ORIGINAL RESEARCH

The Effects of Public Infrastructure and Household Characteristics on Inequality and Infant Mortality in Mexico: What Has Changed Between 1990 and 2005?

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Abstract
The reduction of infant mortality (IM) continues to be a primary goal throughout much of the developing world, and a suite of methods have been proposed with which to achieve it. However, most attempts at IM reduction have taken place within the context of an almost bewilderingly complex regimen of simultaneous changes occurring in the physical environment, sociopolitical structure, and health care. Which of these various elements is truly causal in reducing IM and which may be merely correlated but nonprimary agents? During the past two decades Mexico has constituted an extraordinary field laboratory with which to decipher the roles of these various potential agents of IM reduction. Health resources include community access to proper drainage, safe drinking water, electrical power, as well as a suite of individual, if highly intercorrelated, family and household characteristics. Despite considerable demographic and socioeconomic heterogeneity, dramatic reductions in IM have been achieved, and additional ones are certainly possible. We weigh the factors that have reduced infant mortality in this country. Particular infrastructure improvements in the Pacific South, the Gulf, and the Yucatan peninsula must be continued. This would impact both inequality and, in turn, infant health and survival in this country.

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Introduction

The infant mortality rate is the most widely recognized indicator of health, wealth, and living standards throughout the world (Farahani, Subramanian, & Canning, 2009). While surveys of infant mortality (IM) provide the basis for demographic projections, the factors influencing the health of newborns in particular environmental and cultural settings must be assessed. Otherwise future risk reductions may be non-synchronous or uneven geographically. While there may be immediate, delayed, or even limited responses to advances in medical technology, policy changes for better nutrition, national immunizations, and clean water programs, the epidemiological challenge is to isolate and compare the strengths of particular factors.

The allocations of resources for healthcare improvements are increasingly evidence-based. In the absence of controlled randomizations (see "Progresa" below) aggregate data may be used in the explication of demographic change through the construction of time-specific mathematical models. An understanding of the relationships of environmental and social correlates with IM at specific junctures in time provides a foundation for informing healthcare policies. This report analyzes recent national surveys in order to assess the determinants of declines in IM across Mexico as observed at four points in time: 1990, 1995, 2000 (see Roldán *et al*., 2004), and 2005. After this, the most recent eight regional models (2005) are compared in the context of the evolution of demographic structure during the first years of the new century, and in preparation for a study of the 2010 survey.

Inequality, Epidemiology, and Experimental Design

Brazil has long been ranked among the countries with the highest income concentrations, with the poorest 60% of that population receiving less than 5% of the income. This has begun to change, imperceptibly at first, but measurably quite recently. In fact, it has become a leader in the global campaign against poverty and inequality through widespread economic growth and job creation. But Brazil's relative resilience in the face of the global economic crisis suggests that there is something more. In addition, a key factor there has been the Bolsa Família Program which along with food and school clothing provides payment to families who have their children undergo regular health check-ups, including vaccinations (Margolis, 2009; Bolsa Família, 2010). While this effort has been modest compared to other Brazilian social programs, it has had two important and unique results: reducing inequality, and providing incentives to families for investing in their children, thus attempting to break the cycle of intergenerational poverty. Costing less than a half percent of Brazil's GDP, Bolsa Familia now affects 11 million families, a major portion of the poorest people of that country.

An earlier program in Mexico, called "Progresa," included cash stipends to impoverished women (but not men) for participation in health and nutritional education and for childrens' attendance in school, especially high-school girls (Skoufias, 2005; Rosenberg, 2006). In 1995 the deputy finance minister Santiago Levy had seen enough of an existing antipoverty program which served the needs of the food companies more than the poor. After the crash of the peso Levy organized an experimental antipoverty program away from the capital, in Campeche, where it would attract neither attention nor opposition. "Records were carefully kept, tabulating the results in villages where the program was introduced and in a control sample of comparable villages" (Kristoff & Dunn, 2009, p. 173). When President Ernesto Zedillo was given these data he phased out the old food subsidies and initiated the program nationwide. Now called "Oportunidades," the program's expansion is a prime example of evidence-based policy, and some health workers see the merits of its extension to other continents. These programs included not only randomization (villages were assigned to experiment or control group) but also rigorous evaluation by outside experts, features lacking in most other aid programs (Kristof & Dunn, 2009).

