Economies of Size in Local Government:
An Annotated Bibliography

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ABSTRACT

The bibliography contains a listing and annotations for 133 papers, reports, and books which test for size or scale economies in producing local government goods and services. Size economies refer to the set of phenomena that cause average costs of providing a good or service to decline with increasing size of the government unit. This deals solely with the supply side costs of providing services and therefore excludes research on such topics as expenditure determinants of local governments and optimal city size. Research applying to size economies results is generally omitted. An appendix lists some research on these omitted topics.

Keywords: Economies of size, economies of scale, local government, community development, communities, rural development, cost functions, costs.

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The U.S. Department of Agriculture has long been concerned about nonmetropolitan communities, as evidenced through the education and action programs of such agencies as the Extension Service (now part of USDA's Science and Education Administration), Farmers Home Administration, and Rural Electrification Service. By both legislation and tradition, the Department's community-oriented programs have focused on these less-populated communities, whose small governments comprise the vast majority of all government units in the Nation.

In discussions regarding the quantity and quality of service delivery in these smaller communities, there is perhaps no theme more persistent than the need to achieve greater economies of size or scale in service delivery. Size economies refer to the phenomena or considerations that cause average production costs to decrease as the size of the governmental producing unit increases. They may result from such factors as increased specialization and division of labor, increased possibilities of using advanced technological developments and/or larger machines (better use of capital equipment), and possible discounts resulting from buying inputs and supplies in larger quantities.

Because of the importance of this topic, a detailed review of appropriate literature for the use of researchers and policymakers was undertaken. This bibliography is the product. It contains an annotated listing of 133 references whose major focus is testing for size economies. It also includes an appendix of 192 references regarding applications of size economies, expenditure studies, and optimum city size. This material is presented to further the knowledge of both researchers and policymakers about this important subject matter area.
CONTENTS

INTRODUCTION .......................................................... 1
GENERAL AND THEORETICAL RESEARCH ......................... 5
MULTIPLE SERVICES AND ALL SERVICES ........................... 8
EDUCATION .............................................................. 19
ELECTRIC POWER GENERATION .................................... 35
FIRE PROTECTION ....................................................... 38
HOSPITALS ............................................................... 40
POLICE PROTECTION ................................................... 46
REFUSE COLLECTION ................................................... 49
ROADS ................................................................. 53
WATER AND SEWER UTILITIES ..................................... 55
APPENDIX A—AUTHOR INDEX ........................................ 59
APPENDIX B—BIBLIOGRAPHY OF RELATED TOPICS ............ 61
INTRODUCTION

Per capita direct general expenditures of local governments quadrupled during 1944-60 and again during 1960-75. In 1944, per capita direct general expenditures totaled $44.78. By 1975-76 they had risen to $744.06; in 1944 dollars, this equaled $134.62.\(^1\) Growing demand for services has certainly been a significant determinant of the increasing expenditures. Nonetheless, high government costs resulting from inefficiencies in producing goods and services have become important concerns of policymakers and researchers.

Investigation of ways to slow the expenditure increases has taken several paths. One receiving wide attention has been the question whether size or scale economies exist for local government services. Size economies refer to a group of phenomena which usually cause average costs to fall as size of the producing government unit increases. Seven reasons for this—with varying applicability to production of government goods and services—are usually given. First, increased specialization in labor permits workers to gain expertise in their functions and to spend a larger proportion of their time on tasks where their skills are appropriate. Second, increased specialization will also permit managerial skills and time to be used more effectively. Third, only large government producing units may efficiently employ available technologies, which permit meshing of several different machines with dif-

different rates of output. Fourth, large-scale purchasing or selling may have price advantages. Fifth, use of some factors of production, such as a buyer's time, do not necessarily increase with the scale of production. Since the wage rate of the buyer is fixed, the per unit output costs of a product fall with a large scale. Sixth, large organizations can more easily hedge against uncertainty in the demand for services. Finally, large-scale producers are better able to utilize byproducts from the production process.

These seven justifications suggest that average costs would fall monotonically with expansions in output. As output continues to expand, however, diseconomies such as limitations to efficient management may occur and offset these factors. The actual average cost/output relationship, therefore, is expected to be U-shaped.

Size economies research has been undertaken by both metropolitan and nonmetropolitan governments. Metropolitan areas are generally easier to analyze because a large sample of government organizations is frequently available within a small geographic area, permitting factors such as attitudes or price levels to be disregarded. Therefore, data collection becomes easier because defining and quantifying attitudes can pose the most difficult data collection problems.

Not surprisingly, much of the initial research following Werner Z. Hirsch's seminal article was focused on metropolitan areas. However, the earliest research identified which seeks to relate local government output to unit costs was a 1935 Montana study by Roland Renne. For a variety of reasons, much recent work has focused on nonmetropolitan areas. One reason has been the recent population shift into nonmetropolitan areas. Another is the special problems associated with providing services in low population density areas, such as the high costs of transporting people to services and services to people. Primary and secondary education are examples of transporting people to the services; water and sewer utilities are services transported to people. Finally, because of small populations, nonmetropolitan governments are the likely candidates for cost savings through consolidation.

During the fifties, size economies research applicable to local governments was almost exclusively related to capital-intensive services such as electric production. Presumptions that efficient use of machinery required large size probably led to strong interest in these kinds of services. Since Hirsch's article in

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3 McConnell, p. 508.


1959, the main research focus has been on more labor-intensive, user-oriented services such as education and police protection, mainly because they account for the majority of local expenditures. Education and police expenditures alone represent over one-half of local spending.

Interest in overcoming the conceptual difficulties associated with studying the labor-intensive services is another reason for the concentration of interest in this area. Defining and quantifying output is one problem. Even agreeing on what constitutes a unit of education is probably not possible without considering the difficulties of quantifying the unit. Specifying the relationship between inputs and outputs also involves some unique problems for services such as education and police protection. For example, student and parental inputs into education must be separated from school inputs. For police protection, more police inputs presumably lead to less crime (although more police may lead to more reported crimes).

This annotated bibliography represents a compilation of much of the published and some unpublished research on size economies resulting from a wide search over several years through relevant literatures. Several guidelines directed the selection of articles. First, the annotated bibliography was restricted to that research which fits the definition of size economies discussed before—specifically that related to the supply side costs of providing services. Demand changes which might accompany growth of the governmental unit are unrelated. Therefore, the voluminous “expenditures” literature, which mixes supply and demand determinants, was deemed inappropriate.* Also excluded is the considerable “optimal city size” literature, which has a wider focus than local government costs.

A second guideline was to include only that empirical and theoretical research which seeks to ascertain whether a size/cost relationship exists. Much research on local government structure and behavior deals with issues related to size economies. However, a substantial share of this research seeks to apply size economies results to current problems rather than determine whether such economies exist, and consequently was not included.

In addition, no specific effort was made to find literature which predated Hirsch's 1959 article. However, some research prior to 1959, particularly on electric power generation, is included to illustrate early concerns with efficiency. Finally, foreign journals were not systematically investigated, though some foreign work was discovered and is included.

Within the guidelines, the bibliography comprises all research which could be identified and obtained; 133 articles, research reports, books, and dissertations are annotated.

The bibliography is organized into 10 sections. The first section contains a listing of general and theoretical work with short annotations. Next, research which deals with multiple services and with all services is annotated. The final eight sections list individual services in alphabetical order, along with the corresponding annotated articles.

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* An excellent annotated bibliography of the expenditures literature is available in John Eric Fredland's *Determinants of State and Local Expenditures: An Annotated Bibliography*, NTIS, U.S. Department of Commerce, SHR-0000844.
Except for the general and theoretical work, the annotations for each study were divided into five categories which were adopted from Fredland. Each category should be interpreted as:

Theory (T): Presents the theoretical developments achieved or theory applied in the research. Is used for annotating reviews of the literature.

Data (D): Reports the data sources, units of analysis, sample size, and range of size studied.

Model (M): Lists the dependent and independent variables used in the empirical analysis. Where more than one equation is estimated, the reported equations are numbered. Includes comments on variations or special features of the estimated model.

Estimation (E): Discusses estimation techniques used in the study. OLS is an abbreviation for ordinary least squares regression; 2SLS, two-stage least squares regression.

Results (R): Presents empirical results and conclusions of the research.

"N/A" indicates that information for a particular category was not available in the documents examined or that one of the above categories was not relevant for the type of research.

Appendix A is an author index; appendix B lists 192 research documents which deal with related topics, but were deemed inappropriate for the main text. Appendix B thus includes research on expenditure determinants, optimal city size, measures of local service output, and applications of size economies results.

* Fredland, p. 2.
GENERAL AND THEORETICAL RESEARCH


A review for noneconomists of the conceptual issues in studying scale economies. Includes a discussion of the meaning and purpose of economies of scale and a literature review.


Discusses the meaning and applicability of economies-of-scale analysis to the provision of public services. No attempt is made to identify specific public services in which economies of scale may exist.


Argues that per capita expenditures are generally a poor proxy for average cost, and that a per unit measure of people's valuation of the service would be more appropriate. The simple relationship between population and per capita expenditures is shown to have several interpretations and therefore does not provide a test of scale economies.


