Estimating the Effect of County Spending on Life Expectancy Through Structural Equation Modeling

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Abstract

Several studies have identified the impact of public health and social service sector spending on health outcomes in the US. The following study analyzes county spending across multiple sectors to understand how county spending in 2002 and 2007 impacts county life expectancy at birth (LEB) in 2005 and 2010, respectively. Annual spending data came from the Census of Governments. Through structural equation modeling, we classified counties' spending into categories of "social," "infrastructure," or "law and order" indices to streamline analysis and interpretation. Constraining the effect of the "infrastructure" spending index to 1, a "social" spending index significantly increased LEB and a "law and order" spending index significantly decreased LEB in both the 2002-05 and 2007-10 models. Results were consistent for rural counties, specifically for the 2002-05 model, but not for urban counties. These findings may inform how county governments could redirect spending allocations to benefit the health of their constituents.

Introduction

This paper develops and tests a model linking public spending by counties to county-level life expectancy. Obviously not every dollar spent by a county is intended to

improve the health of residents. However, almost all counties do spend funds on a local health department and there are obvious connections between spending on social welfare and spending on law and order to the health of a population. Whereas past studies looked exclusively at county health and hospital spending impact on life expectancy, this paper will take a broader view and examine a structural equation model linking the major categories of county spending.

The conceptual framework is that there are social determinants of health and so government spending that might alter those social determinants can also alter health. Rather than asserting that health "should be" in all policies as called for by many leaders of public health, we test the empirical proposition that there are health impacts of all policies. The paper does not assert the ability to detect a causal mechanism, but just an association. Places that healthy people flock to may also have political forces that endogenously allocate higher levels of various categories of public spending causing spurious correlation. Furthermore the spending may not cause people to be healthy, but it might cause differential migration rates between healthy and less healthy individuals. Nevertheless, with all due circumspection, testing whether there is any association between non-health sector spending by counties and county health will shine light on a commonly assumed tenet of public health.

Background

Several studies have identified the importance of public health and social service spending on health outcomes in the US.[1-7] For example, analysis of data from the Census Bureau found that an increase in state nonhospital public health spending is correlated

with a decrease in the incidence of the vaccine preventable diseases mumps and rubella.[4] Furthermore, Bradley et al. found that states with higher ratios of social to health spending had significantly better health outcome measures from 2000 to 2009 for adult obesity, asthma, mentally unhealthy days, days with activity limitations, and mortality rates for lung cancer, acute myocardial infarction, and type 2 diabetes.[3] These studies suggest that investments to improve health should not be limited to only the health care sector but should also include the social services sector.

While the impact of public health and social spending on health has been well studied on a state level, less is known about how routine budgetary allocations in multiple sectors by local governments affect health. At the county level, McCullough and Leider found significant positive associations between seven spending categories from the Census Bureau and County Health Rankings, a broad measure of health outcomes in counties by the Robert Wood Johnson Foundation.[6] The spending categories included social and health spending such as K-12 education, public hospitals, and community health care and public health spending. However, other sectors were also positively correlated with the County Health Rankings, such as fire protection and corrections spending. McCullough further found five patterns in county social spending in 2012 using cluster analysis that related to varying health outcomes across counties.[8] One cluster consisted of lower income counties that had lower social spending and worse health outcomes than other counties. Two other clusters consisted of high-income counties with high social spending and stronger health outcomes. While this

study focuses solely on social spending, it suggests that counties can be classified by patterns of allocating expenditures.

Analyzing county expenditure patterns in multiple sectors presents a data reduction problem as counties allocate their budget in many areas. The Census of Governments survey collects tax, expenditure, and revenue data every five years for each county government in the U.S.[9] The Census Bureau has consolidated the data on county expenditures into over 20 categories. However, these spending categories are cross-correlated. Attempts to attribute population outcomes to any specific outlay of funds would be subject to confounding bias and multi-collinearity.