The Decline of Infant Mortality in Mexico

Mexico has a gross domestic product per capita of more than US$6000. It is the third largest country in the western hemisphere, behind the United States and Brazil, with more than 100 million inhabitants. About a quarter of its people live in rural areas, and perhaps one out of nine lives in communities with fewer than 500 members. In response to the debt crisis of 1982, Mexico's federal administration implemented austere fiscal and monetary policies which resulted in cutbacks in health spending in an already poorly funded, inefficient, and highly centralized system (Hernández, et al., 1997). More recently there has emerged better training for health personnel, new technologies, and improved medical procedures (Cutler, Deaton, & Lleras-Muney, 2006); however, their distributions within the regions of Mexico regardless of total wealth remain uneven. Compounding these inequalities is the fact that the highest fertility rates occur in the poorest areas of Mexico, resulting in relatively greater demographic expansion with even less economic growth. Also in such areas typically there has been both increasing migration and declining employment. These are the engines of socioeconomic inequality, not only in Mexico but globally as well.

To further reduce IM the challenges that Mexico faces and the efforts that it mounts will be quite different from those of much of Africa and Asia, and at least one country in South America. Unlike Nepal, Bangladesh, Eritrea, Malawi, Laos, Bolivia, Chad, Congo, and Kenya, to name a few (UNICEF, 2009),

Table 1: Infant Mortality in Mexico by Year and Geographic Region

Region	Year	Mean (± 1 S.D.)*	n
Gulf-Yucatan	1990	442 (±107)	346
	1995	370 (±98)	347
	2000	316 (±67)	352
	2005	245 (±57)	354
West-Central	1990	407 (±87)	452
	1995	336 (±77)	456
	2000	281 (±52)	457
	2005	222 (±43)	458
D.F. & Surroundings	1990	416 (±108)	515
	1995	342 (±98)	532
	2000	288 (±67)	532
	2005	224 (±57)	535
Northern Mexico	1990	400 (±99)	334
	1995	324 (±89)	336
	2000	273 (±65)	338
	2005	204 (±56)	338
Pacific South	1990	466 (±116)	756
	1995	396 (±102)	757
	2000	338 (±72)	764
	2005	274 (±65)	769

* Infant Mortality = # infant deaths/10,000 births/year

much of Mexico had experienced large reductions in those infectious killers of infants and children so easily defeated by less expensive technologies years ago. The last two decades may have seen basic prevention of infectious diseases at the municipal level, especially water-born pathogens, but the next part of the transition will be relatively more costly, and evidence-based. While a portion of Mexico's public health care delivery system had been decentralized (Secretaria de Salud, 1996) and some of the financing and the quality of care had been improved by the early 1990s, health-care services have yet to be extended to all parts of Mexican society.

The last two decades have seen new efforts in basic services, facilities, and infrastructure, however uneven, which gradually increased adequate municipal sewage removal, clean safe water, and expanded electrical service in many areas. It is the purpose of this analysis to isolate and measure their benefits to infant health and survival, and to do so in the context of variations in household resources and socioeconomic status. It is ironic that the health inequalities of Mexican society provide an experimental alternative to the randomization that formed the basis of the comparisons in the Progresa program.

The last 75 years have seen the most pronounced and rapid improvements in infant survival in Mexico's history (U.N. Common Database, UNICEF, 2008). The national IM rate has undergone a nearly linear decline and today is about 15% of the 1930 value. This has continued during the last two decades as shown by Mexico's nearly 2500 municipalities within five broad geographic regions (Table 1). While IM has always been higher in the southern Gulf regions, the Yucatan, and especially the Pacific South, the average differences across the regions of Mexico, measured by municipality, are small compared to the within-region temporal declines. Variations *within* municipalities are another matter. These patterns in fact represent the penultimate phase of a remarkable national mortality transition, and one of the most salient features of modern Mexican demography.

