution when offering a possible explanation. For example, from the calibrated model the estimated life expectancy for the state of Chiapas in the far south of Mexico (74.01 years) is the fifth highest of the 32 states, despite being among the poorest of the states. The official life expectancy for Chiapas from a life table is also unexpectedly high (73.96), the ninth highest among the states. A closer analysis of this difference may indicate, to some extent, under-registration of deaths. The so called 'paradox of information', in which populations that actually have high mortality appear to have low mortality because of the incomplete registration of deaths, may account for the high life expectancy in the most marginalized areas of the country.

This 'paradox' is present particularly in the states of Guerrero, Chiapas and Oaxaca (Lozano-Ascencio, 2008; p.530). These states have the highest percentage of deaths without medical certification or with the cause of death given as "ill-defined cause" (ICD-10 codes R96-R99), including unattended deaths, sudden deaths, or other unknown and unspecified causes of mortality. These are deaths that occurred from a natural, but unknown, cause due to the lack of medical care at death or during the illness or condition leading to death (PAHO, 2003; p. 2). In order to explore this in Mexican official deaths statistics, we show the total "ill-defined" number of deaths in Mexican states for 1999-2001 (see Table 6). Not surprisingly, the states with the highest percentages of total "ill-defined" deaths as a percentage of total deaths are Chiapas, Durango, Guerrero, and Oaxaca. Summary measures such as life expectancy, whether estimated by conventional or other methods, are only as good as the data underlying them.

Despite these issues, this study has provided life expectancy estimates for sub-state geographic units, municipalities, from which statistical inferences can be derived given data availability. As far as we are aware, there have not yet been any studies with similar analyses for other Latin American countries or other countries at a similar state of economic development. Hence, this study should serve as a starting point for further research regarding relationships between local socioeconomic status and local health outcomes.

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3 Specifically, Kulkarni et al. (2011) applies this method for counties in the U.S. by aggregating those with fewer than 7,000 males or 7,000 females based on contiguity among counties in the same state with similar size, income, and percent of population that is black or Native American.

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