THE DEMAND FOR WASTEWATER TREATMENT FACILITIES IN RURAL MINNESOTA COMMUNITIES.

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

BY

BARRY MARTIN RYAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTERS OF SCIENCE

MARCH 1988

Acknowledgements

Special thanks to Tom Stinson for his guidance and encouragement throughout this study. Also to Bill Easter and Ed Foster for their committee time and valuable comments. And finally to the staff of the Minnesota Pollution Control Agency for the courteous assistance.

THE DEMAND FOR WASTEWATER TREATMENT FACILITIES IN RURAL MINNESOTA

CHAPTER 5 REVIEW OF THE EMPIRICAL LITERATURE

CHAPTER 6 DATA AND ESTIMATION METHODS

CHAPTER 7 FINDINGS AND CONCLUSIONS

APPENDIX A - STATISTICAL METHODS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

The condition of America's sewage treatment infrastructure and the effectiveness of government programs designed to stimulate their production are questions of significant social and economic importance. Public health and community development are dependent on adequate sewage treatment facilities, yet across America rural communities are falling short of the investment needed to conform with the goals set by the federal Clean Water Act. A recent study put this investment backlog in rural facilities at $20.2 billion, or about one third of the nation's entire need. In the State of Minnesota, rural communities require some $328 million in capital spending. Again, about a third of the states estimated $1.09 billion backlog.

Public policy goals have been clear from the start -- protect and preserve the nations waterways; ensure affordable, cost effective pollution abatement; and provide adequate funding for communities not in compliance with water quality standards. Implementation of the policy has been less clear, and many unanswered questions remain about who will pay to eliminate the backlog and how.

The Federal government, with its many categorical programs targeting local government services, has long been a dominant force in public sector finance. Many of these programs, however, are now being reduced or eliminated, and the responsibility for funding community services has shifted back to state and local governments. The Reagan administration's new federalist philosophy and deficit reduction pressures have changed the structure of intergovernmental fiscal relations. Tighter budgets and an increased demand for services are a fact of life at all levels of government. This is particularly true in small, rural communities.

Rural sewage treatment needs bring together many of the equity and efficiency arguments economists make in favor of government intervention. These two tenets of public finance call for fair economic treatment across society, and best resource use at the margin. Pollution control on a small scale raises the efficiency questions of externalities, public goods, and decreasing cost monopolies. Equity, and the implicit right to clean water, become social issues when small, and low income rural communities are involved.

Solutions to these problems have focused largely on the use of intergovernmental grants designed to stimulate local demand through changes in project prices or in community income. A better understanding of how changes in these, and others factors, affect local expenditures on sewage treatment will greatly improve the likelihood of successful policy solutions.

This study examines the sewage treatment expenditure decisions of rural Minnesota communities. The goal is to estimate the likelihood that communities who have yet to make needed capital improvements will do so, given changes in price, income, and other factors determining expenditures. The paper proceeds as follows. Federal, state, and regional grant programs available to Minnesota communities for sewage treatment projects are summarized in chapter two. Chapter three provides the economic rationale for government intervention in the marketplace for rural sewage treatment services. Public choice and intergovernmental grants are examined in chapter four. Five is an empirical review of six relevant studies. Data, sampling, and estimation methods are all discussed in chapter six. Actual estimates and the implications of those findings are outlined in chapter seven.

CHAPTER 2. WASTEWATER TREATMENT CONSTRUCTION GRANT PROGRAMS

Five separate government programs are available to support public wastewater treatment facility construction in Minnesota. These grants-in-aid change the community's price for a project, and hence the demand for public facilities. It is important, therefore, to understand these programs, their funding levels, and cost-sharing mechanisms before modeling the decision making environment in rural communities.