What were the determinants of these most recent declines in IM? How did factors interact before and after the turn of the new millennium to continue to produce such dramatic mortality reductions? Finally, why will direct measures against inequality represent the most effective routes to better infant health and survival in Mexico?

Table 2: Correlates of Infant Mortality in Mexico, 1990-2005

Variable	
Municipal Facilities and Infrastructure	
% Households without drainage	D
% Households without access to potable water	W
% Households without electrical service	E
Rural-Urban Continuum	
% Households within communities with fewer than 5000 inhabitants	R
Characteristics of Household*	H*
% Persons that cannot read or write Spanish	H_1
% Persons ≥15 years of age that have not completed elementary school	H_2
% Households with >2 persons per bedroom	H_3
% Households without hard flooring	H_4
% Persons with income ≤2 minimum salaries	H_5

All variables were measured on the municipality. For 1990: n=2403 municipalities, 1995: n=2428, 2000: n=2443, 2005: n=2454. * The summary variable Household (H) was calculated as the arithmetic mean of H_1, H_2, H_3, H_4, and H_5.

The Database: Mexico, 1990-2005

Five-year surveys for this study were generated by several government agencies: (a) Censo General de Población y Vivienda (XI & XII); Conteo de Población y Vivienda (I & II), generated by the Instituto Nacional de Estadística, Geografía e Informática -INEGI-; (b) Estadísticas Vitales de Mortalidad, (1989-2005) Secretaría de Salud; (c) Indicadores Socioeconómicos e Índice de Marginación Municipal (1990-2005); (d) Probabilidades de fallecer en el primer año de vida por municipio, (1990-2005), Consejo Nacional de Población (CONAPO). Standardized methodology, increased accuracy, and municipal desegregation represent national goals, and as such these semi-decadal surveys mark the beginning of a useful comparative series. Nevertheless, they can never replace studies of sibships, families, and households, or case-control, follow-up, and longitudinal analyses, all of which are used ultimately to confirm causality with demographic data. In lieu of these, it is important to continue to enlarge the scope of national surveys, particularly in ways which may move us closer to identifying the relationships between family formation variables and health. For instance, the rise of contraceptive use in Mexico has protracted average inter-birth intervals which in turn has improved not only maternal health but infant survival as well (Juarez et al., 2008). It would be difficult to isolate the effects of such a widespread secular change in reproductive behaviour on health, even with improved measurement of contraceptive use at the level of the municipality.

Three classes of variables are examined. Proportions of households within municipalities have been measured according to: (1) access to facilities and infrastructure; (2) local population density; and (3) characteristics of home and household head (Table 2). These data provide elements of regression models to explain the structure of Mexico's ongoing transition to lower IM. Of course, while each variable emerges as a strong correlate of infant survival, simple association may not reflect a causal relationship. Therefore, any predictive power must be interpreted in a series of time-specific models. Attempts to determine causal structures at the four points in time will provide a useful beginning for understanding improving health conditions in the new millennium. Because of the aggregate nature of community-based proportions compared to within-household characteristics, each of the components of any predictor battery must be examined in the context of several methodological issues.

Issues in Mathematical Modeling: Redundancy, Interactions, and Departures from Linearity

The municipal data exhibit a high degree of inter-correlation. That there is no within-family structure to measure is one reason that redundancy among municipal characteristics is so pronounced, and this is

Table 3: Principle Components Analysis, Correlates of Infant Mortality, 2005

Variable	Principle Component Loadings				
	1	2	3	4	5
D	.44	.13	.87	-.08	.09
W	.61	.56	-.19	.15	.50
E	.61	.59	.03	.21	-.44
R	.64	-.36	.08	.63	.06
H_1	.89	-.11	-.01	-.19	-.08
H_2	.88	-.23	-.03	.04	-.07
H_3	.84	.12	-.29	-.08	-.10
H_4	.77	-.02	-.03	-.47	.07
H_5	.81	-.39	-.12	-.03	.06
Eigenvalue	4.86	1.03	0.90	0.73	0.49
% of Variance	54	11	10	8	5