Develops a model of optimal local public services production and includes scale economies as one consideration. The model is applied to library services, police protection, refuse collection, park and recreational services, and fire services in the Binghamton, N.Y., Standard Metropolitan Statistical Area (SMSA).

Discusses ways to incorporate quality measures into production functions, cost functions, and economies of size analysis. A two-equation system is proposed where quality of education is explained in a production function and enters as an explanatory variable in the cost function.


Reviews and discusses conceptual issues in size economies research, including output measurement, public goods nature of some services, demand/supply interaction, and differences in the responsibility of various governmental units. Reviews cost and expenditure determinant studies.


Discusses economies of scale as one element in deciding the appropriate area for providing local services. Argues that scale economies are generally less likely for public than for private services because they are user oriented and labor-intensive. Concludes that air pollution control, power, sewage control, water, public health services, hospitals, planning, and transportation are most likely to be characterized by scale economies.


Discusses local government production and average cost functions. Reviews the literature on production, cost, quasi cost, and expenditure determinant functions for police protection. Demonstrates the inapplicability of expenditure determinant functions for measuring economies of scale.

Includes chapters on government production, costs, and supply of government services. Reviews some of the economies of scale literature.


Discusses measurement of quality and quantity of services. Reviews the existing literature on production functions, cost functions, expenditure determinants studies, and economies of scale analysis.


Contains a model of scale economies in public services and examines police and fire protection, recreation services, and cultural assets and activities. Demand and supply is examined for each service and relevant literature is reviewed.


Discusses nine criticisms of statistical cost research. Six of the criticisms pertain to short run and three to long run cost curves. Shows that many objections are invalid or misleading.


Argues that economies of scale can arise from the tautological, metaphysical, or common sense approach. Tautological refers to indivisibilities in the use of inputs; metaphysical refers to economies of scale arising from a factor fixed in supply. Common sense approach, viewed as the best, examines the effect of a proportionate change in inputs on output.

Argues that a cardinal scale of quality must be used across a sample in order to make definite statements about quality. An ordinal scale is insufficient. Short of a cardinal scale, an ordinal scale which provides information on the resultant bias should be developed. Is a comment on Hirsch (1959).


Contains a chapter on scale economies in local government. Reviews some literature on scale economies. Argues that scale economies are not useful for questions pertaining to optimal city size. Problem in scale economies research is specifying a long run average cost curve with an appropriate output measure.


Reviews the Hirsch (1959) article. Argues that population is an inappropriate surrogate for output of a public good. Demonstrates that demand factors must also be accounted for in scale economies research.


Discusses size economies in the provision of local government services. Costs for all services are highest for small towns, low and similar for cities of 20,000 to 1 million residents, then increase gradually for cities above 1 million. Hospital, school, and fire services explain high small city costs, and air pollution control and crime protection explain large city cost differentials.

**MULTIPLE SERVICES AND ALL SERVICES**

T: Uses conventional economic theory to develop the estimated model.
D: Cities between 25,000 and 250,000 in Ohio, Texas, and New Jersey.
M: Per capita spending = f (city size, percent population change, population density, percent of population 65 and over, median school years completed by those 25 and over, median income).
E: OLS and inspection of average data.
R: Concludes that increased population alone does not lead to decreased average costs. Finds some diseconomies for cities with population above 250,000.

R: Finds diseconomies of scale for police expenditures. Per capita fire expenditures decline to 500,000 and rise throughout the rest of the range. Per capita highway expenditures decline to 1,500,000 and gradually rise for larger populations.


T: Uses conventional economic theory to develop the estimated cost curve.
D: All Kansas counties and cities with population above 700. "Budget and Financial Statements," filed by each city and county with the Kansas State auditor.
M: Per capita expenditures = f (population). Estimated separately for 16 categories of city and county expenditures.
E: OLS.
R: Significant size economies are reported for county court house operations, roads and bridges, secondary roads, schools, and total expenditures. Significant diseconomies are obtained for city fire, police, health and sanitation, electric, and total expenditures. No significant economies or diseconomies are found for city general government, water, or sewers, or for county health, jails, or welfare expenses.


T: Uses conventional economic theory to develop the estimated model.
D: Cities over 25,000 in Ohio, Texas, and New Jersey.
M: 1) Per capita total expenditure = f (population, population density, rate of population change, percent of population 65 and older, median number of school years for those 25 and older, median family income).
   2) Number of full-time equivalent employees engaged in common functions = f (same as equation one).
   3) Number of full-time equivalent employees = f (same as equation one).
E: OLS.
R: Generally finds no economies of scale for services provided in cities with population up to 250,000. Diseconomies are found for cities over 250,000 population.


T: Uses conventional economic theory to develop the estimated model.

D: All cities with population 25,000 to 250,000. All cities over 25,000 for eight selected States, 1960.

M: 1) Per capita spending = f (population, population density, percent population change 1950-60, percent population nonwhite, percent population 65 and over, median years of school completed).
2) Per capita employment = f (same as 1). The cities in each State form a separate sample.

E: OLS.

R: No scale effects for cities with 25,000 to 250,000 population. The evidence suggests some diseconomies for larger cities.


T: Develops a behavioral model for local governments using a utility function for the median income family and a linear cost function.


M: Expenditure per family = f (private family expenditures, median education, average family income/median family income, taxable property per family, manufacturing wages, percent Irish, business leadership, political leadership, density, population, population²).

Estimated for nine services and where possible, for current, capital, and total expenditures.

E: 2SLS.

R: A typical pattern was rising population increases expenditures per family but increasing population density decreases expenditures per family. The population-
expenditure relationship is an inverted U for fire, sewer, and sanitation expenditures. The population-expenditure relationship is U-shaped for financial administration and general control.


T: Uses conventional economic theory to develop the estimated model.
M: Expenditures by all local governments in a county = \( f \) (population, migration for 1960-70). Separate equations are estimated for each State.
E: OLS and OLS weighted by the inverse of county populations.
R: Concludes that economies of size are possible since the evidence suggests that marginal costs are below average costs.


T: Derives tax and expenditure equations using a social welfare function to develop the behavioral framework.
M: 1) Per capita government expenditure = \( f \) (income, per capita grants-in-aid, population).  
2) Per capita taxes = \( f \) (local expenditures-intergovernmental revenues).  
Metropolitan and nonmetropolitan are estimated separately.
E: 2SLS.
R: Population is positively related with expenditures in metropolitan areas and negatively related with expenditures in nonmetropolitan areas. Concludes that decreasing costs may exist for providing public services to nonmetropolitan areas.

T: Uses a quasi-dynamic model which considers metropolitan growth as part of a process of horizontal, vertical, and circular integration. Discusses the possible existence of economies of scale for each service and the general shape of the quasi, long run per capita expenditure function.

D: 149 government units in metropolitan St. Louis.

M: 1) Per capita police protection = \( f \) [night time population (P), \( P^2 \), night time population density (PD), total street mileage, percent nonwhite, percent under 25, combined receipts of wholesale, retail, and service establishments (R), index of scope and quality of police protection, average per capita assessed valuation of real property (A)].

2) Per capita fire protection = \( f \) [area in square miles, density of dwelling units (DD), night time population growth 1950-55, index of scope and quality of fire protection, P, \( P^2 \), R].

3) Per capita refuse collection = \( f \) (P, DD, R, A, persons per dwelling units, index of contractual relationships between municipal governments and refuse collectors).

4) Primary and secondary education per pupil plus debt service = \( f \) [number of pupils, (number of pupils)\(^2\), high school pupils/total primary and secondary pupils, pupils/square miles, percent increase in pupils 1951-56, index of scope and quality of education, R]. Equation four was also estimated for educational administration expenditures.

E: OLS and correlation analysis.

R: No scale economies are found for police protection, refuse collection, and education. Fire protection is characterized by a U-shaped average cost curve with a minimum 110,000 population. School administration has a U-shaped average cost curve with a minimum at 44,000 population. Concludes that across the board metropolitan consolidation would not be beneficial.


T: Establishes a supply and demand model to test for scale economies. Develops a quality index as a function of input usage and basic input levels.


M: 1) Cost of all local services = f (test scores, fire casualty ratings, clearance rates, population, log population, teacher wage rates, other government wage rates, population density, number of governmental units, population growth).
   2) Quality index = f (population, after tax income, partial derivative of cost with respect to quality, age, income, education, poverty).
   3) Taxes = (cost-intergovernmental transfer)/population.

E: OLS, 2SLS, and maximum likelihood estimation.
R: Finds a U-shaped average cost curve with a minimum for all services at 400,000 population. The results support the importance of quality factors in explaining differences in expenditures by local governments.


Police Protection:

T: Uses conventional economic theory to develop the estimated model.


M: 1) Per capita crime rates = f (per capita police, dummy variables for city size classes, percent nonwhite, median income, population density, median age, percent males, dummy variables for geographic regions, per capita police, city size and police interactions).
   2) Per capita police = f (lagged per capita crime rate, lagged per capita police, dummy variables for city size classes, percent nonwhite, median income, population density, median age, percent males, dummy variable for geographic region).