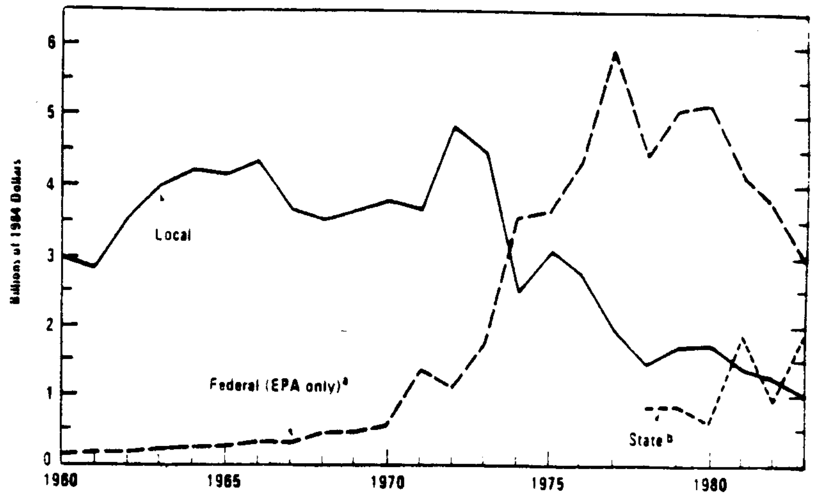
This chapter reviews those state and federal programs which impact public sewer system construction. The Environmental Protection Agency, and Farmers Home Administration each administer a federal program. While the state operates three of its own, primarily for economic development, through the Legislative Commission on Minnesota Resources, the Department of Energy and Economic Development, and the Iron Range Resources and Rehabilitation Board.

Environmental Protection Agency.

About 3% of the total 1984 federal budget, or 18% of the non-defense discretionary budget, went to public works programs. Just over 11% of all federal infrastructure outlays, some $3 billion, was spent on wastewater treatment capital construction. The Environmental Protection Agency's Construction Grants Program is far and away the largest source of aid for facility construction, accounting for 87% of 1984's $3.0 billion outlay.

The Federal Water Pollution Control Act (FWPCA) of 1956, first authorized the federal grants to local governments for construction of sewage treatment facilities. The level of aid was initially set at 30% of construction costs, and appropriations in fiscal year (FY) 1957 were only $50 million. After being amended for the third time in 1966, the basic federal grant under FWPCA increased to 40%, provided the states contributed at least a 25% matching grant themselves. If states enforced water quality standards an additional 10% subsidy also became available. Appropriations in FY67 reached $150 million. Landmark revision of the law in 1972, commonly known as the Clean Water Act (CWA), changed water pollution abatement efforts dramatically. Federal contributions went to 75% of all eligible costs. Appropriations jumped to $2 billion in FY73, and peaked at $9 billion in FY76. Outlays peaked the following year, and have fallen steadily since (figure 2.1).

The CWA was amended again in 1977, to include an additional 10% subsidy when innovative or alternative treatment technologies were employed, but appropriations fell to $1 billion. Program shortfalls were acknowledged with the 1981 CWA amendments, and significant program changes were made. The federal share of construction costs were reduced from 75% to 55%. Eligible need categories were limited to the basic or core system components. Funding levels were reduced from the previous $4 to $6 billion annual appropriation range, to $2.4 billion.



SOURCE Congressional Budget Office from data in *Historical Tables, Budget of the United States Government*, and in Department of Commerce, Bureau of the Census, *Annual Survey of Government Finances.*

[a] Excludes spending by Department of Housing and Urban Development, Farmers Home Administration, and Economic Development Administration

[b] Data for spending on wastewater treatment by states before fiscal year 1978 are not available

Figure 2.1 - Wastewater Treatment Capital Outlays By All Governments Fiscal Years 1960-1983

The latest amendments to the Clean Water Act were approved in January 1987, amid a power struggle between Congress and the White House over fiscal responsibilities and funding priorities. Nearly unanimous support over-rode the President's veto in a reaffirmation of bipartisan environmental concerns. Congress authorized $20 billion in program spending, well above the administrations $12 billion proposal. Yet the compromise to emerge -- an 8 year phase out of EPA's construction grants program, instead of the Administrations 4 year proposal -- results in a withdrawal of direct federal support for sewage treatment facility construction.

