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ECONOMIC ESTIMATES OF URBAN INFRASTRUCTURE NEEDS

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Abstract

This paper criticizes commonly employed measures of capital-spending needs and offers an alternative method for constructing needs estimates. The usual technical estimate of needs compares an inventory of current conditions with some "ideal" level of capital stock, and is inadequate because of the arbitrary (and sometimes unrealistic) benchmarks that are employed in its construction. The alternative economic measure proposed here is based on a model of city spending decisions. Using these estimated parameters, this method provides a measure of the typical or average spending patterns of policymakers, and controls for the particular circumstances faced by each city. It is suggested that this standard for capital-spending needs will be more relevant to administrators and decision-makers who must reconcile capital-stock deterioration with tight budgets.

The empirical work in the paper is a pooled time-series cross-section analysis of aggregate highway spending within ten midwestern urban counties between 1965 and 1976. This aggregated data is shown to be representative of the average city within each county. Finally, actual and needed highway expenditures for each county are presented.

I. Introduction

Recently, a great deal of attention has been focused on the condition of the nation's infrastructure--its public capital stock of roads, bridges, sewers, transit systems, and public buildings. Conventional studies of this problem have brought forth alarming figures about the extent of infrastructure deterioration. For example, the Congressional Budget Office (1983) has estimated that, nationwide, it will cost $53 billion per year to ensure that the nation's highways, transit systems, sewer and water facilities, and airports are (in its words) "adequate". Another widely quoted study (Choate and Walter, 1981, p. 2) notes that in the 1980s, it will take $40 billion to service the infrastructure needs of New York City alone.[1]

Typically, these technical estimates of infrastructure needs are based upon a detailed examination of the quantity and quality of existing public capital. This information is then combined with an assumption (usually implicit) about the standard or benchmark against which current conditions are to be measured. When such standards are made explicit, they are usually based upon one of two approaches: the author's subjective determination of the "proper' amount of public capital, or the views of technical experts, such as civil engineers or urban planners.

The arbitrariness of these underlying assumptions has diminished the usefulness of many of the capital-spending needs estimates in these studies. For example, the federal government classifies as "inadequate" bridges that have "inappropriate deck geometry"--that is, the bridge itself is narrower than the connecting highway. Estimates of spending needs for bridges, then, will include the cost of widening these bridges, even if there is not enough traffic on the bridge to warrant additional investment. Lacking appropriate benchmarks for budgeting purposes, communities are in danger of abandoning capital investment planning altogether, pursuing instead a pay-as-you-go strategy.

This problem in setting policy goals is most acute in the older cities of the Midwest, where an aging infrastructure base is combined with changing demands for public services. Presumably, the reduced population and slower rates of income growth in these cities might affect the desired amount of capital spending in these cities, but the technical approach offers no method for quantifying these changes.

In this paper, economic estimates of infrastructure needs are developed as a supplement to the technical approach. Investment in public capital is modeled as the result of conscious choice on the part of public authorities, given the resources available to them. The econometric estimates of this model provide an answer to the question, "What would a community like ours in terms of income, population, density, age, etc., normally spend on public capital goods?" This, then, becomes the basis for capital-spending need standards. The empirical analysis in the paper examines aggregate spending on highways (including roads, streets, and bridges) within ten midwestern urban counties between 1965 and 1976. A demand function from the almost ideal demand system (AIDS) cost function is employed, and it is demonstrated that aggregate spending for a geographic area corresponds to that demanded by the average or typical city in that area--even when income is adjusted by non-monetary factors such as population, area, and age of capital stock.

Section II explains the basic model, beginning with the notation employed. A static, one-period model is first examined, and then the model is amended to incorporate the long-lived, many-period nature of capital goods. Finally, the specification of the model is examined under the case of data that are aggregated for all local governments within a geographic area. Section III presents an empirical test of the model, beginning with the data used, the sources of error in the model, and the estimation technique employed. After the estimated coefficients of the model are analyzed, capital-needs estimates are detailed for all ten urban counties in the study. Section IV contains some brief concluding comments.

II. An Econometric Model of Local Public Capital Spending

Notation.

Let:

$x^i_{j,k}$ represent real per capita spending at time i by city j in urban county k.[2] The i, j, and k subscripts represent these same dimensions for all variables in the paper. However, for the sake of simplicity, not all of these letters will be used in every instance.

Let:

p^i = the real opportunity cost of owning the capital stock each year, including both the foregone interest and depreciation costs. Following Gramlich and Galper (1973, p. 26), Let:

$$p^i = (r^i + \delta)\,\theta^i/\lambda^i,$$

where:

r^i = the real municipal bond rate. In this study, the real rate is proxied by the nominal bond rate minus the current inflation rate

δ = the rate of depreciation

θ^i = an index which reflects the cost of constructing new capital

λ^i = the GNP deflator,

let:

y_j^i = the real per capita income of the city

w_j^i = the share of expenditures on the capital good as a fraction of total income--$w_j^i = x_j^i / y_j^i$

s_j^i = the per capita quantity of the capital good

q_j^i = the per capita flow of services from the capital good each year. Units of services are defined so that each unit of capital yields one unit of service--q_j^i = s_j^i.