E: Recursive least squares is used to estimate the model. The coefficients are used to examine police cost per capita when the crime rate is held constant.

R: Finds declining costs of holding the crime rate fixed until city population reaches 375,000. Costs rise above 375,000 population.
Air Pollution Control:
T: Uses conventional economic theory to develop the estimated model.
D: Twenty-seven metro areas, population 370,000 to 15,470,000. National Air Pollution Control Administration. Senate document 91-40, *The Cost of Clean Air.*
M: 1) Sulfur oxides/square mile = f (city size, city size², manufacturing index, annual median precipitation, wind velocity, annual number of degree days).
   2) Particulates = f (same as 1 above).
   3) Social cost of control = f (particulates, sulfur oxide, city size).
   4) Carbon monoxide emissions = f (city size, gasoline sales, annual median precipitation, wind velocity, annual number of degree days).
   5) Gasoline sales = f (city size, city size², density).
E: OLS is used to estimate the regression coefficients. The estimated coefficients are used to derive the social cost of air pollution control.
R: Sizable diseconomies of city size are found with regard to air pollution control.

Fire Protection:
T: Uses conventional economic theory to develop the estimated model.
M: Class of fire protection = f (city size, per capita spending for fire protection).
E: OLS is used to estimate the regression coefficient. The estimated coefficients are used to estimate a cost of fire protection for cities with homogeneous structures of per capita wealth and per capita expenditures.
R: Finds sizable economies of city size to 1 million population when all private and public costs are included.

Hospital Costs:
T: Uses the model and regression results developed by Carr and Feldstein (1967).
D: N/A
M: N/A
E: N/A
R: Large economies of city size until a population of 100,000 is attained. Constant costs for larger city sizes.

Education:
T: Uses the model and regression results developed by Freddie Cad White. See White and Tweeten (1973).
R: Finds optimal size city for providing education services is 9,800 residents. Neither economies nor diseconomies resulted for cities above 9,800 population.


T: Is concerned with size of economic center, not the size of the governmental unit. Argues that economies of scale at a decreasing rate exist for services such as health, roads, and libraries. Diseconomies of scale exist for other services such as government administration.

D: *New South Wales: Statistical Register Western Australia Yearbook, Victoria Municipal Financial Statistics.*

E: Plots per capita costs for each category of analysis versus population of the entire area.

R: Demonstrates that the percentage of total expenditure which goes for administration falls as population increases.


T: Discusses characteristics of cities.


E: Examines per capita expenditures for six city size classifications.

R: Finds total cost of government per capita rises with city size. Generally finds per capita costs rise with population for individual services.


T: N/A

D: *Local Statistical Returns-Great Britain.*

E: Examines cities by size class versus per capita expenditures for eight local services.

R: Finds per capita costs are lowest for cities and towns in the 100,000 to 250,000 population range.

T: Discusses the impact of individuals and pressure groups on the level of taxes and services.
M: Six principal components are derived from 26 original variables.
E: Principal components analysis.
R: Finds population size positively related with expenditures. Argues that this most likely results from a wider range of services offered rather than cost differentials.


T: Discusses the structure of Montana County governments.
D: Fifty-six counties in Montana.
M: N/A
E: Derives an output index for a number of services by weighting the activity of each service according to experienced officers’ judgment of what is important. Calculates unit costs and relates this to volume of work.
R: A U-shaped average cost curve is observed for the office of clerk and recorder, treasurer’s office, and office of assessor. Declining costs through the observed range were found for the sheriff’s office, clerk of courts, and superintendent of schools.


T: Uses pragmatic empiricism to relate expenditures and population.
M: N/A
E: Compared population size of county within geographic regions with per capita expenditures. Uses zero order correlation coefficients.
R: Neither population or density affect total per capita spending. Population and population density are positively correlated with fire, police, and sanitation expenditures, and negatively correlated with streets and highways and public education.
T: Develops an index for measuring service output.
D: Nineteen cities and villages and 18 school districts in Milwaukee County, Wis.
M: Variables correlated with service output index are population, per capita current expenditures, total current budget, population density, date of incorporation of municipality, area, equalized per capita property values and percent of land area developed.
E: Correlation analysis.
R: Infers economies of scale over all services because no relationship is found between per capita expenditures and population, and a positive relationship is found between service output and population. Also finds economies of scale for police and general government.


T: Uses casual empiricism to examine the per capita spending-population relationship.
M: N/A
E: Examines per capita expenditures for nine county population size groups within each State.
R: Generally finds the highest per capita expenditures in the smallest and largest counties. Argues that the smallest counties are experiencing diseconomies of scale and the large counties have high per capita expenditures because of high service levels.

T: Applies the Schmandt and Stephens (1960) output index to counties.
M: Activity = f [total population, area in square miles, population density, full value of property, percent of full value property within cities and villages, total expenditure (net of capital outlays and debt service), per capita expenditure (net of capital outlays and debt service)].
E: OLS.
R: Population is correlated with the total number of activities performed and individual activities for general government, protection of person and property, and parks.


T: Discusses economic rationales for consolidation.

D: Unpublished.

M: Per unit costs = f [1/volume of work (W)]. Per unit costs = f (W, W^2). Examines eight county services.

E: OLS.

R: Finds the parabolic form generally explains the relationship between per unit costs and the volume of work.

**EDUCATION**


T: A behavioral model is developed for school district behavior.

D: Educational Testing Service; 520 school districts in Michigan serving grades K-12.

M: Instructional expenditures per pupil = f (achievement scores, average teacher salaries, students' socioeconomic status, school district size, two measures of students' attitudes, dummy variable for metropolitan status of the school district, dummy variable for geographic region of the State). The model is estimated for all school districts and individually for classes of metropolitan status for school districts.

E: 2SLS

R: The author does not specifically address the question of size economies. The size coefficient is statistically insignificant except for school districts in cities over 10,000 population which are focal points for local economic activity. Slight evidence of size economies is found for these districts.

T: Uses conventional economic theory to develop the estimated cost curve.

D: 377 Iowa State High Schools. Iowa State Dept. of Public Instruction.

M: 1) Quality (average composite score on Iowa Tests of Educational Development in 1963 for twelfth grade minus average composite score in 1961 for tenth grade) = f (college hours per teaching assignment, average number of different subject matter assignments per high school teacher, median high school teachers' salaries, number of credit units offered, building value per pupil in average daily attendance, bonded indebtedness per pupil in average daily attendance, average class size in average daily attendance).

2) Per pupil school costs = f (quality, school size, same variables as in equation 1).

In different equations, school size is measured by variations of average daily attendance (ADA), ADA² and 1/ADA.

E: OLS.

R: Finds economies of scale. Concludes the average cost curve is U-shaped with a 1500-student minimum.


T: Using constrained cost minimization, a cost curve is derived from a production function. The authors argue that the appropriate unit of analysis for education is programs within each curriculum.

D: This is a reply to Micnelson (1972).

M: N/A

E: N/A

R: N/A


T: N/A

D: Unpublished data from Ontario's Dept. of Education.

M: 1) Total cost = f [average daily attendance (ADA), ADA², ADA³].

2) Total cost = f [ADA weighted by quality index of test scores, (ADA weighted by quality index of test scores)², (ADA weighted by quality index of test scores)³].
3) Total cost = f [ADA weighted by quality index measured by inputs, (ADA weighted by quality index measured by inputs)^2, (ADA weighted by quality index measured by inputs)^3].

Estimated for three educational programs and across all programs.

E: OLS.

R: Generally finds either continuing economies of scale or constant returns to scale for individual programs. Portions of the cost curve exhibited diseconomies when all programs were examined together.


T: Discusses the interrelationship between per pupil expenditures, the pupil-teacher ratio, and average teacher salaries.

D: 262 North Dakota School Districts. 269 Indiana School Districts.

M: Per pupil expenditures = f (enrollment and log enrollment).

E: OLS.

R: Finds size economies for instructional costs in North Dakota but not Indiana. Size economies are found to emanate from higher pupil-teacher ratios. Concludes size economies would probably be offset by higher teachers' salaries and transport costs if schools were consolidated.


T: N/A


E: OLS.

R: Finds no evidence of scale economies.

T: Develops a demand and supply system of equations for local education.


M: 1) Educational attainment (ratio of selective service passes to selective service failures) = f (teacher salary per pupil, fraction of the population which is school age, average daily attendance/average daily membership, percent of blacks in the population).
   2) Teacher salary per pupil = f (educational attainment, income per capita, fraction of the population which is school age).

E: OLS, 2SLS.

R: Finds slightly increasing returns to scale, although the relationship is not statistically different from constant returns to scale.


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T: N/A


M: Uses the model of H. Thomas James and others to find unexplained variation in education spending, then estimates residual = f (school size, school size²).

E: OLS.

R: Finds the minimum unit cost for school districts varied from 20,000 to 160,000 pupils for the nine States, with 50,000 pupils as the median.

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T: Discusses the meaning of and interrelationship between economies of scale, average cost, and marginal cost.


M: Uses the model of H. Thomas James and others to find unexplained variation in education spending, then estimated residual = f (school size, school size²). Estimated the equation separately for school districts with fewer than 1,500 pupils and more than 1,500 pupils.

