ECONOMIC AND ENVIRONMENTAL DETERMINANTS OF URBAN MORTALITY

Timothy D. Hogan and Lee R. McPheters, Arizona State University

The urban environment has become the dominant setting for contemporary life in the United States, with more than 73 percent of the population residing within metropolitan areas. The benefits of urbanization include numerous economies of scale in production and consumption. However, the process of urbanization has entailed mounting negative side effects or externalities, including crime, congestion, and environmental deterioration. In addition, urban mortality rates exceed those of non-metropolitan areas (7).

This paper examines factors associated with the level of urban morality in the United States. We seek evidence on the existence of a systematic relationship between urban mortality and a variety of socio-economic, environmental and health care characteristics of the urban setting. In particular, several alternative measures of the supply of health care services and of environmental quality have been included as variables in our analysis. This has been done so that we can explicitly investigate the relative effects of differences in the provision of health services and of variations in pollution levels upon urban mortality levels, since these factors are two potentially important determinants that can be affected by social policy. The U. S. society currently allocates huge sums of money to health care expenditures, and there is growing pressure for the establishment of an even more expensive national health insurance system. At the same time, we have in recent years seen a social and governmental response, involving both increased expenditures and regulation, to the growing awareness of the adverse effects of pollution and other environmental contaminants. Many argue that, in an affluent society such as the United States, other factors such as personal habits, diet, pollution, etc., have more impacts on health than the availability of more and better medical services (6,9). We hope to gain some insight into this controversy within the context of the urban environment with this empirical analysis.

II. Review of Previous Studies

Although the determinants of urban mortality are undoubtedly complex, initial studies attempted to link variation in mortality with differences in a single or small number of suspected influencing variables. For example, in one of the earliest reported studies, Altenderfer (1) examined the relation between per capita income and mortality in 1940 for 92 cities with population greater than 100,000 persons. Altenderfer concluded that overall mortality and the death rate for ten broad diagnosis groups were inversely related to income (1, p. 1688).

In a later study, Patno (14) related mortality to "economic level," using 1940 and 1950 census tract data for the white population of Pittsburgh, Pennsylvania. The measures employed as indicators of economic level were median value of owner occupied housing and median monthly rental, and median family income. Based upon this evidence, Patno determined "In general, the highest mortality occurred among persons within the areas designated as being of low economic level, and the most favorable experience was found among the residents of the areas of higher economic status" (14, pp. 845-846).

The particular problem of racial differences in infant mortality in urban areas was examined by Jiobu (11) who found post-natal infant mortality related to socio-economic measures. He suggested that ghettoization may affect infant mortality due to influences of factors such as overcrowding and quality of medical care.

In a more qualitative investigation considering a wider range of influences of mortality, Biraben linked urban mortality to certain aspects of urban living such as increased personal contacts, traffic, pollution, and the general pace of city life (4).

A major collection of studies on the economics of health and medical care was published by the National Bureau of Economic Research in 1972 (8). One of these essays (2) attempts to test the impact of medical care variables on health, as measured by white mortality rates. While this study analyzed state, rather than urban data, the authors, Auster, Leveson, and Sarachek, took a more sophisticated approach than previous studies by including a number of socio-economic and environmental variables to control for differences among geographic areas. They discovered the influence of medical care on mortality to be small, while the association between mortality and education was strong and negative. Surprisingly, an income measure was found to be positively related to mortality in this study, contrary to much of the previous evidence.

Another study included in that collection, which is perhaps the most comprehensive investigation of the determinants of urban mortality to date, is that of Silver (15) who examined both Standard Metropolitan Statistical Area and state data to explain spatial variation in black and white mortality rates. Silver applied regression analysis to some forty explanatory variables. Again, Silver found the relation between education and mortality to be negative and usually significant. The excess of black over white mortality was attributed to differences in income and educational levels for the two groups. Generally, Silver found a negative relation between income and mortality, with education excluded from the model. One exception was the case of white male mortality, using state data. Re-estimating the white male mortality equations with income broken into labor and non-labor components, the sign of non-labor income was strongly negative, while labor income was not usually significant. This suggested to Silver that "pure" increases in income may have a positive effect on health, but incomes earned by more strenuous or dangerous work may be unfavorable to health.