Over the next 4 years, $9.6 billion will be spent on the traditional EPA construction grants program, while $8.4 billion will be available in fiscal years 1990 through 1994 to establish state revolving infrastructure funds. Just over $2 billion is earmarked for special projects, such as lake restorations. By 1995, state and local governments will be completely responsible for financing, building, maintaining, and operating municipal sewage treatment systems.

Minnesota Pollution Control Agency.

The Clean Water Act also requires state government participation in implementing the EPA Construction Grants program. Under federal guidelines, states set spending priorities, oversee planning and construction, and enforce water quality standards. Forty states, including Minnesota, provide financial assistance to offset the non-federal share of community project costs. Since 1957, Minnesota has received over $920 million in federal funds for municipal treatment, while the state has contributed another $202 million.

Between 1972 and 1984, Minnesota communities participating in the EPA program could reduce their cost of facility construction by at least 90%. Qualifying projects got the basic 75% federal matching grant, plus a 15% subsidy from the state. Where the federal 10% subsidy for innovative and/or alternative technology (I/A) applied, the state share went to 9%, leaving the community with only 6% of the projects eligible costs.

In 1985, the basic federal grant fell to 55% with the option of an additional 20% from I/A uses. Minnesota's cost sharing mechanism changed as well, from a fixed percentage to a sliding scale based on financial hardship. Up to 15% of a projects eligible costs may now be paid by the state. This means, of course, that 30-45% of eligible costs alone (not total costs) must be paid by the local government.

Recognizing the diminishing federal role in financing treatment systems, Minnesota devised its own construction grants program. Established in 1984 by the Legislative Commission on Minnesota Resources (LCMR), this program is also administered by the Minnesota Pollution Control Agency. Funding is derived through an excise tax on cigarettes, and nearly $12 million annually was spent in fiscal years 1984 to 1986. Much of this has gone to the combined sewer overflow problems of the seven county metropolitan area. Cost-sharing for the LCMR program is set at 50% of eligible costs, with no additional funding for I/A projects. Communities that build advanced treatment components into the system can, however, earn an additional 15% subsidy. The capability to treat industrial waste, it is reasoned, encourages industry and advances economic development.

The explicit recognition of the development aspects of the LCMR program, are in contrast with those of EPA. The federal program had been heavily criticized for its use in pork barrel politics, with the 1981 CWA amendments its mission was reaffirmed as one of pollution control, not economic development. The LCMR program is also less restrictive in terms of cost eligibility; reserve treatment capacity and land acquisition costs are both eligible under the state program.

Farmers Home Administration.

To help balance some of the fiscal inequities inherent in small, rural communities, the Farmers Home Administration (FmHA) has long been a source of low interest loans and outright grants. Involvement began with the Water Facilities Act of 1937, which made federal funds available for farm water projects in 17 western states. The program grew slowly, until 1965 when it was amended to provide loans and grants for wastewater treatment in addition to the traditional water supply projects. By the time the Rural Development Act of 1972 was passed, the program had a budget of $300 million and served all rural communities of up to 10,000 persons.

The primary objective of the FmHA program has been to help small, low income communities provide water and sewer services. Eligibility, therefore, is restricted to communities and projects with the following characteristics.

1. Cities must have populations of 10,000 or less.
2. Cities must be unable to borrow funds elsewhere at reasonable rates and terms.
3. Median household income (MHI) of the service area must be below $12,176 (85% of Minnesota's 1980 non-metro MHI of $14,325).
4. Grants can not exceed 75% of the eligible project costs.