E: OLS.
Continuous scale economies for school districts under 1,500 pupils. Found the minimum unit cost for school districts varied from 20,000 to 160,000 pupils for the nine States, with 50,000 pupils as the median.


Uses conventional economic theory to develop the estimated cost curve.


Cost/average daily attendance = f [average size of elementary school (uses a three-step measure of size), average size of secondary schools (uses a three-step measure of size), average teacher salary, number of auxiliary persons per average daily attendance, percent average daily attendance in secondary schools, equalized valuation of property per average daily attendance].

OLS.

For elementary schools, insignificant economies of scale to 300 pupils and diseconomies of scale for more than 300 pupils were found. Secondary schools exhibited economies of scale to 600 pupils.


Uses conventional economic theory to develop the estimated cost curve.

116 New South Wales primary schools, 1971, enrollment 9 to 928 pupils.

1) Expenditures for instruction and administration per pupil = f (1/average enrollment, teachers in promotion positions/total full-time teachers, average salary of teachers, salary of teachers not in promotion position, dummy variable for differences in expenditures resulting from staffing procedures for school administration, taking a value of 1 if greater than or equal to 600 and 0 otherwise, dummy variable for small enrollment taking a value of 1 if greater than or equal to 35 and 0 otherwise, enrollment dummy/enrollment, enrollment dummy/enrollment^2).
2) Maintenance expenditures per pupil = \( f \left( 1/\text{average enrollment}, \text{average age of school buildings}, \text{a dummy variable for whether a teacher's residence is at the school, taking a value of 1 if in residence} \right) \).

E: OLS.
R: Economies of school size with most economies attained for instruction and administration at 100 pupils and for maintenance at 200 pupils. Diseconomies for maintenance and administration at 600 pupils.


T: Develops an “ideal” model of education costs.
D: Twenty-seven school districts in St. Louis County, Mo. 1951-52 and 1954-55. 600 to 84,000 pupils enrolled.
M: Per pupil expenditure = \( f \) (pupils in average daily attendance (ADA), ADA\(^2\), high school pupils in ADA as percentage of the total pupils in ADA, ADA per square mile, percentage increase in ADA 1951-56, assessed valuation per ADA, index of scope and quality).
E: OLS.
R: No significant economies of scale were found for school districts.


T: Uses conventional economic theory to develop the estimated model.
M: Minimizes the total cost of transporting and educating the students in the county subject to constraints on school location and school capacity.
E: Separable programming.
R: Found little financial advantage in adjusting students to minimize transportation costs while holding school enrollments fixed. One percent saving was possible from adjusting students while holding only school plant size fixed. Approximately 1 percent savings from adjusting students while permitting all local school costs to vary.
Concludes that efforts to take advantage of internal schooling economies are generally offset by higher transportation expenses.


T: Contains a discussion of cost curves.
D: Thirty-eight high schools in West Virginia which were accredited and also paid teachers $6,250 or more, 1969-70.
M: Total cost = f [average daily attendance, average daily attendance times total square feet of facility, (total square feet)$^2$].
E: OLS.
R: Finds a U-shaped average cost curve with minimum cost output at 1,426 pupils and a facility with 124,062 square feet of area.


T: Includes a discussion of inputs and outputs in the education process.

M: Current cost/average daily membership = f (number of students, percent teachers with masters, percent permanent teachers, medium class size, student/staff, percent students in crowded classrooms, percent capacity utilization, percent teachers with 10 years experience.)
E: OLS.
R: Finds a positive relationship between instructional costs per student and number of students in the school district, and instructional costs per student and percentage of capacity utilized.


T: Examines educational production functions and the costs of educational quality.

M: 1) Total costs/pupil = f (enrollment, enrollment², capacity, capacity², enrollment X capacity).
   2) Total costs/pupil = f (enrollment, percent of teachers accredited, percent of teachers with masters degrees, percent of teachers with over ten years experience, percent of students in uncrowded classrooms, pupil/teacher).

E: OLS.

R: For equation one, a U-shaped per pupil cost curve with a minimum between 1,400 and 1,800 pupils is found. Enrollment is found to be negatively related with costs in the linear equation two.


T: Contains a discussion of quality measures and surrogates.

D: Project Talent Report. Includes schools from across the nation.

M: Measure of quality = f (intelligence, per pupil expenditure, average daily attendance, socioeconomic index). Estimates the equation for different socioeconomic classes; also estimates regression coefficients with size and expenditures used as dummy variables to test for linearity. Regressions are estimated by region of the country and type of school district.

E: OLS.

R: Concludes that size and facilities cannot be used to examine size economies. Generally finds constant returns to scale for expenditures.


T: Uses conventional economic theory to develop the estimated model.

D: Quality Measurement Project, New York State Dept. of Education.
Average school district achievement in basic subjects = \( f(\text{average pupil intelligence score, } \ln\text{ expenditure per pupil, } \ln\text{ average daily attendance})\). The model is estimated separately for six socioeconomic groups and for grades 4-5-6, 7-8, and 10-11.

OLS.

No evidence of economies of scale is found. Possible diseconomies are discounted on the basis of geographical differences among school districts.


Includes a discussion of how costs relate to the rate of output and time of operation. Discusses types of costs in government production.


N/A

Simulation.

School gymnasium facilities are found to be significant contributors to overall economies of scale.


Uses conventional economic theory to develop the estimated cost curve.


Per pupil expenditures = \( f(\text{average daily admissions, (average daily admission)}^2, \text{percent of special students, dummy variable for special schools, dummy variable for geographic location, capacity utilization, percent of permanent teachers with masters degrees, percent of probationary teachers with masters degrees})\). The model was estimated a number of times using various combinations of the variables.

OLS.

Small size economies are suggested by this paper.

T: Argues that only teachers costs, in particular the pupil-teacher ratio, should be examined for size economies.


M: 1) Sixth grade reading score = f [third grade reading score (RQ3), mean experience of teachers (MET), log of the pupil-teacher ratio (PTR), percent of students participating in the free lunch program (FLP), dummy variable for schools west of Rock Creek Park (WEST), dummy variable for schools east of Anacostia River (ANAC), size of the school (SIZE)].

2) RQ3 = f [FLP, WEST, dummy variable for model schools (MODEL)].

3) MET = f (FLP, ANAC).

4) PTR = f (FLP, ANAC, MODEL, SIZE).

E: Path analysis and 2SLS.

R: Cost savings from a larger school are not necessarily economies of scale because the size difference creates a larger pupil/teacher ratio which leads to lower test scores for the students.


T: Analyzes the considerations in optimum government size.

D: *California Testing Program 1970-71*. 144 largest unified school districts (over 2,000 students), 6th and 12th grade; omitted six largest.

M: 1) Median correct answers on test/median incorrect = f (median IQ for each grade, total current expenditure per student, average daily attendance).

2) IQ = f (index of family poverty, percent minority students, assessed valuation per student, average daily attendance).

E: 2SLS.

R: Size of district is negatively related with student performance.


T: Uses conventional economic theory to develop the estimated model.
M: Expenditure per pupil = f [dummy variable for breadth of curriculum, tax levy, assessed valuation per pupil, median education attainment, dummy variable for location in the Ozarks, average daily attendance, (average daily attendance)^2, (average teacher salary)^2, percent of students in high schools, Ohio Psychological Test Score].
E: OLS.
R: Economies of size were found with a minimum average cost at 2,244 pupils.


T: Uses conventional economic theory to develop the estimated model.
D: 15 Missouri high schools. Unpublished data.
M: Expenditure per student = f [number of students, (number of students)^2, average teacher salary, tax levy, assessed valuation per student, student-teacher ratio, number of classes].
E: OLS.
R: Found economies of size with minimum average cost at 488 pupils.


T: Descriptive in nature; does not attempt to develop a theoretical model.
M: N/A
E: Looked at number of States with counties of various class sizes. Examined how many counties in the size group had the highest or lowest expenditure.
R: Little association was found between per capita expenditure and population.

T: Uses conventional economic theory to develop the estimated model.


M: 1) Expenditure per pupil = f (local revenue for education/total revenue for education, income per capita, transportation expenses per pupil, dummy variable for the year, average daily attendance).
   2) Explained variation from equation one = f (dummy variable for the year, average daily attendance).

E: OLS and linear programming.

R: Significant size economies were found.


T: Uses conventional economic theory to develop the estimated model.

D: 109 high schools in Wisconsin.

M: Operating expenditure per pupil = f (enrollment, enrollment², average teacher salary, number of credit units offered, average number of courses taught per teacher, change in enrollment during 1957-60, percent of classrooms built after 1950).

E: OLS and observation.

R: Significant size economies were found until the school reached 1,675 pupils.


T: N/A


M: N/A

E: Inspection of the average cost, enrollment relationship.

R: Tends to find a U-shaped average cost curve.


T: Argues that a lack of understanding of the relationship between size and output in the production relationship makes analysis of size economies difficult.