In addition, define:

X_k^i = the sum of x across all j in k:

$$X_k^i = \Sigma x_{j,k}^i$$

$\bar{x}_k^i$ = the mean of x across all j in k:

$$\bar{x}_k^i \equiv X_k^i/n = \Sigma x_{j,k}^i/n.$$

This notation will be used consistently across all variables in this paper.

<u>A simple spending model</u>. The residents of each city are assumed to be interested in q and m, where m represents real income left over from capital spending, available for use on all other goods.

In addition, previous studies have shown that a city's expenditure decisions (and therefore presumably its utility function) are affected by the composition of its effective income between locally generated revenues and grants-in-aid. In this paper, this effect is modeled by including t, the share of effective income provided by grants-in-aid, as a parameter in the city's utility function. This parameter is not a choice variable for the city, but rather, enters the utility function exogenously.

Several explanations for this composition of income effect have been given in the literature. One approach is to argue that the voter mistakes his average tax rate for his marginal tax rate, and to note that lump-sum grants lower this average tax rate. In our model, this would mean that utility would be positively related to this share of income variable, since more aid means a lower <u>perceived</u> tax price and a higher <u>perceived</u> level of satisfaction. Alternatively, it has been argued that composition effects occur because of differences in the tax bases of national, state, and local government, so that, even though grants-in-aid must be financed through taxes at the higher level of government, the pivotal voter may find his total taxes changed by a shift in composition of effective income. In this case, utility might be positively or negatively related to t, depending upon the nature of the pivotal voter's tax liabilities.

The city's political process maximizes $u(q,m,t)$ subject to $pq + m = y$. This maximization process results in choices $q^* = f(p,y,t)$ and $m^* = g(p,y,t)$. No particular assumption about the nature of this public choice mechanism is made in this paper. The city's decisions may follow the dictates of the median voter or some dominant political party. The political process may be biased toward certain interest groups or dominated by the wishes of bureaucrats and municipal employees. All that is required is that these decisions correspond to the wishes of <u>some</u> individual or group within the city, and that these two goods are important to that party.

In order to estimate q^* and m^*, a functional form for the utility function of the community must be assumed. For reasons which will become apparent later, the AIDS demand function was chosen for this study.[3] This specification represents utility not by a direct utility function, but by a cost function which quantifies the cost of achieving a particular level of utility given the price level of each of the goods in question. In this case, the AIDS cost function may be written:

$$(1) \quad \ln(C(u,p)/O) = a + b \ln p + c(\ln p)^2/2 + udp^e - ft$$

where a through f are parameters to be estimated and C(u,p) is the cost of achieving a given level of utility. The resulting demand functions are most often given in budget share form:

$$(2) \quad w = b + c \ln p + e \ln (y/Op^v) + eft$$

where v is a weight determined by the average proportion of spending on the good access all cities, counties, and time periods:

$v = (\Sigma w^i_{j,k})/n$, and y = per capita private income plus per capita grants-in-aid.[4]

The parameter O is a weighting factor which adjusts the necessary expenditure in each city by expenditure "needs". Its purpose is to identify the most important historical and demographic factors which necessitate different levels of spending in different cities. To construct this measure, two sources of information were used. First, the literature on intergovernmental grants was examined to ascertain which variables are used to indicate the "need" for additional money from the federal government. Two of the most frequently used factors in formulas for distributing federal dollars are population and land area. Therefore, all income and expenditure terms were put in per capita terms, and land area and population were included as need variables. Next, the literature on technical analysis of capital needs was reviewed, to see if any exogenous factors not already included in the model might affect spending. A recurring theme in this literature is that the average age of the capital stock is very important in determining the cost of maintaining it, so this variable was also included in the need index.

Since the literature on local public spending indicates that these variables often affect expenditures in a log-linear way, our assumption about expenditure needs takes the following form:

(3) $$0 = -\exp(g_1 \text{ population} + g_2 \text{ area} + g_3 \text{ age})$$

where the g's are parameters to be estimated.

Integrating these factors into equation 2 results in the following functional form for this simple spending model:

(4) $$w = b + c \ln p + e \ln(y/p^v) + eft + e(g_1 \text{ population} + g_2 \text{ area} + g_3 \text{ age}).$$

A more complex model. The preceding model, of course, totally ignores the long-lived nature of capital goods; it is constructed as if these goods are built and consumed within a single time period. A realistic model of the public spending process must recognize the benefit spillover of expenditures from one time period to the next, as well as the slow manner in which gaps in the supply of public capital are filled.

To deal with this difficulty, the preceding model is amended so that capital spending by each city is equal to the cost of maintaining the previous year's capital stock (δs^{i-1}) plus some portion of the gap between the previous year's capital stock and "desired" capital stock (s^{i*}. Formally this flexible accelerator model is given by:

$$(5) \quad x^i = \delta s^{i-1} + \gamma[s^{i*} - s^{i-1}]; \quad 0 \leq \gamma \leq 1$$

where γ is a parameter to be determined by the data. The model can be put into budget share form by dividing through by income:

$$(6) \quad w^i = x^i/y^i = \delta s^{i-1}/y^i + \gamma[s^{i*} - s^{i-1}]/y^i$$

$$= \gamma s^{i*}/y^i + (\delta - \gamma)s^{i-1}/y^i.$$

By definition, s^{i*} is the steady-state capital stock; it is the capital stock the city would choose if, as in the preceding simplier model, stock levels could be completely adjusted in one year.