Structural equation modeling (SEM) is an analytical technique that can be applied to the problem of multiple correlated indicators. SEM has the ability to test several regression equations with both observed and latent variables using non-experimental data.[10] SEM has been used to answer a variety of questions. For example, Roman utilized SEM to determine factors of sustainable procurement by US public agencies.[11] Other applications of SEM with data related to spending have involved consumer impulse buying behavior in grocery retailing and minimum wage's impact on spending on food away from home.[12,13] SEM has also been used in the health field, such as to model the association between metabolic score and cardiovascular disease mortality.[14] Thus far, SEM has not been used to analyze the impact of government spending and its effect on health outcomes.

Methods

Data

Expenditure data were drawn from the Census of Governments, which is conducted by the Census Bureau every five years to collect tax, revenue, and expenditure data from every county government in the U.S.[9] Data were available for 3,140 counties for years 2002 and 2007. The analysis focused on county direct expenditure variables that included direct expenditures on sewerage, fire protection, solid waste management, highways, public health, elementary and secondary education, natural resources, libraries, parks and recreation, public welfare, police protection, judicial and legal, and housing and community development. See Table A-1 in the Appendix for the definition of the expenditure categories.[15] Expenditure data were adjusted by the Consumer Price Index (CPI) to 2016 prices in order to make appropriate cross-year comparisons, CPI estimates were retrieved from the Bureau of Labor Statistics.

To mitigate any skewing effects of more populous counties having larger expenditures in general and vice versa with less populous counties, we constructed per capita expenditures by diving each county direct expenditure variable by their corresponding estimated population each year. We later took the log of the per capita expenditure. Population data were retrieved from Current Population Survey conducted by the Census Bureau.[16] Population data were not available for 10 counties; thus, our sample was reduced to 3,130 counties each year.

Some counties had extremely high and low expenditures and were skewing the analysis. To control for this, we excluded counties whose total per capita expenditure was above the 99% percentile or below the 1% percentile. The exclusion rule dropped 32 counties each year, leaving 3,098 counties to be analyzed. Table A-2 in the Appendix lists the counties that were excluded from the analysis. The lists were similar between the two years, in which sixteen counties were dropped in both years – five corresponding to the state of Texas.

The outcome of interest was life expectancy at birth (LEB), which was retrieved for years 2005 and 2010 in order to allow a 3-year lag for spending to have an effect on population's health. Life expectancy at birth (LEB) was retrieved from the National Center for Health Statistics.[17] LEB was not available for county Denali Borough in the state of Alaska, thus our sample consists of 3,097 counties for each year analyzed. Estimates for the 3,097 counties can be found on Table A-3 and A-4 of the Appendix.

Additionally, we noticed some counties declared having zero expenditure on certain direct expenditure variables because these were being covered by either state or federal governments instead of local governments. Since the aim of this study is to estimate the effect of local governments spending on life expectancy at birth, we decided to drop those counties whose expenditure is zero. Our final sample consists of 1,897 counties for the 2002-05 analysis and of 2,028 counties for the 2007-10 analysis.

The analysis was stratified by urban and rural areas, for which counties were defined as urban or rural based on the Rural-Urban Continuum Codes developed by the United States Department of Agriculture (USDA).[18] The USDA provides the urban-rural

definition for years 2003 and 2013. Urban areas are defined based on the population size of counties metro area and the definition of rural areas is based on the degree of urbanization and adjacency to a metro area. We assumed those definitions did not change over a decade – decades were defined as 1994-2003, and 2004-2013; thus, the 2003 definition was used for year 2002 and 2013 definition was used for year 2007. Out of the 1,897 (2,028) counties included in the 2002-05 (2007-10) analysis, 799 (873) counties were classified as urban.

Structural Equation Model

We first aimed to determine buckets of spending for structural equation modeling. We conducted an exploratory factor analysis using per capita expenditure variables to reveal underlying spending structures in counties. We hypothesized that the analysis would find factors for different categories of spending, including one for social spending. However, the results were underwhelming and did not find easily interpretable factors. We next used clustering techniques to look for county spending typologies but this analysis also failed to find buckets of spending that made sense. Therefore, in reviewing the literature and interviewing several state budget officers, we decided to classified counties' spending into categories of "social," "infrastructure," or "law and order" spending for the structural equation model (Figure 1) to streamline analysis and interpretation.