See Table 2 for definitions.

problematic for assembling a battery of regressors from a community survey[1]. A principal components analysis (PCA) of the nine municipal variables reveals that there are fewer independent dimensions of variation (Table 3). The first principal component of the 2005 data corresponds to more than half of the variation, and it loads positively and strongly on all nine variables. Therefore, a linear combination of these scales could simply be labeled "poverty". A second orthogonal component accounts for much less variation in this system. Municipalities which rank high on this component tend to be deficient in potable water and electrical service, but are less rural and have relatively fewer household incomes under that year's minimum. The third component is no more than an independent measure of sewer/drainage insufficiency. No subsequent component loads strongly on any variable. This PCA shows that the use of all of the scales as individual regressors in a model to predict IM would result in a degree of multicollinearity so large as to render the estimates of each partial regression coefficient very unstable[2] (Berk, 2004).

To insure stable estimates of all coefficients the models predicting IM contain only five main effects: D, W, E, R, and H (Table 2). Throughout the analyses the magnitudes of "variance inflation factors" (Chatterjee & Price, 1977; Berk, 2004) were monitored. The VIF values for regressors in all final models were sufficiently low that multicollinearity posed no estimation problems, supporting the PCA-based inferences. In addition, the time-specific regression models for each region (see below) tended to be very similar to each other, which also confirm the stability of the estimation of coefficients.

At each time period, the five main regressors and all ten two-way interactions (i.e., DW, DE, DR, etc.) formed the bases of full models as well as the starting points for potential stagewise reductions. Following the methods of Kleinbaum, Sullivan, & Barker (2007) for logistic models in epidemiology, we regard household (H) as the study variable and the four two-way interactions which include H to be potential "effect modifiers." It is also useful to term the remaining six two-way potential interactions which do not include H as "confounders" (Kleinbaum *et al.*, 2007). This classification determines two stages of bulk tests for an efficient procedure for simplification.

For each of the years (1990, 1995, 2000, 2005) separating three quinquennia, the removal of all of the effect modifiers at once from the full models saved four degrees of freedom but resulted only in the addition of approximately one child death (per 10,000) to each of the standard deviations from regression. This translates to a loss of less than one percent of the amount of variance explained by the reduced models, and confirms that these interactions are not required for estimation and prediction. Next, a composite test (Kleinbaum et al., 2007) of the remaining six two-way interactions as a group prompted continued reduction to each of the time-specific models. The removal from the models of this stage of confounder terms resulted in a further increase of the standard deviations from regression for the early years (1900 and 1995) by less than three child deaths. The increase in the standard deviation was less than one child death for both later years (2000 and 2005). Therefore, as a result of only

Table 4: Regression Models for Infant Mortality, Mexico, 1990, 1995, 2000, 2005

Year	Infant Deaths/ 10,000 Births	Standard Deviation from Regression	Regression Coefficients							R^2
			b_o	b_1 (D)	b_2 (W)	b_3 (E)	b_4 (R)	b_5 (H)	b_6 (H^2)	
1990	432	31.7	366.2	0.62	1.51	1.93	0.18	-4.48	5.47	.915
1995	359	30.1	301.7	0.71	1.33	2.32	0.10	-3.78	5.68	.907
2000	304	17.9	204.9	0.70	0.32	1.34	0.29	-1.02	4.05	.937
2005	240	15.4	130.9	0.70	0.29	1.61	0.33	0.18	3.17	.941

two efficient bulk tests for every model, all two-way interactions were excluded.

Even such small amounts of lost precision could be recaptured. This is not an issue of regressor interaction; rather, there were minor departures from linearity involving the study regressor. Simple bivariate plots of IM on each of the other four main regressors did in fact display linearity. However, infant deaths increased slightly geometrically with the household variable (H), and this could be corrected by the addition of a single-degree-of-freedom quadratic term.