Since $s^{i*}/y^i = q^{i*}/y^i = w^{i*}/y^i$, we have that:

$$(7)\quad w^i = \gamma[b + c \ln p^i + e \ln(y^i/p^i)^v) + eft + eg_1\, pop^i + eg_2\, area^i + eg_3\, age^i]/p^i + (\delta-\gamma)s^{i-1}/y^i.$$

<u>Aggregation in the model.</u> Those doing econometric research in local public finance have long been faced with a dilemma about the use of data that are aggregated over all governments within a geographic area. If researchers used aggregate data, they could never be sure that these data were representative of individual units. If, instead, they used data for individual jurisdictions, they avoided this aggregation problem but risked additional error due to non-uniformity in the type and level of services offered by individual governments. To cite some concrete examples: Baltimore and St. Louis have integrated city and county governments, so that these governments have greater responsibilities than the city governments of Detroit or Cleveland. Thus, by using jurisdictions with different levels of responsibility in a cross-section estimation procedure, the researcher risks confusing expenditure differences due to varying levels of responsibility with additional expenditures made by one jurisdiction due to changing circumstances within that city.

Fortunately, innovation in modern demand theory has led to the development of functional forms that fit the data well and aggregate perfectly--that is, aggregate demand can be shown to be determined by the economic conditions of the average city in the sample. The AIDS demand functions are generally of this type. Thus, aggregate data can be utilized without concern about their representativeness. However, this property has never been demonstrated over all possible functions for 0, the needs variable; typically, 0 is assumed to equal unity for all observations. Hence, it seems worthwhile to examine this perfect aggregation property in the context of the present model.

We begin by making two assumptions (A.l and A.2) about the distribution of characteristics across cities: (A.1) Across time and across counties, the intracounty distributions of city per capita income are approximately proportional. That is, for any two counties (k_1 and k_2) and time periods (t_1 and t_2) for cities with equivalent positions in the income distribution (or more precisely, for cities at the same percentile in the frequency distribution of city incomes), there exists a parameter $\tau^{i1,i2}_{k1,k2}$ such that:

$$y^{i1}_{j1,k1} = \tau^{i1,i2}_{k1,k2} \, y^{i2}_{j2,k2}.$$ [5]

(A.2) Across cities within each county, age, area, and population are independent of income.[6]

Armed with these assumptions, we can now proceed with the aggregation. Note that:

$$W^i_k = \Sigma x^i_{j,k} / \Sigma y^i_{j,k}$$

$$= \Sigma y^i_{j,k} w^i_{j,k} / Y^i_k.$$ Using 7 and the definition of t:

$$(8)\quad W_k^i=(\Sigma y_{j,k}^i[\gamma b/p^i+\gamma c\ln p^i/p^i-\gamma ev\ln p^i/p^i])/Y_k^i$$

$$+ (\Sigma y_{j,k}^i[\gamma ef\ aid_{j,k}^i/y_{j,k}^i p^i + (\delta-\gamma)s_{j,k}^i/y_{j,k}^i])/Y_{j,k}^i$$

$$+ (\Sigma y_{j,k}^i[\gamma eg_1 pop_{j,k}^i/p^i + \gamma eg_2 area_{j,k}^i/p^i + \gamma eg_3 age_{j,k}^i/p^i])/Y_k^i$$

$$+(\Sigma y_{j,k}^i\ [\gamma e\ \ln y_{j,k}^i/p^i])/Y_k^i.$$

Each one- or two-line group on the right-hand side of 8 can now be addressed separately. Notice, first of all, that the first line consists of constants and a variable (p^i) that does not vary across units. Therefore, these variables can be pulled outside the sumnation operation; as a result the ys disappear, since $\Sigma y_{j,k}^i/Y_k^i = 1$. The second two-line group is also straightforward, since when the summation is carried out, the little ys disappear, leaving the following:

$$\gamma ef\ AID_k^i/\ (p^i Y_k^i) + (\delta-\gamma\ )\ S_k^{i-1}/Y_k^i.$$

The third two-line group requires the use of the independence assumption A. 2. Consider first the population term in that line. Under independence, and letting N equal the number of cities in the county:

$$(\gamma eg_1/p^i)\ \Sigma y_{j,k}^i\ pop_{j,k}^i/Y_k^i$$

$$= (\gamma eg_1/p^i)\ \Sigma(y^i_{j,k}\ pop^i_{j,k}/N)/(Y^i_k/N)$$

$$= (\gamma eg_1/p^i)\ y^i_{j,k}\ \overline{pop}^i_{j,k}/y^i_{j,k}$$

$$= (\gamma eg_1/p^i)\ \overline{pop}^i_{j,k}.$$

Similar results apply to area and age.