While the more recent attempts to estimate the relative contributions of various determinants of urban mortality have included larger numbers of variables than earlier approaches, the increased number of variables has introduced the possibility of multi-collinearity and thus mis-interpretation of the empirical results. Below, we follow an approach which allows for consideration of a large number of variables, but minimizes the problems associated with multicollinearity.

III. Design of the Study

Our fundamental hypothesis is that variation in urban mortality is dependent upon a complex milieu of determinants, including economic variables, environmental variables, population characteristics, and various measures of health care availability and utilization. We test this hypothesis in a least squares regression analysis, using data for the 64 largest SMSA's within the continental U. S. for 1970.[1] Since the inclusion of all the potential determinant variables in one regression equation would prove unwieldy and statistically suspect, we reduce the information contained in the original large data matrix through extraction of its principal components.

Briefly, principal component analysis takes observations on a large number of correlated variables and finds a smaller set of orthogonal or uncorrelated variables which capture as much of the variability of the original data set as possible (5, pp. 53-65). The resulting components may be used to construct index variables which can be employed as independent variables in ordinary least squares regression analysis.

The original data used in our analysis are shown in Table 1. Included are measures of economic variables, population characteristics, environmental measures, and medical care variables. Many of these variables have appeared independently as explanatory variables in previous analyses of mortality.

Extracting components until the resulting Eigen-values fell to 1.0, we derived nine orthogonal components or factors which accounted for over 75 percent of the variance in the original data matrix. To facilitate interpretation of each of the derived factors, we performed varimax rotation, which preserves orthogonality while simplifying the columns of the factor matrix.[2] The loadings shown in Table 2 measure the correlation between the original variables and each of the respective components after varimax rotation.

The first factor extracted in principal component analysis is usually a general factor expressing a summary of the linear relationships present in the data. After rotation, the first factor (F1) seemed to measure the general character of urban areas especially with respect to motor vehicle dominance. This factor is positively associated with motor vehicle registrations, days of sunshine, per capita income and education, and negatively related to hospital occupancy rates and pollution variables. We found SMSA's with high scores on this factor are likely to be newer "sun belt" cities.

The second factor (F2) tends to be most highly associated with variables measuring economic level, including percent of the population above the poverty level and retirement benefits. The third factor (F3) reflects influence of suburbanization on the middle class; it is negatively related to population density and housing dilapidation, but positively related to education and proportion of housing owner occupied.

Factor four (F4) is most strongly associated with property or non-labor income, while factor five (F5) is linked to measures of health care services, including doctors and dentists per 100,000 persons and per capita health care expenditures by local governments. Factor six (F6) is associated with air quality and water pollution variables, while factor seven (F7) is interpreted as a medical facilities factor, loading highly on hospital beds per 100,000 persons. Factor eight (F8) seems closely associated with both savings and black white income differentials, and factor nine (F9) loads most highly on unemployment.

These factors were used as weights in constructing indices corresponding to each component. Each of the 64 SMSA's thus received a weighted value or "score" for each component. The SMSA's with the highest and lowest index values for each factor are shown in Table 3.

The constructed indices were utilized as orthogonal independent variables in an ordinary least squares regression equation of the form

$$M_i = a + b_1F1 + b_2F2 + b_3F3 + b_4F4 + b_5F5 + b_6F6 + b_7F7 + b_8F8 + b_9F9 + u$$

where M_i is the age-adjusted mortality rate for the ith population category a is an intercept term and u is the stochastic error term.

The mortality variables used in the study are age-adjusted mortality rates for whites (MW) and blacks (MB) for 1970 expressed in index form. Data for construction of the mortality variables were obtained from (17) and (21). The computation procedures followed those set out in (16, p. 242). The mortality index measures the ratio of SMSA mortality to expected deaths based upon national age-specific mortality rates.