Between 1966 and 1985 a total of $8.6 billion in loans, and $2.75 billion in grants had been awarded nationally. Minnesota, during this period, received nearly $212 million in loans and grants. The Reagan administration brought budget cuts and higher loan rates to the FmHA water and sewer program in 1981. The effects on funding are shown in table 2.1. For FY84 loan authority was cut nearly in half, and funding for grants, by two-thirds. In addition, other subsidies which had lowered the loan rate to 5% were dropped. All subsequent loans have been made at the prevailing municipal bond rates, with the exception of those to low income communities where the 5% loan rate still applies.

Table 2.1 Funding levels for FmHA Water and Wastewater Disposal Loan and Grant Program (1980-85)

Year	Loan	Grant	Total
(Millions of current year dollars)			
1985	$250	$ 90	$340
1984	270	90	360
1983	600	300	900
1982	375	125	500
1981	750	200	950
1980	700	283	983

Source: Farmers Home Administration, USDA.

Department of Energy and Economic Development.

Minnesota also has a Small Cities Development Program (SCDP) which helps communities finance public works projects, including wastewater treatment systems. Funding comes from the federal Community Development

Block Grant program (CDBG). Worthy projects must meet three qualifications; low and moderate income persons must be the primary benefactors; the activity must prevent or eliminate slums and blight; and a community's need must be recent, serious, and financially burdensome to its residents. Awards are competitive, with community rankings dependent on needs and project feasibility. Generally, any town or city under 50,000 persons may apply for assistance, as well as any county not already receiving federal Housing and Urban Development funding.

Since the State took over this program from Housing and Urban Development (HUD) in 1983, funding levels have been in the $15-18 million range. Wastewater treatment projects are ideal candidates for funding, as are street repairs, public housing, and an array of other community services. Entire sewage systems have received partial support under this program, but more typically just the sewage collector component of a system -- which are ineligible under the EPA program -- are financed.

Iron Range Resources and Rehabilitation Board.

The unique economic characteristics of the six counties on the Messabi iron range in northeastern Minnesota make them eligible for infrastructure development grants through the Iron Range Resources and Rehabilitation Board (IRRRB). Financed primarily from a tax on taconite extraction, the IRRRB is responsible for many economic and environmental improvements in the region.

The IRRRB's primary goal is to create jobs and promote economic development, which it hopes to achieve through job training and infrastructure improvements. Project proposals are selected by the Board on individual merit. The IRRRB was spending roughly $18 million annually at the height of its budget capacity in the late 1970's. The continued decline of the steel and iron ore industries, coupled with changes in the distribution of taconite production tax revenues, has reduced IRRRB revenues and hence spending, to $3 million in 1985. About a third of all IRRRB money has gone to wastewater treatment system construction. Local shares were paid on some federal projects, while other facilities were financed in whole. Since its creation in 1943, the IRRRB has spent about $50 million, or 1/3 of its funds, on sewage treatment projects.

Summary.

This chapter has outlined five programs which offer rural communities aid in constructing sewage treatment facilities. Each program has its own mission and method of lending support. Depending on demographics and geographics, communities in rural Minnesota face a range of subsidy levels. Virtually all communities may receive Environmental Protection Agency or state program support, reducing project costs by at least half. A community eligible for Farmers Home

Administration assistance can lower its costs further through direct grants or loan subsidies. Communities on Minnesotas' Iron Range, supported by the Iron Range Resources and Rehabilitation Board, may face no construction costs at all. It is this range in subsidy levels that allows the estimation of community responsiveness to price changes in the demand analysis which follows.

CHAPTER 3. REASONS FOR GOVERNMENT INTERVENTION

To the free market economist, government intervention is justified when the marketplace fails to allocate resources efficiently according to the rules of marginal cost pricing. Three such failures are common to the market for rural sewage treatment -- negative externalities, public goods, and decreasing-cost monopolies. Of further concern to economist' are the equity aspects of resource allocation -- the distribution of wealth, and the provision of merit goods. This chapter examines each of these issues in turn.