Finally, the last line of 8 employs the proportionality assumption. Ignoring the γ, e, and p^i terms, which are constant under aggregation, the line consists of:

$$\Sigma y^i_{j,k}\ \ln y^i_{j,k}/Y^i_k.$$

Now, consider a hypothetical county with an income distribution proportional to each of the sample cities and a mean city income of one. This county is denoted by the index k_0. Under proportionality:

$$\bar{y}^i_k = \tau_{k,ko}\bar{y}^i_{ko} = \tau_{k,ko} \text{ for any county k.}$$

Therefore, it follows that:

$$y^i_{j,k} = \bar{y}^i_k y^i_{j,ko} \text{ for any city } j$$

and that:

$$(\Sigma y^i_{j,k} \ln (y^i_{j,k}))/\Sigma y^i_{j,k}$$

$$= \Sigma(\bar{y}_k^i y_{j,k0}^i \ln(\bar{y}_k^i y_{j,k0}^i))/\Sigma \bar{y}_k^i y_{j,k0}^i$$

$$= (\Sigma y_{j,k0}^i(\ln \bar{y}_k^i + \ln y_{j,k0}^i))/\Sigma y_{j,k0}^i$$

$$= (\ln \bar{y}_k^i)\Sigma y_{j,k0}^i/\Sigma y_{j,k0}^i) + (\Sigma y_{j,k0}^i \ln y_{j,k0}^i)/ \Sigma y_{j,k0}^i$$

$$= \ln \bar{y}_k^i + z,$$

where $z = \Sigma y_{j,k0}^i \ln y_{j,k0}^i/\Sigma y_{j,k0}^i$ is a constant index of inequality. The effect of the proportionality assumption A.1, as shown by the k0 subscripts, is to make this index invariant across counties, removing its influence on the coefficients of the regression.

Using all of these results, and rearranging the equation somewhat, 8 becomes:

$$(9) \qquad W^i - \delta S_k^{i-1}/y_k^i = \gamma(b + ez)/p^i + \gamma c \ln p^i/p^i + \gamma e (\ln \bar{y}_k^i - v \ln p^i)/p^i + \gamma ef\, T_k^i/p^i - \gamma S_k^{i-1}/Y_k^i + \gamma eg_1 \overline{pop}_k^i /p^i + \gamma eg_2 \overline{area}_k^i/p^i + \gamma eg_3 \overline{age}_k^i /p^i$$

where $T_k^i = \Sigma\, aid_{j,k}^i/\Sigma y_{j,k}^i$. In its unrestricted, estimatable form, this becomes:

$$
\begin{aligned}
(10) \qquad W^i - \delta S_k^{i-1}/Y_k^i &= b'/p^i + c' \ln p^i/p^i \\
&+ e' (\ln \bar{y}_k^i - v \ln p^i)/p^i + f' T_k^i/p^i \\
&- \gamma S_k^{i-1}/Y_k^i + g_1' \overline{pop}_k^i/p^i \\
&+ g_2' \overline{area}_k^i/p^i + g_3' \overline{age}_k^i/p^i
\end{aligned}
$$

where:

$b' = \gamma b + \gamma e z$

$c' = \gamma c$

$e' = \gamma e$

$f' = \gamma e f$

$g_1' = \gamma e g_1$

$g_2' = \gamma e g_2$

$g_3' = \gamma e g_3$

III. An Application to Urban Highways: 1965–1976

The data and specification of variables. The data used for this study and the source for each variable are listed in table 1. Ten urban counties were chosen for investigation, each of which has been designated by the Census Bureau as the central portion of a midwestern standard metropolitan statistical area (SMSA): Allegheny County, Pennsylvania

(Pittsburgh); Cook County, Illinois (Chicago); Cuyahoga County, Ohio (Cleveland); Erie County, New York (Buffalo); Hamilton County, Ohio (Cincinnati); Hennepin County, Minnesota (Minneapolis-St. Paul); Jefferson County, Kentucky (Louisville); Milwaukee County, Wisconsin (Milwaukee); and Monroe County, New York (Rochester).[7]

It should be noted that some of the variables employed are proxies for the true variables in the preceding model. Instead of the average per capita income across cities in each county, the per capita income for the entire county is employed. The age of the highway capital stock is approximated by the ratio of the number of bridges built before 1930 to the number of bridges built between 1930 and 1955 for the central city in each county. The real rate of interest is proxied by the Bond Buyer's 20-bond index of yields on municipal bonds minus the average inflation rate (as measured by the GNP deflator) over the previous three years.

The capital stock measure employed in this study is only an estimator of the true level of capital stock. Unfortunately, data on the highway expenditures that are aggregated over all jurisdictions in an urban county are not available before 1965, except for the Census of government carried by the Census Bureau in 1957 and in 1962. However, there is information about the expenditures, of the largest few cities in each of these counties as far back as 1941; these constitute, on average, about 50 percent of the total. Accordingly, we estimated the expenditures for each year back to 1941 by multiplying the sum of these large city expenditures by the ratio of total expenditures to large city expenditures in the nearest census year. This measure is neither complete (many bridges in use, for example, were doubtless built before 1941) nor exact, but it should capture the lion's share of variations in capital stock across urban counties. Because the data do not go back further than 1941, the age of capital-stock proxy was retained to pick up differences in expenditures prior to that date.

In testing the model, intergovernmental grants were simply added to the income of the community. The Advisory Commission on Intergovernmental Relations (ACIR) reports that (1977, p. 20) as of 1972, 96 percent of all grants received by local governments came from the state, not the federal level. (This remained true even when federal money that is passed through state highway departments on its way to local governments was included in the federal total.) Of this money, only 3 percent was in the form of project grants; the rest was revenue-sharing grants based on some measure of need such as area, mileage, motor vehicle registration fees, and license fees (ACIR, 1977, p. 31). Since local governments have little control over these factors, it seemed reasonable to model these grants as having an income effect but not a price effect on the decisions of local leaders. Also included in this grants total (and also modeled as a noncategorical grant) was the direct expenditure of state highway departments on local roads and streets in each county.