D: School districts in Illinois. One hundred districts for elementary, secondary, and unit type districts.
M: Costs = f [log average daily attendance, log (average
daily attendance)^2].
E: OLS.
R: Finds U-shaped average cost curve with a more exten-
sive range of economies for unit type districts.

Shapiro, David. "Economy of Scale as a Cost Factor in the Operation of
6(1), pp. 114-121.

T: Uses conventional economic theory to develop the esti-
mated cost curve.
D: N/A
M: Per pupil expenditure = f [hundreds of pupils, (hun-
dreds of pupils)^2, dummy variable for school divisions
and counties, equalized assessed property value per
pupil, median years of education of adults in the census
divisions in which the district is located, dummy
variable for Catholic districts, dummy variable for
districts in Edmonton and Calgary, dummy variable for
districts in smaller cities, dummy variable for northern
Alberta, dummy variable for southern Alberta, percent
rate of growth of enrollment in past year].
E: OLS.
R: Finds economies of scale with the relationship best
described by a logarithmic function. Argues that
relative population densities are important to potential
cost savings.

Sher, Jonathan R. and Rachel B. Tompkins. "Economy, Efficiency and
Equality: The Myths of Rural School and District Consolidation," *Education
in Rural America: A Reassessment of Conventional Wisdom*. Ed. Jonathan P.

T: Uses existing literature to argue that economies of scale
in education will be offset by other diseconomies such as
in transportation and purchasing. Concludes that
school consolidation would not be cost saving. Also
argues that school size and achievement may be inverse-
ly related. Accepts that some administrative economies
may exist for school districts.
D: N/A
M: N/A
E: N/A
R: N/A

T: Surveys 25 studies relating schools and school district size to educational outcomes and costs.

D: N/A
M: N/A
E: N/A
R: N/A


T: Develops cost functions based on a production function and cost minimization. Argues that one need not include inputs in empirical cost functions if output is included and school districts minimize costs.

D: Oregon State Dept. of Education, 1968-69. All unified school districts with at least 100 students.
M: Total costs = f (students, students², students³).
E: Stepwide polynomial regression.
R: Finds a U-shaped average cost curve with minimum average cost at 51,000 students.


T: Uses conventional economic theory to develop the estimated cost curve.


M: 1) Teacher salary/students = f (teacher education (TE), teacher experience (TX), 1/number of students in the school (N)).
2) Teacher salary/N = f (TE, TX, N, N²).
3) Other operating costs/number of students in the district (M) = f [number of elementary students (NE), number of secondary students (NS), number of special programs grades 11 and 12 (P), assessed property valuation (A), population density (D), number of students in nonacademic programs (NA)].
4) Other operating costs/M = f [(NE + NS), (NE + NS)², P, A, D, NA].
5) Other operating costs/M = f (1/(NE + NS), P, A, D, NA).
6) Administrative costs/M = f [1/M, P, A, D, NA, number of schools in district(S)].
7) Administrative costs/M = f (M, M², P, A, D, NA, S). Other operating cost equations included separate estimations for other instructional expense, operations, and maintenance and repair.

E: OLS.
R: Finds size economies for each component of costs. Only evidence of U-shaped average costs is for maintenance and repair, although U-shaped curve may be found for other costs if the sample included larger districts.


T: Using a production function as the basis, an equation for estimating the return to a unit of schooling is developed. The effects of quality and quantity of education are measured through their effect on an individual's income in the work force.


M: Per unit return to schooling = f (nonwhite return as a proportion of white, quantity of schooling, number of persons employed, nonlabor inputs, total current expenditures per pupil, average salary per member of instructional staff, members of staff per 100 pupils, enrollment per secondary school, dummy variables for the South and Pacific divisions).

E: OLS.
R: Finds size of the secondary school one of the most important determinants of school quality. Concludes that there are gross economies of scale which originate with school centralization or consolidation.


T: Includes a discussion of educational production functions.

D: Five percent stratified sample of districts in Oklahoma. Oklahoma State Dept. of Education.

M: 1) Administrative cost/average daily attendance (ADA) = f (ADA, 1/ADA, composite achievement grade 11, pupil-teacher ratio (PTR), PTR²).
2) Plant operation and maintenance/ADA = f (same as equation one).
3) Annual cost of buildings/ADA = f (same as equation one).
4) Annual cost of equipment/ADA = f (same as equation one).

E: OLS and separable programing.
R: Finds economies of size. Optimal size school district depends on desired educational program and student transportation costs. Least cost size rises with the quality characteristics of the desired program and the transported student density.


T: Argues that previous research has generally ignored the impact of transportation costs on potential size economies.
M: 1) Administrative costs/average daily attendance (ADA) = f [eleventh grade composite achievement score (ACH), pupil-teacher ratio (PTR), PTR², 1/ADA].
2) Plant operations and maintenance costs/ADA = f (ACH, PTR, PTR², ADA, 1/ADA).
3) Facilities costs/ADA = f (ADA, 1/ADA).
E: OLS on separate cost components. Individual components are added to obtain cost curve.
R: The average cost curve is U-shaped with a minimum at 675 pupils, although relatively flat between 400 to 1100 pupils. The cost curve is shown to vary with pupil densities and the desired level of educational quality.


T: Uses conventional economic theory to develop the estimated cost curve.
D: 108 high schools in Kansas. Kansas State Dept. of Public Instruction.
M: Cost of school plant operation per pupil = f (per pupil assessed valuation of property, average daily attendance, valuation of school furnishings and equipment, valuation of school buildings).
E: Simple corrections and simple regressions.
R: Higher per pupil costs were found for small schools. Schools below 100 had particularly high per pupil costs. High costs resulted from high pupil-teacher ratios.

ELECTRIC POWER GENERATION


T: Examines the implications of output per unit of input technique for measuring productivity changes.
M: Output per unit of cost = f [installed generating capacity, load factor (Kwh produced in 1959 per installed Kwh)]. All variables are estimated in logarithms.
E: OLS.
R: Economies of scale are found. Concludes that 23 percent of the increase in productivity over the sample period is due to increased plant size and 18 percent to increased load factor. Also concludes that 48 percent of the increase is due to increased customer size.


T: Contains a discussion of the features of the translog cost function.
M: Ln costs = f (ln output, ln output^2, ln of prices of capital, labor and fuels, ln interaction between prices, ln output X price). Six variations on this equation to examine homotheticity, homogeneity, and unitary elasticities of substitutions.
E: Maximum-likelihood estimators from a multiple equation multivariate regression system.
Scale economies are found to diminish with firm size and are generally exhausted within the range of firms examined. Concludes that production costs fell during 1955-70 because of technical innovations, not scale increases. Evidence is found that scale economies are overestimated by ordinary least squares.


Develops a generalization of a constant elasticity of substitution production function.

362 electric generating plants constructed during 1937-59. Each plant serves as an observation in the year after construction.

Output = f (fuel, capital). Regression estimates are obtained for four different time periods and for four size classes of firms.

OLS, 2SLS.

Increasing returns to scale are generally available. Finds increasing returns to scale are generally more homogeneous over size classes for the final time period (1955-59) than for any other period.


Discusses cost curves, including the problems of capital durability and peak load demand.


Expense/Kwh generated and received = f [log steam capacity, (log steam capacity)^2, utilization of total capacity, (utilization of total capacity)^2, dummy variables for geographic location, fuel cost, wage cost, percent coal BTUs, percent oil BTUs, percent nuclear capacity, percent hydro capacity, percent gas turbine capacity, dummy variable for holding companies, underground circuit miles/1000 customers, structure miles/1000 customers, type of consumer, number of line transformers/customer, average use per type of consumer]. Different combinations of the variables above were used as regressors for production expense, transmission costs, distribution expense, administrative and general expense, customer accounts expense, and sales expense.
A U-shaped long run average cost curve is found for production, distribution, administrative and general, customiers account, and total operating expenses. Minimum point of the cost curve is 1600 MW for total operating costs and 3100 MW for fixed investment. No significant scale economies for transmission and sales expenses.


Evaluates the mathematical formulations of cost-output relationships.

Ministry of Fuel and Power, *Engineering and Financial Statistics*, annual volumes. Forty stations in Great Britain. Seventeen firms had no change in capital stock; 23 had changes.

Total deflated working expenses = f [annual output, (annual output)^2, time].

Time series OLS for each firm, using between 13 to 20 years.

Finds constant marginal cost and average cost for the short run. In the long run, average cost falls for small levels of output but becomes constant for the rest of the output range.


N/A

Not published.

N/A

Simulation.

Appear to be economies of size which have not been fully attained.


Uses conventional economic theory to develop the estimated cost curve.

Uses steam generators of a certain size and a certain age, using either coke or coal.

M: Log costs per unit generated = f (log capacity of the generators, log load factor).

E: OLS.

R: Economies of scale are found in electricity generation.


T: Discusses the impact of tax exempt State and local government borrowing on the cost of municipality provided electricity.


M: N/A

E: Inspection.

R: Concludes that there would be substantial economies associated with small municipalities purchasing power from larger power systems rather than producing power themselves.

**FIRE PROTECTION**


T: Uses conventional economic theory to develop the estimated model.

D: Cities and fire districts in Seattle-King County, Wash.