IV. Empirical Results

Regression analysis yielded the following regression results for white and black mortality (t-values are in parentheses, with those significant at the 5% level marked with an asterisk):

$$\text{(1)}\quad MW = \underset{}{100.1} - \underset{(2.90)}{1.99\,F1^*} + \underset{(1.08)}{.746\,F2} - \underset{(-4.49)}{3.09\,F3^*}$$

$$- \underset{(-2.489)}{1.71\,F4^*} - \underset{(-.652)}{.448\,F5} + \underset{(2.13)}{1.46\,F6^*} + \underset{(2.69)}{1.85\,F7^*} -$$

$$\begin{array}{lll} 1.69\ F8^{*} - & .086\ F9 & R^2 = .501 \\ (-2.47) & (-.126) & \end{array}$$

$$(2)\quad MB = 106.4 - \underset{(-.911)}{2.68\ F1} - \underset{(-2.19)}{6.45\ F2^{*}} - \underset{(-1.03)}{3.03\ F3} -$$

$$\underset{(-.303)}{891\ F4} - \underset{(-1.89)}{5.55\ F5^{*}} + \underset{(.410)}{1.21\ F6} + \underset{(1.10)}{3.24\ F7} +$$

$$\underset{(2.05)}{6.03\ F8^{*}} - \underset{(-1.02)}{2.96\ F9} \qquad R^2 = .239$$

Since the indices are based on standardized variables, the importance of each factor to the equation can be measured by the size of the regression coefficient. For white mortality, the most important factor is F3, the measure of suburbanization, which includes low population density, high median education, and high proportion of owner occupied housing. The negative sign on this factor suggests that the process of suburbanization has a definite favorable impact upon mortality.

These results are consistent with a number of previous studies which found an inverse relationship between education and health and mortality. For example, Kitagawa and Hauser found a "consistent decline in mortality as years of schooling increased" (12, p. 38). They interpreted the education variable as a proxy for all the various socioeconomic variables which may be linked to education, including income, level of occupation, style of life, diet, quality of housing, and others. Grossman also found a similar relationship, within the framework of a more sophisticated human-capital model (10).

Our approach suggests that higher levels of education in urban areas are closely tied to other important socioeconomic variables, especially those associated with suburbanization. Previous studies utilizing single variables in regression equations may have failed to capture the composite nature of the relationship involved.

The second most important determinant of white mortality in this equation is F1, the measure of general urban character. This index enters with a negative sign, which suggests newer, rapidly growing SMSA's may have a more favorable mortality experience, in spite of high motor vehicle density.

Also important is F7, the medical facility factor. The sign is positive, which may be an indication of simultaneity in the underlying structure of the relationships of the equation. That is, areas with higher mortality rates may require a large stock of medical facilities.

Factor F4, non-labor or property income, is significant and negative in sign. This confirms earlier findings of Silver (15). That is, increases in income may be beneficial to health and longevity if they are not directly associated with additional emotional or physical stress. Similarly, factor F8, a factor which was highly associated with savings, has a negative effect on mortality.

The final significant determinant of white mortality is the pollution index (F6). The positive sign here supports the view that higher pollution levels are detrimental to health.

Three of the factors were not significant at the 5% level. These were the economic level index (F2), the health services index (F5) and the unemployment measure (F9). The insignificance of the health services factor supports a growing body of literature which suggests that in advanced societies there may not be a strong link between supply of health services and health status (6, 9).

The results for black mortality are substantially weaker than for white mortality, with less than 25 percent of the variation explained by three significant indices. The most important of the significant variables is factor two which is highly correlated with the proportion of the population above the poverty level. This variable was insignificant for whites, suggesting mortality gains to whites from increasing affluence have possibly been exhausted, but such benefits to blacks are still forthcoming.

This interpretation is given weight by the results for factor eight, which is highly associated with savings and the black-white income differential. While this factor had a negative influence on white mortality, the sign for black mortality is positive.

The third variable of interest is the health care services index (F5). As with the poverty variable, health care services was not significant for white mortality, but is significant and of negative sign for black mortality. While incremental physicians or public expenditures on medical services have no apparent significant influence on white mortality, black mortality seems to be influenced in a beneficial way by the availability of such services.