Efficiency and Market Failures.

Externalities.

Water pollution is the classic example of a negative externality. Inadequately treated effluent discharged by one agent or community, adversely affecting a neighbor's environment. Because the two perceive different marginal costs and benefits to cleaner water, the market fails to allocate sufficient resources to pollution abatement efforts. The goal of public intervention is to equate the marginal value each agent puts on the water resource. A variety of corrective actions may be taken -- regulations imposed, property rights established, taxes levied or subsides given. In practice, a combination of these and other policy responses are used.[1]

Subsidies are the response most relevant to this study. Their effects on the behavior of polluters can be illustrated graphically (figure 3.1). Increasing levels of pollution are measured on the horizontal axis, costs on the vertical axis. The downward sloping marginal benefits curve (MB) reflects the diminishing returns to the polluter for each additional unit of output. The marginal damage (MD) suffered by the polluters downstream neighbor is assumed to increase with higher levels of pollution. Marginal costs, private (MPC) and social (MSC) -- for instance, treating drinking water supplies -- increase as well with pollution levels. Note, that the marginal social cost is the sum of the marginal private costs and marginal damages.

Initially, the most efficient level of output for the polluter is q_1, where marginal private costs equal marginal benefits. Society, however, would prefer the output level q_2, equating their marginal costs to marginal benefits. By providing the polluter with a grant or unit subsidy of ab, public intervention effectively pays the polluter not to pollute. The marginal cost curve shifts to the left by the amount ab, and a new equilibrium is established at q_2. Both polluter and neighbor hold the resource in equal value, and thus an efficient allocation is achieved.

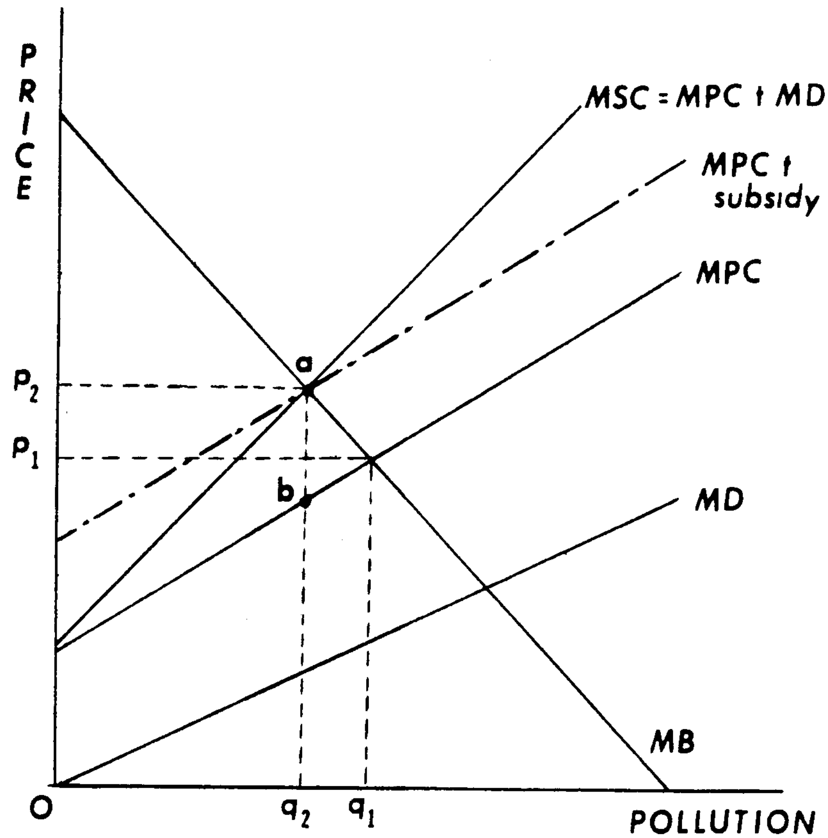


Figure 3.1 - Model of an Externality

Often, the preferred instrument for dealing with externalities is a categorical matching grant. Ideally, the grantor's matching rate is equal to the percentage of the marginal benefit experienced outside the service-producing, tax-paying jurisdiction. Difficulties in identifying the problem, the players, and the percentage of spill-over benefits, are significant drawbacks in application. And since costs and benefits are difficult to measure precisely subsidies can also lead to over production, an equally inefficient solution. Distortions may also result in other sectors of the economy as revenues are raised to pay the subsidy.