Therefore, the following form represents all final models:

$$IM_i = \beta_0 + \beta_1 D_i + \beta_2 W_i + \beta_3 E_i + \beta_4 R_i + \beta_5 H_i + \beta_6 H_i^2 /100 + \varepsilon_i$$

in which the IM_i represent the numbers of infant deaths per 10,000, i = 1, 2, . . . k, and k is the number of municipalities in observation. The variables D_i, W_i, E_i, and R_i, are measured as percentages, and the H_i are arithmetic averages of the five household percentages (see Table 2). The H_i^2 are the same household averages, quantity squared and divided by 100 to match the common magnitudes of all coefficients). The distributions of the residuals of the models (ε_i) are summarized by standard deviations from regression, and by coefficients of determination.

Applications of the Model: 1990 – 2005

The elements of the regression models are presented for each of the four quinquennial points in time (Table 4). The municipal constructions of proper drainage for communities and plumbing connections to households remained equally effective during the study period (i.e., the b_1 did not change substantially after 1990, Table 4). The pronounced and nearly linear increases in the actual proportions of municipalities with adequate sewage removal, which had attained a value of 90% in the nation by 2005 (i.e, 10% deficit, Table 5), paralleled the steep and linear decreases in total IM in Mexico during the past two decades. At each of the four points in time a ten percent increase in sewer/drainage infrastructure is associated with a saving of approximately 7 infants per 10,000 per year (values of b_1, Table 4). The same correspondence between these two variables obtains within regions (see below). The implication is that drainage improvements at any time period have powerful and consistent consequences.

Improvements in the availability of potable water were important determinants of IM in the 1990s. However, the magnitude of this effect declined prior to the new millennium. This is seen in a single-step decrease in the slopes after 1995 (see values for b_2, Table 4), as well as in the asymptotic decline approaching 15% deficits in potable drinking water by 2005 (see W, Table 5). Yet, the status of the year 1995, the b_2 for which should be more like subsequent years rather than 1990, is curious. The Clean Water Program was initiated between 1990 and 1995 (Frenk, *et al.*, 2003), however, the abrupt decline in water-born diarrheal child mortality (i.e., ages 1 to 4 years, not shown) had not yet taken place by 1995. These data lead to questions about the regional coverage and the temporal extent of implementation of this national program.

Table 5: Percent Deficits in Correlates of Infant Mortality, Mexico, 1990-2005

Year	Deficits in Correlates of Infant Mortality								
	D	W	E	R	H_1	H_2	H_3	H_4	H_5
1990	42	34	24	77	23	57	67	41	77
1995	31	25	14	75	20	52	61	36	77
2000	19	19	10	74	18	46	56	31	73
2005	10	18	5	73	17	39	51	25	67

All values reflect the average percent of households in a municipality without specified service of each variable. See Table 2 for definitions.

The effects of new domestic access to electrical power from 1990 to 2005 are more difficult to interpret. The large coefficients for this regressor imply a steady force for IM reduction from 1990 to the present (see values for b_3, Table 4). Yet, the provision of electrical power, which was more than 75% in 1990, was almost universal by 2005. How can there remain this strong relationship with IM when there appears to have been such a decline in the differences (among the E_i) with which it could co-vary? The reason is hidden inequality: some of the few municipalities in 2005 with limited electrical service in fact had *very* limited service, and in turn large numbers of infant deaths. The conclusion is that the lack of universal electrical access remains a sizable determinant of IM as well as an indicator of poverty and segregation.

The regression model contains a variable for each municipality that measures the proportion of rural communities (R). It is defined as the percent of households within the municipality which are located in communities with fewer than 5000 inhabitants. In these analyses this covariate is used to account for any variations in IM due to rural living beyond those due to the infrastructure and the totality of household characteristics. By this arbitrary 5000-person delimiter, Mexico has continued to increase its proportion of non-rural households by about two percent per decade (see R, Table 5). This general residual variable had an independent but limited effect on IM during the 1990s and a slightly larger one in the new millennium (b_4, Table 4).