IV. Conclusions

While there is substantial variation in mortality rates among urban areas, there appear to be certain urban characteristics which are systematically related to mortality levels. These characteristics have a differential impact on white and black mortality rates.

The empirical results of our study demonstrate the mortality experience of whites in newer, automobile oriented, suburbanized areas is more favorable than that found in older, higher density metropolitan areas. While early studies found a persistent negative relationship between economic level and urban mortality, studies based on more recent data have found a positive relationship between economic factors and mortality. Our results confirm the explanation offered by Silver for this anomaly. The negative relationship between our property income factor and white mortality and the insignificance of our index of economic level (F2) replicate Silver's findings for non-labor income and aggregate income measures.

The results for mortality experience of urban blacks seem the virtual inverse of that for whites. Factors related to suburbanization and character of the SMSA are found to be insignificant determinants of black mortality. On the other hand, two factors found to be insignificant for whites (economic level and medical services) were significant and of the theoretically expected sign for blacks. This evidence is consistent with the hypothesis that improvements in economic level and medical services continue to offer potential mortality gains to blacks, which may be no longer true for whites.

The empirical results also provide some interesting evidence for the controversy dealing with the proper mix of public policies to improve the health of the U. S. population. The findings relating to white mortality tend to support the contention that efforts should be concentrated away from the traditional medical approach toward a broader approach of lifestyle modification. At the same time, however, results from the analysis of black mortality imply that continued emphasis on improved medical care and increased availability of such services to the black and minority populations would have significant impact upon the health status of these disadvantaged populations.

FOOTNOTES

[1]Honolulu was excluded due to its unusual socio-economic and demographic characteristics.

[2]Such a simplification is equivalent to maximizing the variance of the squared loadings of each column. Hence, the name "varimax."

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Table 1

ORIGINAL VARIABLES USED IN PRINCIPAL COMPONENTS ANALYSIS

Symbol		VARIABLES
V1	(IVFG)	Annual Inversion Frequency
V2	(SUN)	Annual Sunshine Days
V3	(T32)	Number of Days Temperature Above 32^{o}
V4	(HBDS)	Hospital Beds Per 100,000 Persons
V5	(TCRM)	Total Crime Rate Per 100,000 Persons
V6	(COST)	Cost of Living Index
V7	(SEG)	Housing Segregation Index
V8	(APOV)	Percent Families Above Poverty Level
V9	(MCYC)	Motorcycle Registrations per 100,000 Persons
V10	(PDNS)	Population Density
V11	(BWYA)	Ratio of Black to Total Median Family Income
V12	(MV)	Motor Vehicle Registrations per 100,000 Persons
V13	(DDS)	Dentists per 100,000 Persons
V14	(HSOC)	Hospital Occupancy Rates
V15	(MD)	Physicians per 100,000 Persons
V16	(HCEX)	Per Capita Local Government Expenditures on Health
V17	(MDED)	Median School Years Completed
V18	(PART)	Mean Level for Total Suspended Particulates
V19	(SLDX)	Mean Level for Sulfur Dioxide
V20	(DLPD)	Percent Housing Units Dilapidated
V21	(WSTE)	Tons of Solid Waste from Manufacturing
V22	(WTPL)	Water Pollution Index
V23	(RTBF)	Average Monthly Retiree Benefits
V24	(UNPLY)	Unemployment Rate
V25	(PRSY)	Per Capita Personal Income
V26	(SVG)	Per Capita Savings
V27	(PYPSY)	Property Income as a Percent of Personal Income
V28	(OWOC)	Percent Owner Occupied Housing
V29	(MVAL)	Median Value of Owner Occupied Housing

Sources: V1, V2, V3, V6, V7, V14, V18, V19, V22 are from (13); V8, V10, V17, V20, V25, V28, V29, are from (17); V11, V23, V24, V26 are from (18); V4, V13, V15, V16 are from (20); V9, V12 from (23); V5 is from (22); V21 is from (3); V27 is from (19).