To assess the effect of county spending on life expectancy, we constructed a structural equation model (SEM) using the log of per capita expenditure as the main independent variables and LEB as the outcome of interest. Our SEM follows a linear

regression model, equations are modeled simultaneously, and we used the maximum likelihood method to estimate the parameters. The analysis was conducted separately for years 2002-05 and 2007-10 and stratified for urban-rural areas.

We begin by characterizing life expectancy at birth as a function of expenditure buckets and economic status resulting in the following LEB function:

[Eq.1] $$\mathrm{LEB}_i^{t+3} = \alpha_0 + \beta_1 \mathrm{Social}_i^t + \beta_2 \mathrm{Infrastructure}_i^t + \beta_3 \mathrm{Law}_i^t + \beta_4 \mathrm{Economy}_i^t + \varepsilon$$

Life expectancy at birth in period *t+3* (*t*=2002 and 2007) for county *i* (*i*=1,897 in 2002-05 and *i*=2,028 in 2007-10) is a function of per capita social expenditure, per capita infrastructure expenditure, and per capita law and order expenditure. LEB is also affected by economic status, which is included as a latent variable affecting LEB. Economic status is composed of poverty, and unemployment. A representative county chooses the amount of per capita expenditure on social, infrastructure, and law and order as a function of each other since resources are limited and expenditure buckets are competing between them for resources. In addition, counties allocate their resources depending on their level of poverty and unemployment. Allocation happens as follows:

[Eq.2] $$\mathrm{Social}_i^t = \alpha_0 + \gamma_1 X_i^t + \gamma_2 \mathrm{Infrastructure}_i^t + \gamma_3 \mathrm{Law}_i^t + \gamma_4 \mathrm{Economy}_i^t + \varepsilon$$

[Eq.3] $$\mathrm{Infrastructure}_i^t = \alpha_0 + \theta_1 Y_i^t + \theta_2 \mathrm{Law}_i^t + \theta_3 \mathrm{Social}_i^t + \theta_4 \mathrm{Economy}_i^t + \varepsilon$$

[Eq.4] $$\mathrm{Law}_i^t = \alpha_0 + \eta_1 Z_i^t + \eta_2 \mathrm{Social}_i^t + \eta_3 \mathrm{Infrastructure}_i^t + \eta_4 \mathrm{Economy}_i^t + \varepsilon$$

X, *Y*, and *Z* are three matrices whose elements are expenditure budget lines. *X* is formed by expenditure on public health, elementary and secondary education, natural

resources, libraries, parks and recreation, and public welfare. *Y* is formed by expenditure on sewerage, fire protection, solid waste management, and highways. And *Z* is formed by expenditure on police protection, judicial and legal, and housing and community development.

Results

Table 1 displays the output of the SEM for all counties as well as urban and rural counties separately for both the 2002-05 and 2007-10 models. The SEM constrains the effect of counties with a primarily infrastructure spending index to 1 and all other coefficients must be interpreted relatively. For the analysis of all counties, counties with a primarily social spending index in 2002 and in 2007 had a significant increase in LEB in 2005 (2.96) and 2010 (2.41) respectively compared to counties with a primarily infrastructure spending index. In contrast, counties with a primarily law and order spending index in 2002 and in 2007 had a significant decrease in LEB in 2005 (-3.54) and 2010 (-2.42) respectively compared to counties with a primarily infrastructure spending index. As expected, economic status had a negative impact on LEB in both the 2002-05 (-14.81) and 2007-10 (-23.72) models for all counties.