The arithmetic average of five percentage deficits, the household variable (H), comprises very strongly intercorrelated measures: percentages of households which are overcrowded, which have dirt floors, and whose heads lack Spanish language skills, primary schooling, and a threshold income. The proportional amount of variation in IM explained by the household measure combined with that of its squared value does not change very much from 1990 to 2005, and therefore the relative contribution of these within the battery of regressors increases in small amounts with time (not shown). Furthermore, the decline in the estimated values for the quadratic coefficient indicates that the curvilinear nature of this relationship has become less pronounced (see b_5, b_6, Table 4). In addition, the values for the five components of the household variable all decrease in a monotonic fashion (Table 5). The degrees of multicollinearity within this composite variable are such that no attempt can be made at this time to disentangle the unique contributions of each component to variations in IM. This must await new within-family studies. And while the average degree of improvement in the Mexican standard of living is clear, its distribution within municipalities, i.e., inequality, must be surveyed and analyzed in this way as well.

From 1990 to 2005 there have been average advances in both municipal infrastructures and household environments. It might appear that the predominance of rural living in Mexico has not changed in such a way as to contribute to the mortality transition, but any lack of statistical effect is illusory. A rural existence will for the foreseeable future retain its basic relationship with IM, although its direct statistical impact may be diluted by the other main effects in the various applications of the models. In summary, the basic IM model is robust, i.e., the changes in the regression *models* (i.e., the coefficients) from 1990 to 2005 are incremental. First, there has been a decline in the rate of improvements due to guaranteed safe water, as the population’s access increased from approximately two-thirds to almost five in every six households. Second, the regressions of IM on the strong household variable have become less curvilinear by the end of the study period. The

Table 6: Regional Regression Models, 2005, Regions Ordered by Infant Mortality Rate

Region	Infant Deaths/ 10,000 Births	Regression Coefficients							R^2
		b_o	b_1 (D)	b_2 (W)	b_3 (E)	b_4 (R)	b_5 (H)	b_6 (H^2)	
Northeast Mexico	190	78.8	0.84	0.04	0.27	0.19	3.17	2.43	.95
Northwest Mexico	213	138.1	0.64	0.07	1.59	0.41	-0.41	4.62	.96
Pacific-Central	219	115.4	0.71	0.26	1.80	0.26	2.15	0.03	.95
D.F. & Surroundings	224	93.3	0.98	0.28	1.78	0.24	2.10	1.41	.96
Central	228	87.4	0.57	0.33	1.40	0.32	3.35	-1.36	.96
Yucatan	238	116.5	0.40	0.53	1.84	0.27	-0.17	5.22	.97
Gulf South	248	126.3	0.55	0.41	1.34	0.31	-0.24	4.55	.96
Pacific South	274	114.9	0.62	0.34	1.45	0.36	-0.16	4.02	.96

temporal changes in the *variables* present a complexly correlated pattern. There are linear and pronounced improvements in drainage and electrical services, and asymptotically diminishing improvements in safe drinking water. There are sizable and linear decreases in deficiencies in schooling, crowding, and the presence of hard flooring. Household income had begun to improve as well, however, this is very likely vulnerable to the global and Mexican economic declines which began last year. New data for 2010 will address this prediction. Incremental advances in Spanish literacy appear to be slowing. All of this reflects improvements to living standards in Mexico, but not to its economic inequality.

Applications of the Regression Model: Regional Comparisons in 2005

Except for Northeastern Mexico, where in 2005 the variations in neither electrical access nor safe water play roles in determining its level of IM (2nd lowest value of mortality), and Northwestern Mexico, where there is no effect of potable water on IM (lowest), a single regression model is nearly sufficient for the entire 2005 Mexican population. Moreover, the high stability of the coefficients as demonstrated by so many equivalent regional estimates confirms the validity of this regression approach to the analysis of Mexican IM (Table 6). That is, there is little variation that exists *among* the regional regression *coefficients* for sewer, water, and electricity. Second, as seen in the four all-Mexico temporal analyses the rural/urban variable appears to bear no consistent relationship to the level of IM in the presence of the other regressors.