Sources of error and estimation technique. An error term, ε^i, must be added to equation 10 because of several factors, including:

a) differences in tastes among city residents
b) geographical and climate difference among cities
c) perceptual errors made by policymakers resulting in the actual values of the independent variables differing from their perceived values

d) differences in revenue structures and public decision-making mechanisms among cities

e) ommitted variables

f) errors due to the aggregation assumptions A.1 and A.2, which are only approximations to actual conditions

Because of the widespread use of incremental budgeting techniques--the use of the previous year's budget as a starting point for consideration of the current budget--these errors are expected to be autocorrelated. Since pooled cross-section and time-series data are used, the estimation technique should account for the possibility of differences in error variance and degree of autocorrelation across units. It is also conceivable that some national event, such as a winter with heavy snowfall or a change in the provisions of federal grants-in-aid, might affect all cross-sectional units at the same period of time, so the estimation technique must also account for this contemporaneous correlation.

One approach to dealing with these three difficulties--heteroskedasticity, autocorrelation, and contemporaneous correlation--was proposed by Parks (1967) and is outlined in the textbook by Kmenta (1971, pp. 512-14). It consists of three steps. In the first step, an ordinary least squares regression is run on the model and the residuals of this regression are used to calculate autocorrelation coefficients for each separate cross-section. The second step consists of partially first differencing all of the variables in the model, using the coefficients estimated above, and running a second ordinary least squares regression on these transformed variables. In the final step, the residuals from the second regression are used to estimate heteroskedasticity and contemporaneous correlation in the model's error term, and a third generalized least squares regression is used on the transformed variables to get final parameter estimates. The result of all these manipulations is estimates which are consistent, asymptotically normal, and have the same asymptotic distribution as Aitken's generalized least squares estimator. This is the methodology employed for this paper.

Empirical results. Table 2 presents the results for this model. In addition to this regression for the entire sample, a sensitivity analysis was performed in which each urban county was separately excluded from the sample and the Parks procedure was run on the remaining nine counties. The results of these regressions, while not enumerated here, were used in interpreting the coefficients of table 2.

First, a word about the depreciation rate used in this study. We began by using the straightline depreciation rates implied by the useful life assumptions employed by the Federal Highway Administration's, estimates of highway capital stock. However, since this figure may be inaccurate, we investigated whether the fit of the regression (in terms of the sum of squared residuals) could be improved by searching over various values of a. This procedure resulted in an unexpectedly high value of 0.085 for δ, which corresponds to a useful life of approximately 12 years. This is the value used for the final regression. All of this suggests that local governments are primarily concerned with maintaining capital (such as pavement) with a relatively short life span, rather than with repairing the longer-lived assets, such as bridges and roadbeds, which are also under their control.

We begin with the most important results. Table 2 shows that the adjustment coefficient between actual and desired capital stock is positive and significant, but extremely low. On average, local governments make up only about 2 percent of the difference between their actual and desired levels per year. This suggests that local administrators are primarily concerned with repairing and replacing old capital stock, rather than meeting the new investment needs of the community.

Table 2 also shows that, consistent with most studies of public goods expenditure, it matters whether community resources come from private income or grants-in-aid. The positive value for f' means that the greater the proportion of a city resources coming from higher levels of government, the more the city will spend on highways.

The need variables in the regression (population, area, and age) are all positive and have interesting interpretations. The area coefficient, which is highly significant in every regression that was run, suggests that greater highway spending is necessary for more dispersed populations. The population coefficient, g_1', implies diseconomies of scale in highway production: the larger the city in terms of population, the greater the share of the income of the entire city (and of each individual citizen) that must be devoted to highways. Upon closer inspection, however, this result appears to be due to the high spending of the second largest unit in the sample--Wayne County in Michigan. When this unit is removed from the sample, this coefficient becomes negative and insignificantly different from zero. A coefficient of zero implies constant returns to scale in the production of highways: each person has to spend the same share of his income on the good, regardless of the size of the city he lives in. The age coefficient, g_3', suggests that the older the capital stock, the more it costs to repair and replace. However, most of the variation in this variable is due to the very high age figure recorded for Hennepin County, Minnesota, so the results are sensitive to this high influence point. When Hennepin County is removed from the sample, this coefficient is not significantly different from zero.

Interpretation of the coefficients c' and e' is complicated by the fact that the dependent variable is in share-of-income form. A negative value for e', for example, means that the share of income spent on highways declines as effective income rises; in other words, highways are necessities and not normal goods or luxuries. As shown at the bottom of the table, the value for e' implies a long-run income elasticity of 0.1772. Interestingly, when the highest income city, Chicago, is excluded from the sample, the income elasticity figure jumps to 1.647. This may indicate a nonlinearity in the response of spending to income. At low levels of income, extra income might allow considerable extra highway spending by the community, but at some point the city's needs are filled, and it devotes little of its extra income to highways when per capita income rises above that point. The positive value for c' indicates that demands are price inelastic. As prices rise, total expenditure and the share of income spent on the goods also rise. Notice, however, that the estimated standard error is quite large, and therefore this coefficient is insignificantly different from zero. The estimated long-run price elasticity is -0.2689.