Results were similar for the analysis of rural counties. Compared to rural counties prioritizing infrastructure spending, rural counties that prioritized social spending in 2002 had a significant increase in LEB in 2005 (2.07) whereas rural counties that prioritized law and order spending in 2002 had a significant decrease in LEB in 2005 (-2.76). For the 2007-10 model of rural counties, rural counties that prioritized social spending had a significant increase in LEB (1.091) compared to rural infrastructure

spending counties. However, rural counties spending primarily on law and order did not have a significant effect on LEB for the 2007-10 model. Economic status had a significant negative effect on LEB for both the 2002-05 (-16.55) and 2007-2010 (-29.02) models. Interestingly, there were no significant results for the coefficients of interest for urban counties in both the 2002-05 and the 2007-10 models.

Goodness of fit (GOF) measures are indicators of how well the structural equation model fits the data. Table 2 displays common GOF measures for both the 2002-05 and 2007-10 models of all counties as well as urban and rural counties. All the models have GOF measures close to the benchmark values of what constitutes a "good fit." In particular, the Standardized Root Mean Square Residual (SRMSR) and Coefficient of Determination (CD) are at or close to the acceptable values. The upper bounds of the 90% confidence interval of Root Mean Square Error of Approximation (RMSEA) are around the benchmark of <0.10 for all models, although the lower bounds are not close to the benchmark of <0.05. Furthermore, the Comparative Fit Index (CFI) and the Tucker Lewis Index (TLI) are near but not quite at the benchmark of around 1.

Discussion

Both the 2002-2005 and 2007-10 structural equation models found that counties prioritizing social spending increased LEB three years later and those prioritizing law and order decreased LEB three years later compared to infrastructure spending counties. The effects were found to be the same for rural counties in the 2002-2005 model, but only the social spending effect held true for rural counties in the 2007-2010 model. No

significant findings were found for urban counties and all models had reasonable goodness of fit measures.

The finding that a primarily social spending index had the most positive impact on LEB is consistent with literature on how investments in social welfare and public health improve health outcomes. The finding that a primarily law and order spending index had a negative impact on LEB could be attributed to perhaps these counties having more crime or systemic factors that deteriorate health of their constituents. Infrastructure spending, the reference for this analysis, may have a more positive impact than law and order spending because, for example, investments in highways allow constituents to access healthcare and sewerage and solid waste management improve community hygiene.

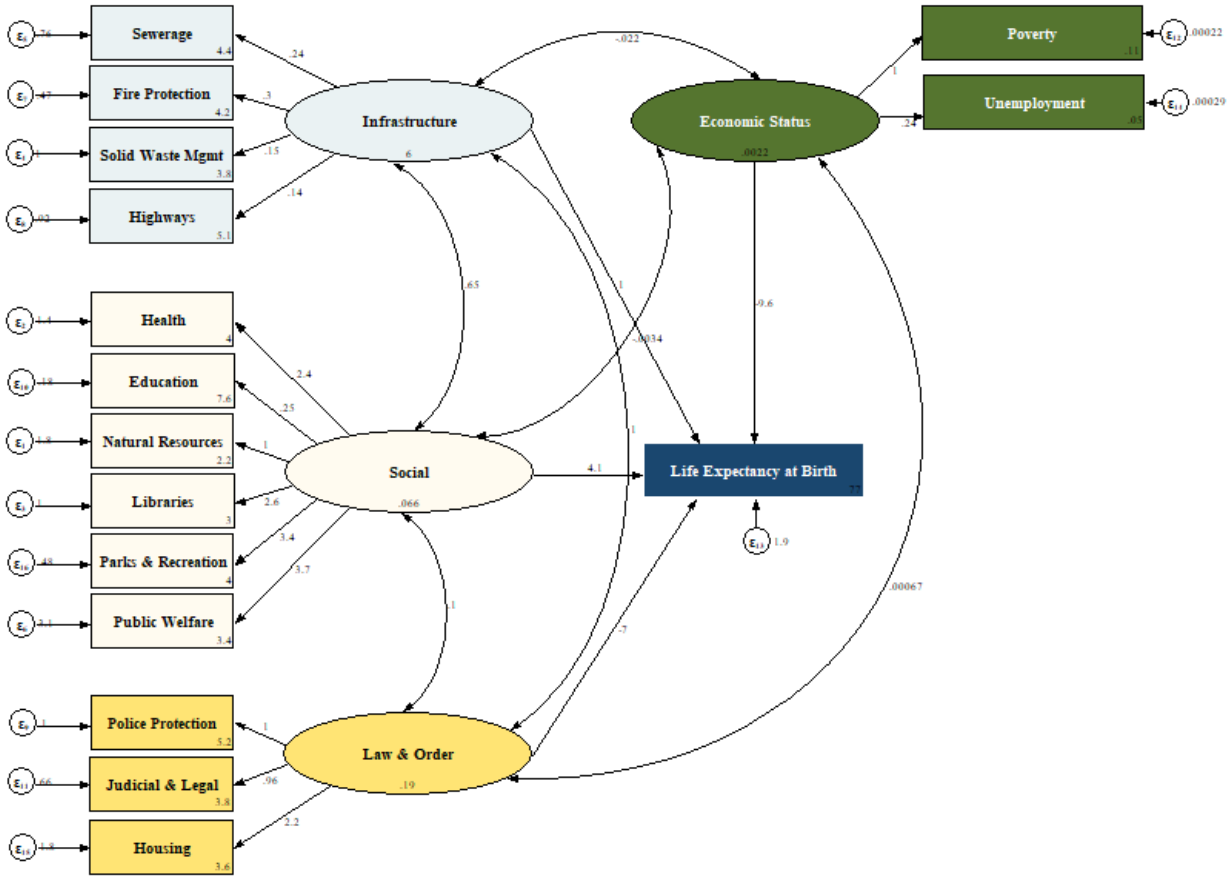
There are several limitations of this study. First, while the goodness of fit measures for the models are reasonable, further tweaking of the model could provide an even better fit. Second, LEB is a predictive measure and therefore is not a direct indicator of health. Third, counties excluded in the analysis that may have common characteristics that are not being captured by the models. Lastly, while we chose a three-year lag period, the impact of county spending on LEB could be even more significant or different beyond three years.