However, while the models themselves may be robust, Mexico is by no means a homogeneous nation, and even some of the average values of the deficiency variables are quite different among the eight regions (Table 7). The percent deficit for adequate sewage disposal has declined by 2005, except in Yucatan, where more than a quarter of its communities are without such access (of course, lowland Yucatan has always presented unique challenges to drainage planners and engineers owing to its dearth of surface water). Approximately 90% of all Mexican communities had clean, safe water by 2005. However, despite the Clean Water Program of the early 1990s (Frenk, et al., 2003), many people in the Gulf South and Pacific South regions appear not to have access to safe drinking water even today. These and the unusual drainage conditions in isolated communities in the Yucatan have resulted in the highest levels of infant mortality in Mexico in 2005, a reminder of the persistence of socioeconomic inequality in Mexico and also a clear indication that the most effective future projects should be in the South. The value for the rural/urban variable in the Pacific South (88% rural) corresponds to its extreme level of 274 infant deaths/10,000.

Culture, family formation, and the resources of the household represent powerful yet the most refractory socioeconomic determinants of IM in the world today. Our household variable (H) is a correlate of this, an alias of poverty, and a strong factor in infant survival rates in developing areas. However, it remains difficult

Table 7: Percent Deficits, by Region, 2005, Regions Ordered by Infant Mortality Rate

Region	Infant Deaths/ 10,000 Births	Deficits in Correlates of Infant Mortality				
		D	W	E	R	H
Northeast Mexico	190	3	11	4	56	25
Northwest Mexico	213	9	12	7	72	27
Pacific-Central	219	9	11	4	62	33
D.F. & Surroundings	224	10	13	3	65	36
Central	228	13	15	5	70	34
Yucatan	238	27	4	4	69	41
Gulf South	248	7	27	6	71	42
Pacific South	274	11	26	8	88	51

All deficits reflect the average percent of households in a municipality without specified service or household condition. See Table 2 for definitions.

to view in terms of a regressor that can be manipulated in a causal statistical model, or improved by evidence-based public health policy. For community studies it must remain a summary variable, owing to the extreme degree of redundancy among its components. At one extreme on this axis are those municipalities with high frequencies of overcrowded dwellings, dirt floors, and low incomes as well as large proportions of persons older than 15 years having no primary education and limited Spanish language skills. Extending from this toward the other extreme along this scale is a gradation to municipalities with progressively fewer such households. Greater resolution of the structure of the causes of infant death in Mexico in the new millennium will now require family studies, stratified and controlled on the basis of municipal infrastructure variables. Only by means of such methodology can the components of household poverty be isolated. These studies should emphasize the Gulf South and the Pacific South regions.

Improvements to infrastructure especially in Mexico's most southern regions--more safe drinking water in the Pacific and Gulf South, as well as sanitation improvements for much of the Yucatan peninsula—might be postponed by global economic stagnation. This poses serious challenges to continued improvements in infant survival in Mexico, because the reduction of household poverty in this country remains the ultimate challenge.

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Footnotes

[1]The purpose of estimating these linear models is to isolate and measure the individual determinants of municipal IM rates. Partial regression coefficients (the β_i) in a predictive model have stable estimates and conventional meanings only if there is correct model identification and proper attention to the assumptions of multiple regression analysis.

[2]Principal component analyses of the same suite of potential regressors for the other three censuses reveal very similar inter-correlation patterns and in turn equivalent eigen-solutions, although sometimes the second and third components alternate positions. Therefore at each point in time the number of true dimensions is a similar fraction of the total variable suite, and the development of an overly complex least squares regression model would in every period be unsteady on a narrow domain. Since it is important to have regression models that are well-anchored on a truly multi-dimensional hyperplane, reduction of this collinearity is imperative.