Unfortunately, the Parks procedure does not provide R-squared--the coefficient of determination--because the final regression uses variables that are extensively transformed from those of the original model.

Nevertheless, it is possible to get a reasonable measure of goodness of fit by examining the in-sample predictive power of the estimated coefficients. Equivalently, one could examine the R-squared that would have resulted if these parameter values were the result of a simple ordinary least squares regression on the dependent variable of interest. This might be called a "rebuilt" R-squared measure of goodness of fit. In equation 10, we take this approach by multiplying both sides of the equation by income, moving the δS term to the right-hand side, and then examining the R-squared of the resulting model of gross real per capita spending. As shown at the bottom of table 2, the resulting rebuilt R-squared is 0.81 36.

Highway needs estimates for ten urban counties. Every capital-spending needs estimate contains within it an element of subjectivity. The analyst is really presenting a particular set of spending preferences as being better than other spending plans. The best the positivist can hope for here is to tap into a widely shared set of beliefs about what circumstances necessitate extra capital spending, and to base his estimates on these. The goal is simply a benchmark from which local authorities can begin debate on capital spending plans, rather than a mathematical formula that determines the final and optimal allocation of resources in any city.

All but two of the independent variables in the preceding model would seem to pass muster as "legitimate determinants" of capital-spending needs. In other words, most people would agree that effective income, the price of capital goods, the stock of capital goods already on hand, population, area, and the age of the capital stock all ought to be considered in determining highway needs. More controversial would be the inclusion of the share of resources coming from grants-in-aid in a capital-spending needs estimate. It might easily be argued that the need for highways is simply independent of the source of financing available to the community. Does a city need more roads simply because Washington or the state capitol is willing to pay for them? It would also be difficult to refute the argument that, apart from its effects on the current capital stock, the previous year's spending levels shouldn't dictate current capital spending needs. Are a city's needs reduced one year just because it refused to spend enough on roads the year before?

To develop estimates of capital-spending needs, then, we first multiplied both sides of equation 10 by income and moved the δS term to the right-hand side to derive a model of gross real per capita highway spending. Using the values given in table 2, the needs estimate was set equal to the predicted values of the resulting equation, except for two adjustments. First, the influence of aid was neutralized by giving every county the average per capita real aid for the entire sample. Second, this equation was not corrected for autocorrelation, heteroskedasticity, or contemporaneous correlation, as would have been done with the Parks procedure. The equation was not partially first differenced, so last year's spending does not appear as a determinant of this year's capital-spending needs.

The resulting estimates are shown in figure 1. For each urban county, the average actual and needed real per capital highway spending are depicted. The gaps between actual and needed expenditures look small on the chart, but in some cases they represent significant sums of money. It turns out that the two most western areas in our sample--Hennepin County in Minnesota and Milwaukee County in Wisconsin--are farthest above their needs estimates, while two old, industrial, more eastern counties--Erie County in New York and Cuyahoga County in Ohio--have the largest capital-spending deficits. To put these figures into perspective, the Cuyahoga County deficit amounts to about 5 percent of actual expenditures or approximately $2 million per year. The Milwaukee County surplus, on the other hand, comprises 6 percent of actual expenditures or approximately $3 million annually.

As table 3 shows, these differences can only partly be explained by differences in aid. Milwaukee and Hennepin counties do have the second and third highest aid per capita, but Cuyahoga County receives more than the average amount of aid (sixth highest) and Erie County gets only the third lowest level of aid. Clearly, some of these differences remain to be explained by factors such as the political culture of each area.

More surprising, perhaps, is the wide range of capital needs levels allowed under this procedure. Since the highway spending process is dominated by repair and replacement considerations, these levels are determined, to a large extent, by the size of the capital stock which must be maintained. Thus, Jefferson County in Kentucky has the smallest capital-spending need of $11.75 per person (1972 dollars) because of its low per capita income and its small, and relatively new, capital stock. Milwaukee County, on the other hand, despite having the smallest land area in the sample and a relatively new capital stock, has the largest capital-stock need ($46.30 per person), because of the sheer size of the capital stock that must be maintained there. This large variation in highway-spending needs also points up how misleading a simple average expenditure figure would be as a measure of capital-spending needs. Such an approach (which is sometimes employed for this purpose) would give seriously distorted estimates for many of these cities.

IV. Conclusion

This paper has attempted two related tasks. First, a positive model of public capital spending was developed and tested using highway spending data for ten midwestern urban counties. The most significant determinants of highway spending were found to be population, the value of the existing capital stock, the land area of the city, and the amount of aid received from higher levels of government. Weaker and less consistent relationships were found between highway spending and income, the price of capital goods, and the age of the capital stock. Second, the estimated coefficients from this model were used to generate capital-spending needs estimates for these counties, on the premise that the predicted values of the model provide the responses of a typical city in the sample to changes in its characteristics. It was found that Hennepin and Milwaukee counties spend considerably more than the needed amount on highways, while Erie and Cuyahoga counties had large shortfalls in spending relative to their need levels. Moreover, not all of the differences between these cities can be accounted for by differences in aid, so some of these discrepancies must be due to factors such as the political environment in each urban area.