Nonetheless, the results of this robust SEM analysis could potentially provide a multi-sector framework for county policy makers to allocate investments to improve LEB. This analysis specifically looked at the trade-offs between investing in social, infrastructure, and law and order spending and therefore could inform policy makers of

how directing spending into one of these categories while cutting from another may impact constituent health. Overall, this study furthers existing literature findings on a local level of how improving health should be approached in a holistic manner across multiple sectors, with an emphasis on sectors that address social determinants of health.

Figures and Tables

Figure 1: Relationship model of direct expenditure and life expectancy at birth among U.S. counties



Note: The log of per capita direct expenditure is measured in 2002, and life expectancy at birth is measured in 2005.

Table 1: The effect of direct expenditure on life expectancy at birth stratified by urban-rural areas

	LEB					
	2002-05			2007-10		
VARIABLES	Total	Urban	Rural	Total	Urban$^{\phi}$	Rural
Social	2.958**	11.37	2.072***	2.408**	-10.67	1.091**
	[1.177]	[11.89]	[0.569]	[0.955]	[12.80]	[0.484]
Infrastructure (*reference*)	1	1	1	1	1	1
	[0]	[0]	[0]	[0]	[0]	[0]
Law and Order	-3.536***	-10.76	-2.759***	-2.421**	13.37	-0.879
	[0.715]	[6.552]	[0.888]	[1.083]	[13.66]	[0.840]
Economic Status	-14.81***	5.518	-16.55***	-23.72***	-88.33	-29.02***
	[2.693]	[23.20]	[3.619]	[5.066]	[53.79]	[6.025]
Constant	76.66***	76.97***	76.44***	77.44***	77.84***	77.14***
	[0.0478]	[0.0706]	[0.0638]	[0.0474]	[0.0713]	[0.0620]
Observations	1,897	799	1,098	2,028	873	1,155

Standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Note: (ϕ) Housing and Community Development is not included in Law & Order for urban 2007-10