M: Expenditures per capita = f (population, area, assessed value, percent of housing lacking plumbing, adjusted wage index, fire insurance rating index, number of aid cars, number of volunteers, number of fire stations, number of full-time personnel, dummy variable for combination paid-volunteer fire department and for all paid, interaction terms). All variables estimated in log form.

E: OLS. Scale economies examined by increasing all independent variables by a given percentage and seeing what happens to costs.

R: Decreasing returns to scale for volunteer and paid volunteer departments. Constant returns to scale for fully paid departments.

T: Uses conventional economic theory to develop the estimated cost curve.


M: Cost = f (output, full value of property per capita, population per $10,000 full value unit of property, total property taxes collected in 1966-67 per unit of property value protected, full paid versus other fire department manpower arrangements, average monthly salary for fire-fighters or hosemen in 1969, intergovernmental revenue received in 1966-67 per capita, intergovernmental revenue received in 1966-67 per unit property value protected, population protected per square mile, full value of property protected per square mile, total A/A deficiency points assessed for adverse climatic conditions, total A/A deficiency points assessed for unusual occurrence, percent of commercial property protected, percent of structures built in 1939 or earlier, percent of black population in 1960, percent of population of Mexican foreign stock in 1960, percent population of German foreign stock in 1960). Cost is defined as: 

\[ C_1 = \text{cost adjusted 1969 fire department operating costs; } \]
\[ C_2 = C_1 + \text{annual charge for capital; } \]
\[ C_3 = C_2 + \text{annual charge for volunteer effort; } \]
\[ C_4 = C_3 + \text{annual charge for water supply; } \]
\[ C_5 = C_4 + \text{private fire insurance costs estimated from projected premiums; } \]
\[ C_6 = C_4 + \text{private fire insurance costs estimated from key rate and property value data}. \]

Output is defined as: 

\[ O_1 = \text{population protected in 1969; } \]
\[ O_2 = \text{full value of property protected in 1968}. \]

E: OLS.

R: Finds evidence of size economies with most economies exhausted for populations greater than 10,000.


T: Discusses issues of the need for services and measurement of services provided.

39
D: Thirty-eight central cities of 50,000 or more. Committee on Fire Department Equipment, **Specifications for Motor Fire Apparatus**.

M: Dollar cost of providing standard units of effort/population = f (1/population).

E: Calculates costs of providing standard units of efforts, then uses OLS.

R: Finds a hyperbolic relationship between cost and population with significant economies to populations of approximately 300,000.

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HOSPITALS


T: Contains chapters on hospital output, productivity, and costs of hospital operations. Reviews the literature on hospital economies of scale studies. Theoretically, economies of scale should exist, but empirically the issue is not settled.

D: N/A

M: N/A

E: N/A

R: N/A

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T: Discusses the meaning of economies of scale and the difficulties associated with testing scale economies when product differentiation exists.

D: American Hospital Assn. Includes 5,293 of the 5,684 nonfederal, short-term general, and other special hospitals registered in 1963. Hospitals are categorized according to whether they offer 28 facilities and services.

M: Average cost = f (total patient days). Runs regressions for 40 different groups of hospitals which provide the same services.

E: OLS.

R: Finds significant economies of scale for 26 of the 40 groups examined.

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T: Discusses the impact of various internal and external costs on the total costs of hospital services.


M: Adjusted total cost = f (patient days, patient days², patient days times the number of facilities available, existence of a professional nursing school, number of interns and residents, number of facilities, number of outpatient visits, number of student nurses, affiliation with a medical school, number of types of internship and residency programs offered). Total costs were adjusted for wage differentials. Regression estimates were obtained for the entire sample and for five separate groups based on services provided.

E: OLS.

R: For the entire sample, a U-shaped average cost curve is found with a minimum of 190 average daily census. When grouped by services, the hospitals generally exhibited economies throughout the observed range. Only the largest hospitals with the greatest number of services had diseconomies.


T: Develops a system for weighting output based on average cost of production.

D: Forty-six New York hospitals which are members of the United Hospital Fund of New York, 1965. Twenty-five hospitals returned usable questionnaires.

M: Total cost = f (weighted index of output²), Total cost = f (patient days²).

E: OLS.

R: Economies of size are found with the minimum average cost between 540 and 790 beds.


T: Develops an adjusted cost measure using relative starting salaries in the hospitals and implements an output index based on the relative average cost of services.

M: 1) Total costs = f (output, output²) estimated for 23 New York City hospitals.
   2) Adjusted costs = f (output, output²) estimated for all 53 hospitals with costs adjusted for wage differentials.

E: OLS.
R: Finds a U-shaped average cost curve with a minimum at 290 to 295 beds for New York City. The cost curve is also U-shaped for all hospitals with a minimum at 160 to 170 beds.


T: Includes an analysis of ways to measure costliness and different types of casemixes.


M: 1) Cost per case (C) = f (number of beds (B)).
   2) C = f (B, B²).
   3) C = f [B, measure of the case mix (CM)].
   4) C = f (B, B², CM).
   5) C = f (B, B², CM, case flow).

E: OLS, instrumental variables.
R: Fails to find a significant relationship between size and unit costs. However, with case flow held constant, finds a U-shaped average cost curve with a minimum at 905 beds. Concludes that medium size hospitals of 300 to 500 beds are at least as efficient as larger hospitals.


T: N/A


M: 1) Average costs per patient day = f (patient days).
   2) Average cost per patient day = f (percent occupancy, patient days, number of services, dummy variable taking value of 1 if an SMSA, interaction terms).

Hospitals are divided into 25 groups according to services offered. Regressions are estimated by groups.

E: OLS.
R: Finds economies of scale for hospitals with few services and up to 70 to 150 beds. Constant returns are found for larger hospitals.


T: Uses conventional economic theory to develop the estimated cost curve.
D: Seventy-two Massachusetts hospitals in 1959, ranging in size from 31 to 332 beds. Hospital Statement for Reimbursement.
M: Cost/available bed days = f (number of nursing personnel employed per bed day, number of available bed days, occupancy rates, total nursing personnel, number of nursing students, distribution of personnel by type or category).
E: OLS, factor analysis.
R: Does not find economies of scale.


T: Reviews the hospital literature up to 1964. Concludes that a U-shaped average cost curve is plausible.
D: N/A
M: N/A
E: N/A
R: N/A


T: Surveys techniques for measuring and analyzing hospital costs. Reviews some literature on important factors in hospital cost variations.
D: N/A
M: N/A
E: N/A
R: N/A

Reviews some literature on hospital cost functions, production functions, and supply of services.


T: Includes a discussion of hospital cost functions.


M: Average costs this period/mean average cost for 14 periods = f (utilization rate/mean utilization rate over 14 periods, size/mean size for 14 periods, dummy variable for teaching status, dummy variable for advanced teaching, average cost, utilization rate, dummy variable for urban, rural, or Pittsburg location, dummy variable for first or second half of year). Different combinations of the variables were included in estimated equations.

E: OLS.

R: Minor if any economies of scale were indicated.


T: Uses conventional economic theory to develop the estimated cost curve.


M: Cost per patient = f (large number of variables including size, 14 other cost variables, and 17 diagnostic variables).

E: OLS. Uses principal components analysis, clustering with principal components and clustering on estimated marginal costs to separate diagnostic variables into five groups.

R: Concludes that aggregating the case-mix variables is important and the estimated marginal cost approach provides the best set of aggregate variables. Finds statistically significant economies of size, but savings from increased size are minor.

T: Reviews empirical research on hospital costs. Concludes that issue of scale economies has not been settled.
D: N/A
M: N/A
E: N/A
R: N/A


T: Uses conventional economic theory.
M: N/A
E: Observation of average data.
R: Observes that larger, short-term hospitals have higher costs per day and per case. Concludes that these higher costs are probably a result of different case mixes and services offered.


T: Discusses the relationships between variables which impact hospital costs.
M: 1) Inpatient expenses per patient day = f (admissions, births, patient days, number of beds, medical education, nursing education, occupancy rate, pressure index, turnover rate, ancillary services/patient care expenses, patient care/inpatient care, labor wages/patient days, X-ray usage/patients days, anesthesia usage/patient days, delivery room usage/patient days, length of stay, operating room usage/patient days, number of facilities, patient days/personnel, wage rate, payroll/operating expenses, personnel/beds, percent of urban population, household income, outpatient expenses/total hospital expenses).
   2) Inpatient expenses per admission = f (same as equation one).
E: OLS pooled data. Stepwise OLS is used to select the appropriate variables to be included.
R: Economies of scale are found to exist over the size range of hospitals analyzed (36 to 794 beds).

T: Discusses the importance of considering political participation and population change in determinants analysis.


M: Per capita expenditures = f (log population change, population, log population density, log crime rate, percent teachers, percent professionals, percentage in crafts, percentage in services, percent age 22 to 39, percent over 55, percent employed in industry, employed in commerce/1970 population, per capita equalized tax base, per capita payments by the municipality for pensions, debt served). Estimated separately for four city population size classes.

E: OLS.

R: Economies of size are only found for the smallest class of city size (600 to 2,000 residents).