References

Bolsa Família. (2010) Changing the Lives of Millions in Brazil. See website: (http://go.worldbank.org/M4EQDZNQX0)

Censo Nacional de Población y Vivienda XI (1990) Instituto Nacional de Estadística Geografía e Informática (INEGI). México, see web site: (http://www.inegi.gob.mx/est/contenidos/espanol/cubos/default.asp)

Censo Nacional de Población y Vivienda XII (2001) Instituto Nacional de Estadística Geografía e Informática (INEGI). México, see web site: (http://www.inegi.gob.mx/est/contenidos/espanol/cubos/default.asp)

Chatterjee, S., & Price, B. (1977) *Regression Analysis by Example*. New York: John Wiley & Sons.

Conteo de Población y Vivienda (1995) Consejo Nacional de Población. México, see web site: (http://www.inegi.gob.mx/est/contenidos/espanol/cubos/default.asp)

Conteo de Población y Vivienda (2005) Consejo Nacional de Población. México, see web site: (http://www.inegi.gob.mx/est/contenidos/espanol/cubos/default.asp)

Estadísticas Vitales de Mortalidad, Secretaria de Salud (1989-2005) México, see web site: (http://www.sinais.salud.gob.mx/mortalidad/mortalidad.htm)

Farahani, M., Subramanian, S.V., & Canning, D. (2009) The effect of changes in health sector resources on infant mortality in the short-run and the long run: A longitudinal economic analysis. Social Science and Medicine, *68*:1918-1925.

Frenk, J., Sepúlveda, J., Gómez-Dantés, O., & Knaul, F. (2003) Evidence-based health policy: three generations of reform in Mexico. *Lancet*, *362*:1667-71.

Hernández, P., Zurita, B., Ramirez, R., Alvarez, F. & Cruz, C. (1997) Las cuentas nacionales de salud. In J. Frenk (Ed.) *Observatorio de la Salud: Necesidades, Servicios, Politicas* (pp.119-142). Mexico City: Fundación Mexicana para la Salud.

Indicadores Socioeconòmicos e Índice de Marginación Municipal. Consejo Nacional de Población (CONAPO) y Comisión Nacional del Agua (1990-2005) see web site: (http://www.conapo.gob.mx/publicaciones/indice2005.htm)

Juarez, F., Singh, S., Garcia, S.G., & Diaz Olavarrieta, C. (2008) Estimates of induced abortions in Mexico: What's changed between 1990 and 2006? International Family Planning Perspectives, *34*:158-168.

Kleinbaum, D.G., Sullivan, K.M., & Barker, N.D. (2007) *A Pocket Guide to Epidemiology*. New York: Springer.

Kristof, N.D., WuDunn, S. (2009) *Half the Sky: Turning Oppression into Opportunity for Women Worldwide*. New York: Alfred A. Knopf.

Margolis, M. (2009) Brazil pays the poor. *Newsweek*, p. 15.

Partida Bush, V. (n.d.) Probabilidades de fallecer en el primer año de vida, por municipio, 1990-2005 en Estimaciones del Consejo Nacional de Población y Vivienda CONAPO.

Roldán J.A., Avila, A., Chávez, A., Alvarez, M., Muñoz, M. & Shamah, T. (2004) Regionalización de la situación nutricional en México. México City: Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán.

Rosenberg, T. (2006) How to fight poverty: Eight programs that work. See web site: (www.nytimes.com, Talking

Secretaria de Salud (1996) Programa de Ampliación de Cobertura. Lineamientos de Operación. Mexico City: Secretaria de Salud.

Skoufias, E. (2005) PROGRESA and its impacts upon the welfare of rural households in Mexico. International Food Policy Research Institute, Res. Report 139.

UNICEF (2009) Child mortality continues to drop. New York, 10 September. (http://www.unicef.org/media/media_51087.html)

U.N. Common Database, UNICEF, see website: (http://globalis.gvu.unu.edu/indicator_detail.cfm?IndicatorID=25&Country=MX)