Table 2: Goodness of fit of the SEM

	2002-05			2007-10			Benchmark
Fit statistic	Total	Urban	Rural	Value	Urban$^{\phi}$	Rural	
Population error							
RMSEA	0.104	0.105	0.099	0.096	0.099	0.097	
90% CI - lower bound	0.100	0.099	0.093	0.092	0.093	0.092	<0.05
90% CI - upper bound	0.107	0.111	0.104	0.100	0.105	0.102	<0.10
p-value	0.000	0.000	0.000	0.000	0.000	0.000	
Baseline comparison							
CFI	0.755	0.784	0.752	0.773	0.806	0.759	~1
TLI	0.690	0.727	0.687	0.713	0.748	0.695	~1
Size of residuals							
SRMR	0.083	0.084	0.078	0.074	0.076	0.075	<0.08
CD	0.981	0.991	0.971	0.967	0.973	0.962	~1

Note: (ϕ) Housing and Community Development is not included in Law & Order for urban 2007-10

Appendix

Table A- 1: Census Bureau Definitions of Expenditure Variables[15]

Description	Definition
Sewerage	Provision, maintenance, and operation of sanitary and storm sewer systems and sewage disposal and treatment facilities, as well as all intergovernmental payments for such activities.
Fire Protection	Prevention, avoidance, and suppression of fires and provision of ambulance, medical, rescue, or auxiliary services provided by fire protection agencies.
Solid Waste Management	Collection, removal, and disposal of garbage, refuse, hazardous, and other solid wastes and the cleaning of streets, alleys, and sidewalks.
Highways	Regular Highways: Maintenance, operation, repair, and construction of highways, streets, roads, alleys, sidewalks, bridges, tunnels, ferry boats, viaducts, and related non-toll structures. Toll Highways: Maintenance, operation, repair, and construction of highways, roads, bridges, ferries, and tunnels operated on a fee or toll basis.
Public Health	Provision of services for the conservation and improvement of public health, other than hospital care, and financial support of other governments' health programs.
Education - Elementary and Secondary Education	The operation, maintenance, and construction of public schools and facilities for elementary and secondary education (kindergarten through high school), vocational-technical education, and other educational institutions except those for higher education. Covers operations by independent governments (school districts) as well as those operated as integral agencies of state, municipal, or township governments. Also covers financial support of public elementary and secondary schools.
Natural Resources	Expenditures related to water resources, mineral resources, agriculture, and the regulation of industries which develop, utilize, or affect natural resources, as well as the regulation of agricultural products and establishments.
Libraries	Establishment and provision of libraries for use by the general public and the technical and financial support of privately-operated libraries.
Parks and Recreation	Provision and support of recreational and cultural-scientific facilities maintained for the benefit of residents and visitors.
Public Welfare - Cash Assistance	Cash assistance paid directly to needy persons under the categorical programs (Old Age Assistance, Temporary Assistance for Needy Families (TANF) and under any other welfare programs
Public Welfare - Vendor Payments	Vendor payments made directly to private purveyors for medical care, burials, and other commodities and services provided under welfare programs; and provision and operation by the government of welfare institutions
Public Welfare - Other Public Welfare	Other public welfare includes payments to other governments for welfare purposes, amounts for administration, support of private welfare agencies, and other public welfare services.
Police Protection	Expenditures for general police, sheriff, state police, and other governmental departments that preserve law and order, protect persons and property from illegal acts, and work to prevent, control, investigate, and reduce crime.
Judicial and Legal	Courts (criminal and civil) and activities associated with courts, legal services, and legal counseling of indigent or other needy persons.
Housing and Community Development	Construction, operation, and support of housing and redevelopment projects and other activities to promote or aid public and private housing and community development.