T: Uses conventional economic theory to develop the estimated model.


M: 1) Recorded offense rate = f (percent of convicted given custodial treatment, percent of young males (15 to 24) in population (A), percent of population that is working class (S) total rateable value per area, total police expenditure per officer, recorded clearup rate (P), number of policemen per capita (C).
2) \( P = f(A, S, C, \text{population, proportion of offenses that are violent (V)}) \).

3) \( C = f(\text{proportion of population that is middle class, V, population density}) \).


E: Full information maximum likelihood estimates.

R: Infer diseconomies from finding that the recorded clearance rate was negatively associated with population.


T: Develops a property crime function with output measured by preventive and punitive police protection. This is used to obtain a production function.


M: Police output = \( f \) (motorcycle teams, field officers, nonfield officers, civilian employees, exconvicts, dummy variable for after 1965).

E: OLS; variables were transformed with a serial correlation coefficient.

R: Concludes that there are increasing returns to the police agency as a whole.


T: Uses conventional economic theory to develop the estimated model.

D: 754 cities with population 25,000 to 1 million. Uniform Crime Reports, 1967-68.

M: 1) Crime rate = \( f \) (per capita police numbers, population size, percent nonwhite, median income, population density, median age of population, percent male, dummy variable for region of country, size-police interactions).

2) Per capita police = \( f \) (per capita police last period, last period crime, population size, percent nonwhite, median income, population density, median age, percent males, dummy variable for region of country).
E: Recursive least squares, then finds social cost of crime.
R: Finds a U-shaped social cost of crime curve with a minimum point in the 250,000 to 500,000 population range.


T: Discusses hypotheses related to the claims for consolidation.
M: N/A
E: Correlation coefficient, inspection of average costs.
R: When quality is taken into account, finds per capita expenditures positively associated with city size.


T: Develops a measure of total costs of police services based on crime prevention expenditures and unrecovered losses from criminal activity.
M: Average cost = f (population, population², density, percent nonwhite, percent 65 and over, percent living in urban areas, percent foreign born, migration rate, percent of workers in manufacturing, mean annual temperature, unemployment rate, median income, percent of population earning less than $3,000).
Model run for total cost/population, police expenditure/population, unrecovered loss/population, for seven types of crime.
E: OLS.
R: Concludes that police services are subject to diseconomies of scale because per capita total costs rise with population. A U-shaped relationship is found between population and expenditures per capita.

T: Discusses nine hypotheses related to the determinants of police expenditures and reviews much of the literature. Notes that studies have found either a positive or no relationship between city size and per capita police expenditures. Discusses the inapplicability of determinants studies for examining economies of scale.

D: N/A
M: N/A
E: N/A
R: N/A


T: Uses conventional economic theory to develop the estimated cost curve. Develops an index of police services from three input measures.


M: Average cost = f [service index, (service index)^2, population density, police officers/population, cleared offenses/total offenses, wages paid recruits, land area]. Regressions are estimated for 1958 and 1960.

E: OLS.

R: Does not find a significant relationship between per capita expenditures and population. Concludes that economies of scale exist because average costs have a U-shaped relationship with the service index.

REFUSE COLLECTION


T: Uses conventional economic theory to develop the estimated cost curve.

Budgeted expenditure per pickup unit = f (yearly collection frequency, combined or separate pickup, pickup location, crew size, residential pickup units per square mile, nature of financing arrangement).

Stepwise OLS.

Finds that yearly collection frequency is positively related with per unit costs.


Uses conventional economic theory to develop the estimated cost curve.

Fifty-three of 93 suburban municipalities in St. Louis county, not including St. Louis central city. Collection systems from under 500 to 11,000 units. Interviews with city officials and private haulers.

Costs per unit = f (log of number of pickup units, three dummy variables for type of system, pickup location, pickup frequency, direct user billing, contract type system).

Observation, OLS, and Beta weights.

Finds economies of scale with benefits accruing at a decreasing rate.


Uses conventional economic theory to develop the estimated cost curve.

Random sample of 32 rural communities in Texas, populations 500 to 25,000. Questionnaire and personal interviews.

Total costs = f (population², number of residences, number of commercial and industrial residences).

OLS.

Significant economies of size were found to exist until the community reaches 9,600 population.


Develops an ideal average cost curve.
D: Twenty-four municipalities in St. Louis. Questionnaire data.

M: Average annual residential refuse collection and disposal cost per pickup = f [number of pickup units, (number of pickup units)^2, weekly collection frequency, dummy variable for pickup location, pickup density, nature of contractual arrangement, type of financing].

E: OLS.

R: Inconclusive results but does not find economies of scale.


T: Develops an average cost curve based on an identity and some behavioral assumptions.


M: Average cost = f (type of service, effective density, frequency of pickups, scale). Estimated separately for municipalities, contract refuse collection, and private refuse collection.

E: OLS.

R: No evidence of scale economies is observed.


T: Discusses theoretically sound output and cost measures.


M: Total cost/population = f (population, population^2, dummy variable for pickup location, separation of garbage and trash, population density, average snowfall, miles traveled per week to disposal sites, payment method, collection frequency, collection from multiple-unit dwellings, labor cost per truck per week, specialized collection vehicles, average vehicle capacity, persons per family, special containers, topographic variation, nature of contractual arrangement, proportion of refuse attributable to residential only pickups).

E: OLS.

R: Finds a statistically significant inverted-U-cost curve. Concludes that diseconomies exist until a city reaches a large size.

T: Discusses a game theoretical approach and derives characteristic functions with several different fixed costs for the transfer station. Is concerned with the selection of the most efficient service points for solid waste collection and disposal in order to take advantage of scale economies.


M: N/A

E: Game equivalent of nonlinear assignment model.

R: Argues that each region must be dealt with separately. The problem is one of finding an optimal partition of the area and a financing scheme to provide all parties with an incentive to join. Market-based pricing will not support an optimal partition into service areas.


T: Studies the provision, organization, political, and legal characteristics, and costs of solid waste services.

D: Survey of 2,060 cities. Cost studies are based on 340 cities.

M: N/A

E: N/A

R: Significant economies of city size to 20,000 population and lesser economies to 50,000 population. Constant costs are found through the remaining range studied (750,000 people).


T: Discusses the efficiency of private versus public provision of refuse collection. Concludes that government monopoly should be the least cost market structure if it operates efficiently. Develops a cost equation based on a Cobb-Douglas production function.

D: 340 public and private firms servicing 2,500 to 700,000 people. Unpublished data, 1974-75.

M: Total cost to the households served for refuse collection = $f$ (monthly wages paid to a refuse collector, total
quantity of refuse collected per year, dummy variable taking the value one if market structure is private monopoly and zero otherwise, dummy variable taking the value one if market structure is competitive and zero otherwise, one plus the number of collections per household per week, one plus the percentage of households serviced by the firm at backyard collection points, number of households per square mile, difference between mean July and mean January temperatures). All variables estimated in log form. Estimated separately for cities under 20,000 population, under 30,000 population, under 50,000 population, and over 50,000 population.

E: OLS, 2SLS.

R: Economies of scale are found for cities up to 20,000 population. Some economies are suggested for cities with 20,000 to 50,000 population. Constant returns are indicated for populations above 50,000. Public monopolies are significantly more costly than private monopolies in cities over 50,000 population. Monopoly refuse collection services are less costly than competitive.

T: Uses conventional economic theory to develop the estimated cost curve.


M: Total cost = f (square miles of area, miles of road per square mile of area, miles of gravel roads per square mile of area, miles of paved roads per square mile of area, measurement of wealthy vehicles registration, population^2, population^4, quality of road, precipitation). County and noncounty are run separately.

E: OLS.

R: Found a U-shaped average cost curve for noncounty roads and an inverted U-shaped average cost curve for counties. Minimum average cost for noncounty roads is at about 800 square miles of area. County highways tend to reach their highest cost for counties with 800 square miles of area and costs fall to at least 1,400 square miles of area.


T: Uses conventional economic theory to develop the estimated cost curve.


M: 1) Total cost = f [road mileage (RM), RM^2, annual snow fall (S_1), number of days with two or more inches of snow (S_2), number of days with five or more inches of snow cover (S_3), motor vehicle registrations per square mile (MV), population density (PD), annual precipitation in inches (P), full value of real property (FV), number of bridges (CB), quality index of county roads (Q), typographic index for county roads (T), dummy if county has public works department (DV)].

2) Maintenance cost = f (CB, FV, MV, P, PD, Q, RM, RM^2, T).

3) Administrative cost = f (DV, FV, MV, PD, Q, RM, RM^2).

4) Snow removal costs = f (FV, MV, P, PD, RM, RM^2, S_1, S_2, S_3, T).

E: OLS, insignificant variables omitted.

R: Significant economies were found up to 400 miles of county roads, up to 590 miles for highway maintenance, and up to 490 miles for snow removal. Administrative costs have a U-shaped average cost curve with a minimum at 465 miles.