Table 2

LOADINGS USED TO CONSTRUCT INDICES

VARIABLES	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8	FACTOR 9
IVFG	.418	-.043	.314	-.582	-.013	.021	.127	-.240	.214
SUN	.748	-.364	.024	.120	.131	-.037	-.108	.039	-.100
T32	-.530	.439	.168	-.283	-.147	.167	.249	-.067	-.328
HBDS	-.036	-.100	-.031	.013	.081	.156	.895	-.022	-.114
TCRM	.548	-.397	-.015	.014	.351	.171	.180	.231	.158
COST	-.089	.455	-.432	.232	.457	-.102	.004	-.012	-.119
SEG	-.154	.772	-.025	-.038	.145	.144	-.121	-.198	-.054
APOV	.032	.892	.107	-.005	.147	-.029	-.029	.062	-.024
MCYC	.772	-.095	.334	-.114	-.045	-.146	-.150	-.020	.321
PDNS	-.036	.113	-.849	-.033	.153	.132	-.069	.091	.070
BWYA	-.424	-.095	.173	.164	-.282	.036	-.252	.627	.114
MV	.728	-.113	.301	.180	-.288	-.207	-.029	.183	-.059
DDS	.027	.255	.026	.304	.744	-.006	.253	.049	.284
HSOC	-.755	-.162	.020	.051	-.099	.052	-.056	.088	-.105
MD	.079	-.030	.012	.162	.797	.040	.293	.023	-.032
HCEX	-.116	.005	-.024	-.428	.724	-.104	-.103	.072	.130
MDED	.220	.286	.681	.114	.415	-.015	-.148	-.071	.122
PART	.037	.006	.043	-.275	-.065	.765	.172	.035	-.219
SLDX	-.351	.365	-.316	.106	.085	.628	-.073	.011	-.026
DLPD	-.130	.079	-.698	.035	-.028	-.175	.099	-.392	.058
WSTE	.097	-.458	.136	.589	-.033	-.004	-.429	.005	-.192
WTPL	-.258	.123	.064	.393	.001	.645	.112	-.048	.233
RTBF	-.215	.802	-.103	.176	.060	.217	.038	.207	.190
UNPLY	.218	.030	-.006	-.150	.133	-.060	-.109	.030	.861
PRSY	.139	.376	.071	.172	.548	-.033	-.371	.062	.114
SVG	.181	.092	-.016	.187	.298	-.031	.079	.771	-.009
PYPSY	.159	.120	.109	.789	.173	-.022	.087	.191	-.020
OWOC	-.024	.196	.646	.089	-.605	-.079	.009	.023	.072
MVAL	.142	.414	-.208	.014	.724	.051	-.274	.088	-.037
Cumulative Proportion of Variance	19.2	35.6	45.8	54.6	61.3	66.3	70.8	74.5	78.0

Table 3

URBAN AREAS WITH HIGHEST AND LOWEST SCORES ON CONSTRUCTED INDICES

FACTORS	HIGHEST	LOWEST
F1	Anaheim Phoenix San Bernadino-Riverside-Ontario	Milwaukee Buffalo Albany
F2	Patterson-Clifton-Passiac Hartford Minneapolis-St. Paul	Memphis San Antonio Norfolk-Portsmouth
F3	Denver Portland Grand Rapids	Jersey City Newark New York
F4	Ft. Lauderdale Miami Tampa-St. Petersburg	Gary-Hammond Sacramento San Jose
F5	New York Washington, D. C. San Francisco-Oakland	Youngstown-Warren Ft. Worth Gary-Hammond
F6	Cleveland Detroit Pittsburgh	Rochester Seattle-Everett Allentown-Bethlehem-Easton
F7	Oklahoma City Minneapolis-St. Paul New Orleans	Norfolk-Portsmouth San Diego Washington, D. C
F8	Ft. Lauderdale Miami Tampa-St. Petersburg	Boston Springfield-Chicopee-Holyoke Providence-Pawtucket-Warwich
F9	Seattle Portland Pittsburgh	Washington, D. C Dayton Denver