Table A- 2: Counties excluded from the analysis by the exclusion rule

2002			2007		
FIPS	**County**	**State**	**FIPS**	**County**	**State**
2013	Aleutian East Borough	Alaska	2130	Ketchikan Gateway Borough	Alaska
2164	Lake and Peninsula Borough	Alaska	2164	Lake and Peninsula Borough	Alaska
2185	North Slope Borough	Alaska	2185	North Slope Borough	Alaska
2188	Northwest Arctic Borough	Alaska	2188	Northwest Arctic Borough	Alaska
2282	Yakutat Borough	Alaska	6003	Alpine County, CA	California
6003	Alpine County	California	6051	Mono County	California
6075	San Francisco County	California	8009	Baca County	Colorado
6091	Sierra County	California	8047	Gilpin County	Colorado
8017	Cheyenne County	Colorado	8065	Lake County	Colorado
8047	Gilpin County	Colorado	8097	Pitkin County	Colorado
8061	Kiowa County	Colorado	20129	Morton County	Kansas
8065	Lake County	Colorado	21041	Carroll County	Kentucky
8097	Pitkin County	Colorado	27011	Big Stone County	Minnesota
8103	Rio Blanco County	Colorado	27077	Lake of the Woods County	Minnesota
8113	San Miguel County	Colorado	31141	Platte County	Nebraska
20025	Clark County	Kansas	32011	Eureka County, NV	Nevada
21041	Carroll County	Kentucky	36061	New York County	New York
27011	Big Stone County	Minnesota	47113	Madison County, TN	Tennessee
27077	Lake of the Woods County	Minnesota	47125	Montgomery County, TN	Tennessee
27099	Mower County	Minnesota	48033	Borden County	Texas
31141	Platte County	Nebraska	48105	Crockett County	Texas
36041	Hamilton County	New York	48173	Glasscock County	Texas
36061	New York County	New York	48261	Kennedy County	Texas
48261	Kennedy County	Texas	48269	King County	Texas
48269	King County	Texas	48301	Loving County	Texas
48301	Loving County	Texas	48311	McMullen County	Texas
48311	McMullen County	Texas	48393	Roberts County	Texas
48461	Upton County	Texas	48443	Terrell County	Texas
51013	Arlington County	Virginia	48461	Upton County	Texas
51830	Williamsburg City	Virginia	51013	Arlington County	Virginia
53007	Chelan County	Washington	56027	Niobrara County	Wyoming
53025	Grant County	Washington	56035	Sublette County	Wyoming

Table A- 3: The effect of direct expenditure on life expectancy at birth stratified by urban-rural areas

	LEB					
	2002-05			2007-10		
VARIABLES	Total	Urban	Rural	Total	Urban	Rural
Social	-1.595	4.085	0.280	1.033	-4.061	0.809**
	[1.498]	[6.822]	[0.444]	[0.886]	[4.224]	[0.359]
Infrastructure (*reference*)	1	1	1	1	1	1
	[0]	[0]	[0]	[0]	[0]	[0]
Law and Order	-2.058***	-6.998**	-1.206***	-2.118***	-1.634*	-0.986**
	[0.452]	[3.283]	[0.270]	[0.629]	[0.899]	[0.416]
Economic Status	-19.61***	-9.616	-19.26***	-24.07***	-37.54***	-25.46***
	[1.993]	[10.13]	[1.861]	[2.648]	[6.644]	[2.582]
Constant	76.49***	76.79***	76.33***	77.19***	77.65***	76.91***
	[0.0373]	[0.0618]	[0.0463]	[0.0388]	[0.0621]	[0.0486]
Observations	3,097	1,077	2,020	3,097	1,154	1,943

Standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table A- 4: Goodness of fit of the SEM

	2002-05			2009-10			Benchmark
Fit statistic	Total	Urban	Rural	Value	Urban	Rural	
Population error							
RMSEA	0.082	0.091	0.083	0.082	0.085	0.084	
90% CI - lower bound	0.079	0.086	0.079	0.079	0.080	0.080	<0.05
90% CI - upper bound	0.085	0.096	0.087	0.085	0.091	0.088	<0.10
p-value	0.000	0.000	0.000	0.000	0.000	0.000	
Baseline comparison							
CFI	0.826	0.827	0.807	0.825	0.844	0.805	~1
TLI	0.780	0.782	0.757	0.778	0.797	0.753	~1
Size of residuals							
SRMR	0.062	0.068	0.063	0.062	0.065	0.063	<0.08
CD	0.981	0.990	0.981	0.968	0.976	0.964	~1

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