T: Uses conventional economic theory to develop the estimated cost curve.
D: Illinois Division of Highways (1953-54).
M: Costs = f (miles of eight types of roads, assessed property valuation). State is divided into the nine operating units for Division of Highways. Estimated separately for construction, maintenance, and administrative costs.
E: OLS.
R: Significant size economies were found for each cost component throughout the entire range analyzed. The largest area had 600 miles of highway and the biggest construction project involved 10 miles.

**WATER AND SEWER UTILITIES**


T: Uses conventional economic theory to develop the estimated cost curve.
M: 1) Total cost = f (total gallons produced, number of customers).
   2) Average cost = f (total gallons produced, number of customers). Estimated in log linear form.
E: OLS.
R: Finds significant size economies associated with increasing water consumption for a fixed set of users. However, the necessity for increased water main mileage which occurs when more locations are serviced offsets any economies from increased quantity of water.


T: Conceptually evaluates cost curves and discusses the use of replacement cost data instead of accounting data.

M: N/A

E: Estimates minimum point of short run average cost curve for each water works. Long run average cost curves are estimated by connecting the minimum points of the short run curves.

R: All short run curves reflect economies of scale. The overall long run average cost curve is U-shaped.

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T: Uses conventional economic theory to develop the estimated cost curve.


M: Costs = f (water flow; water flow^2; water source, turbidity, number of treatments, number of employees, number of manufacturing plants, population density, hardness removed).

E: OLS.

R: Finds declining marginal and average costs with significant savings to 50,000 population. The cost curve differs for surface and ground water.

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T: Uses conventional economic theory to develop the estimated cost curve.

D: Unpublished. 246 water authorities in Pennsylvania.

M: Log total utility cost per million gallons of water sold = f (log total number of customers served, log total water sold, proportion of total expenses that are nonoperating, dummy variables for surface water, advanced treatment, served metered residential customer, served metered commercial customer, served metered industrial customers, and served other metered customers, plus interaction terms among last seven variables and first two variables).
E: OLS.
R: Small-size economies for surface water if customers served and water sold increased at the same rate. Economies increase if the water sold increases more rapidly than the number of customers. No size economies for ground water unless the water sold increases at a faster rate than the number of customers.


T: Uses conventional economic theory to develop the estimated cost curve.
D: 62 systems in Louisiana.
M: Fixed costs = f [number of users, (number of users)^2, density of users, (density of users)^2, dummy variable for treatment, dummy variable for storage type]. Variable costs and total cost also are used as dependent variables for same equation.
E: Stepwise regression.
R: Size economies are found for fixed and total costs. The variable cost curve has a U-shape.


T: Includes a discussion of the meaning and usefulness of discriminant analysis.
D: Twenty-two activated sludge plants, 1965. Indiana Stream Pollution Control Board.
M: Included work load of suspended solids, work load of BOD, millions of gallons treated, percent capacity utilized, percent suspended solids removed, percent BOD removed.
E: Discriminant analysis.
R: Larger plants were found to have lower average costs.


T: Uses conventional economic theory to develop the estimated cost curve.
D: Sewage treatment plants in continental United States, 1956-63.
M: Log costs per unit = f (log number of units). Analyzes costs per population, per population equivalent including commercial and industrial demand and per unit flow.

E: OLS.

R: Finds a downward sloping average cost curve for all types of plants examined.


T: Uses conventional economic theory to develop the estimated cost curve.

D: Fifty-two U.S. cities. Questionnaire.

M: Total treatment costs = f (wastewater flow, index of treatment level, proportion of capacity used, price of labor, price of capital, price of electricity). All variables run in logs.

E: OLS.

R: Costs are found to decrease as flow through the facility increases for both land and conventional technologies.
APPENDIX A—AUTHOR INDEX

Numbers following author’s name refer to page numbers in the text.

Advisory Commission on Inter-governmental Relations, 8, 9
Ahlbrandt, Rogers, Jr., 38
Alesch, D. J., 5
Andrews, Richard A., 55
Alesch, D. J., 5
Andrews, Richard A., 55

Baker, David G., 9
Baritelle, John L., 24
Barzel, Yoram, 35
Beaton, W. Patrick, 46
Berk, Sylvester E., 40
Berry, Ralph E., 40
Biere, Arlo W., 10
Bourcier, David V., 55
Breton, Albert, 5
Brinkman, George L., 8
Brown, Byron W., 19

Carlson, Gerald A., 58
Carr, W. John, 41
Carr-Hill, R. A., 46
Chapman, Jeffrey I., 47
Christensen, Laurits R., 35
Clark, Robert M., 49
Cohen, Harold A., 41
Cohn, Elchanan, 19, 20
Colby, David P., 9
Collins, John N., 50
Cosgrove, Michael H., 56
Cowing, Thomas C., 5

Daugherty, Arthur B., 56
Dawson, Donald A., 20
Day, Lee M., 6
Debertin, David L., 21
Denzau, Arthur T., 21
Dhrymes, Phoebus J., 36
Dougherty, L. A., 5
Downes, Bryan T., 50

Emerson, Robert D., 13
Erickson, Donald B., 10
Feldstein, Martin S., 42
Feldstein, Paul J., 41
Forste, Robert H., 55
Francisco, Edgar W., 42
Gabler, L. R., 10, 11
Gardner, John L., 11
Garland, George A., 49
Goishi, F., 29
Gray, John Michael, 27
Greene, William H., 35
Grupenhoff, Betty L., 49

Hady, Thomas F., 6
Hall, J. Patrick, 50
Hambor, John C., 21
Hamilton, Joel R., 12
Hanson, Nels W., 22
Herald, Polly, 27
Henderson, James M., 12
Hettich, Walter, 23
Hickrod, Alan G., 30
Hind, Ian W., 23
Hirsch, Werner Z., 6, 7, 12, 24, 47, 50
Hitzhusen, Frederick J., 39
Hobgood, W. P., 57
Holland, David W., 24
Holtman, A. G., 5
Hoover, Edgar M., 52
Huettnner, David A., 36
Hushak, Leroy J., 56

Ingbar, Mary Lee, 43
Jansma, J. Dean, 56
Johnson, Gary P., 25
Johnson, R. B., 57
Johnston, J., 7, 37
Jones, Lonnie L., 50
Junk, Paul E., 38

Katzman, Martin T., 25
Kemper, Peter, 51
Kiesling, Herbert J., 26
King, Richard A., 27
Kirchmayer, L. K., 37
Kitchen, Harry M., 51
Klarman, Herbert E., 43
Klee, Albert J., 49
Kurz, Mordecai, 36

Lamb, Steven W., 53
Landon, John H., 36
Lave, Judith R., 43, 44
Lave, Lester B., 43, 44
Lesher, William G., 54
Levy, Mickey, 28
Loehman, Edna T., 13
Lomax, K. S., 37

Mann, Judith K., 45
Mapp, Harry P., 54
Marsden, James R., 57
McNamara, James F., 32
Mellor, A. G., 37
Michelson, Stephan, 27, 28
Millstein, Eugene, 27
Morris Douglas, 14, 47

Neuhauser, Duncan, 45
Neutze, G. M., 16
Niskanen, William, 28

Ochs, Jack, 52
Ogburn, W. F., 16
O’Mara, J. F., 37
Osburn, Donald D., 28, 29
Ostrom, Elinor, 48

Parks, Roger B., 48
Perkinson, Leon B., 29
Peston, M. H., 7
Phillips, H. S., 16
Phillips, Lid, 21
Pidot, George B., Jr., 17
Pine, Wilfred H., 34, 53
Pingry, David E., 57
Popp, Dean O., 48

Quigley, John M., 51

Reid, Richard, 12
Renne, Roland R., 17
Renshaw, Edward F., 8
Richardson, Harry W., 8

Ricker, William D., 29
Riew, John, 20, 30
Ro, Kong Kyun, 45
Rosenberg, Neal E., 30

Sabulao, Cesar M., 30
Savas, E. S., 52
Schmandt, Henry J., 17, 18
Scott, Eric J., 49
Sebold, Frederick D., 48
Shapiro, David, 31
Shapiro, Harvey, 18
Sher, Jonathan R., 31
Silverman, Lester P., 44
Sjo, John B., 10
Sonenblum, Sidney, 47
Stemnock, Suzanne K., 32
Stephens, G. Ross, 17, 18
Stern, N. H., 46
Stevens, Barbara J., 52, 53
Stevenson, J. R., 37
St. Louis, Larry, 32
Swanson, Earl R., 55

Taylor, Lester D., 43
Tiebout, Charles M., 8
Tompkins, Rachel B., 31
Turcotte, Fernand, 45
Tweeten, Luther, 8, 33, 34, 47
Tyner, Fred H., 29

U.S. Dept. of Health, Education, and Welfare, 57

Voelker, Stanley W., 19
Votey, Harold L., Jr., 21

Wales, Terence J., 32
Wall, G. Bryan, 27
Wallace, Richard L., 38
Walzer, Norman, 49
Welch, Finis, 33
Whinston, Andrew, 57
White, Fred, 33, 34
Whitney, Barbara J., 43
Will, Robert E., 39
Wright, Willard A., 34

Yett, Donald E., 45
Young, C., Edwin, 58
APPENDIX B—BIBLIOGRAPHY OF RELATED TOPICS