The economic method of estimating capital-stock needs has two principal advantages over previous methods. First, it requires considerably less staff time to prepare, since no exhaustive inventory of physical units is needed. Second, this method may be more useful to policymakers, since it avoids arbitrariness in the calculation of capital-spending needs by using as its benchmark the typical response of similar cities. Given these advantages, it would be highly desirable to continue research in this area, both to check results and to provide more information for policymakers. It would be useful to see how these results vary across time, across regions of the country, and across types of public capital.

Notes

1. Here Choate and Walter are summarizing the results of a government study.

2. Throughout this paper, I use the term city in a generic sense, to refer to any local jurisdiction such as a city, village, township, or county.

3. The seminal reference on the AIDS demand system is Angus Deaton and John Muellbauer, "An Almost Ideal Demand System," American Economic Review, vol. 70, no. 3 (June 1980), pp. 312-26.

4. Actually, the term $\ln p^V$ is only a linear approximation to the true price index p^*, which is determined by the formula $\ln p^* = a + b \ln p + c (\ln p)^2/2$. This substitution allows the use of least squares rather than maximum likelihood techniques. Deaton and Muellbauer (1980, p. 316) find that this technique yields a close approximation for more than one price, when those prices are closely collinear. Presumably then, the same technique ought to work well for only one price.

5. The first application of the concept of proportionality of income distributions to the study of decision-making in local government, appears to have been in Bergstrom and Goodman (1973, pp. 287-90). For a discussion of the meaning and plausibility of this assumption, see Robert P. Inman, "Testing Political Economy's 'As If' Proposition: Is the Median Voter Really Decisive?" Public Choice, vol. 33, no. 4 (1978), p. 48.

Following Inman (p. 48), this hypothesis was tested by examining the moments of the distribution of intracounty, city, per capita income in seven of the urban counties in our sample. (Three of the sample counties had too few cities to be useful for this purpose.) If income distributions are proportional, the ratios of median to mean and the coefficients of variation (standard deviation/mean) will be equal. According to the 1980 Census of Population, the ratio of median to mean for all incorporated places with populations greater than 2,500 in these urban counties ranged from 0.87 to 0.92 with a mean of 0.90. The coefficient of variation ranged from 0.25 to 0.45 with a mean of 0.34. Some of the difference in coefficients of variation appears to be due to differences in the number of jurisdictions in each county; the greater the number of jurisdictions, the larger the dispersion of per capita incomes. As long as this effect is independent of the overall level of income in the county, it should create no problems for the analysis.

6. In an effort to test this assumption, data were gathered for 46 jurisdications in Cuyahoga County (including the county itself) from the Census Bureau. For this sample, the correlation between 1980 population 1979 per capita income was -0.1 7264, and the correlation between area and 1979 per capita income was -0.11663. Neither of these figures is statistically significant; the data do not reject the hypothesis that these characteristics are uncorrelated. Unfortunately, data concerning the age of public capital were not available at the individual community level.

7. Actually, both Hennepin and Ramsey counties are considered part of the central portion of the Minneapolis-St. Paul SMSA. Hennepin was chosen only because it was more populous.

Figure 1

REAL PER CAPITA EXPENDITURES ON HIGHWAYS

ANNUAL AVERAGES, 1965–1976

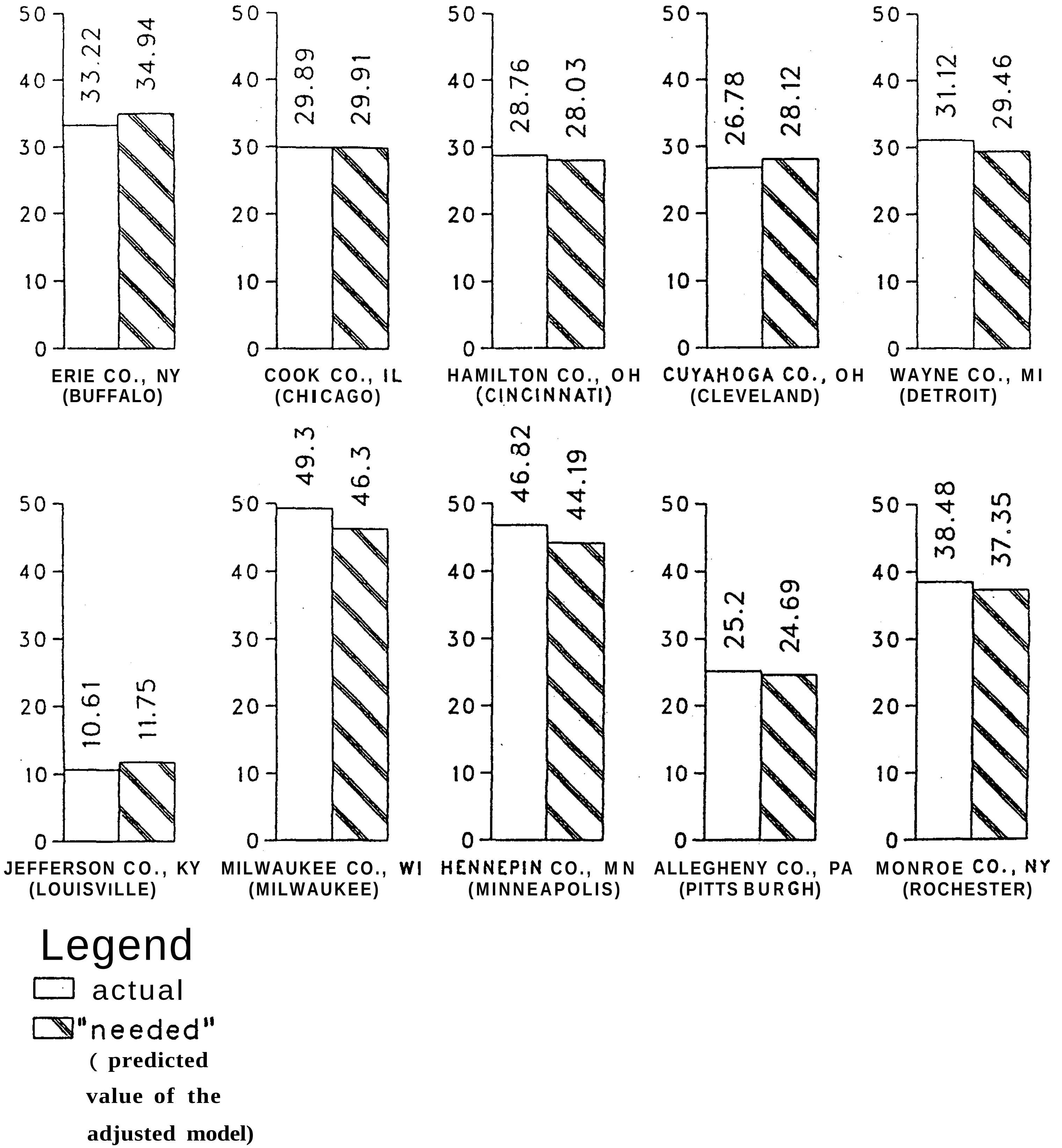

Table 1 Sources of Data

Age of bridges	The Urban Institute, via special release from U.S. Department of Transportation, Federal Highway Administration, Bureau of Bridges.
Area of county	U.S. Department of Commerce, Census Bureau, 1977 City and County Data Book.
Capital stock estimates	Developed using expenditure data from U.S. Department of Commerce, Census Bureau, city finances annuals, 1941-45 and compendium of city government finances annuals, 1946-64.
Cost index, highways	U.S. Department of Transportation, Federal Highway Administration, composite index of prices for federal-aid highway construction.
GNP deflator	U.S. Deparmtment of Commerce, Bureau of Economic Analysis.
Highway expenditures and revenue sharing	Department of Commerce, Census Bureau, Local Government Finances in Selected Metropolitan Areas and Large Counties (annual).
Highway grants	U.S. Department of Commerce, Bureau of Public Roads, special release.
Municipal interest rate	Bond Buyer 20-bond index of yields on domestic municipal bonds.
Number of highway jurisdictions	U.S. Department of Commerce, Census Bureau, 1967, 1972, and 1977 Census of Governments.
Per capita income	Department of Commerce, Bureau of Economic Analysis, Regional Economic Measurement Division.
Population	Department of Commerce, Census Bureau.
State highway department direct expenditure on local roads and streets	U.S. Department of Transportation, Bureau of Public Roads, special release.

Table 2 Regression Results

Parameter	Variable	Estimated coefficient	Estimated standard error	t-Stat
b^1	$1/p^i$	9.21307 E-04	3.9405 E-04	2.3380
c^1	$\ln p^i/p^i$	7.61093 E-05	5.4726 E-05	1.3907
e'	$(\ln y_k^i - v \ln p^i)/p^i$	-8.62769 E-05	4.0956 E-05	-2.1066
f'	T_k^i/p^i	7.28462 E-03	1.9426 E-03	3.7499
γ	$-S_k^{i-1}/y_k^i$	1.63492 E-02	7.7179 E-03	2.1184
g_1'	pop_k^i/p^i	8.04707 E-10	2.6920 E-10	2.9893
g_2'	$area_k^i/_p^i$	5.57594 E-06	5.1343 E-07	10.86
g_3'	$age_k^i/_p^i$	4.03927 E-05	4.6369 E-06	8.7112

estimated : 0.085
estimated income elasticity: 0.1772
estimated price elasticity: -0.2689

"Rebuilt" R^2, for regression on real per capita highway spending using these coefficients: 0.8136

Table 3 Average Real Per Capita Aid, 1965–76
(1972 dollars)

County	Average
All counties, all years	18.24
(Buffalo) Erie County, New York	13.10
(Chicago) Cook County, Illinois	20.69
(Cincinnati) Hamilton County, Ohio	19.66
(Cleveland) Cuyahoga County, Ohio	19.48
(Detroit) Wayne County, Michigan	28.75
(Louisville) Jefferson County, Kentucky	9.76
(Milwaukee) Milwaukee County, Wisconsin	22.85
(Minneapolis) Hennepin County, Minnesota	22.61
(Pittsburgh) Allegheny County, Pennsylvania	14.37
(Rochester) Monroe County, New York	11.11

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