Public Goods.

A second cause of market failure in the delivery of rural sewage treatment services is the public or quasi-public nature of the goods. Unlike pure private goods, for which consumers must bid for consumption rights and the benefits from consumption are theirs alone, public goods exhibit Samuelson's non-rival, non-exclusive characteristics. For these commodities, consumption is joint and simultaneous, and there is no means for excluding non-payers. Without a connection between price and quantity demanded, the market fails to allocate resources efficiently.

Between the two extremes, purely private and purely public, two other goods, toll and common-pool, can be defined. Savas (1982) represents these four types on an all-goods continuum of possible exclusion/consumption characteristics (figure 3.2).

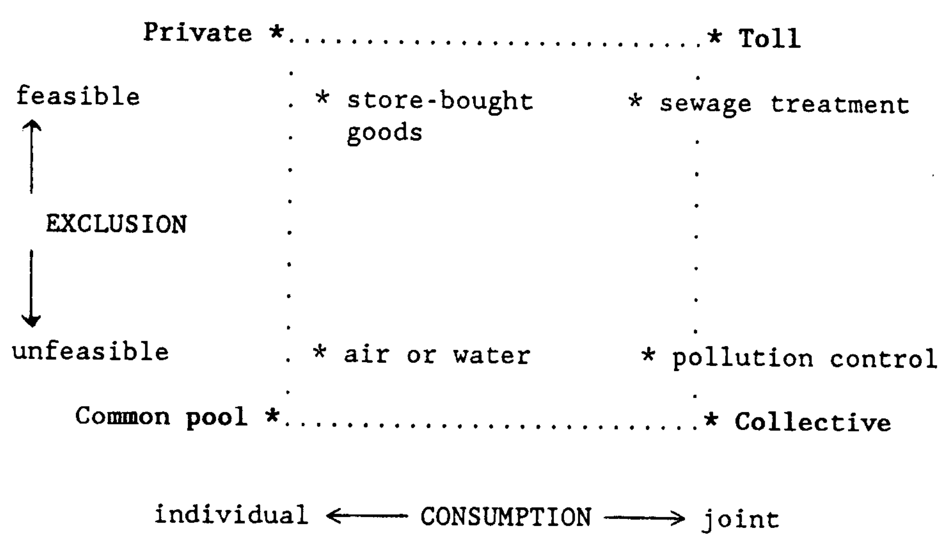


FIGURE 3.2 Goods On An Exclusion/Consumption Continuum.

Private goods are the archetype for studying supply and demand, yet special problems develop when analysis is applied to non-private goods. For common-pool commodities the dilemma is establishing price. While these goods are consumed individually, the exclusion of non-payers is almost impossible. Air and water are nearly pure examples of common-pool goods. Such commodities are underallocated by the marketplace due to their non-exclusive qualities.

Toll goods like sewage treatment are consumed jointly, but non-payers can easily be excluded. With these goods it is the lumpy nature in which the commodity is delivered that creates the analytical problems. Production is often a natural or decreasing cost monopoly, which creates an additional market failure. Collective action is required to creates the monopoly, and regulation exists to protect individual users from exploitation.

Complications in deriving the demand for non-private goods can be demonstrated mathematically in terms of the utility maximization model. The optimal market basket for a consumer is the one that maximizes utility, within the constraints of a budget.[2] At equilibrium, the marginal utility derived from each commodity purchased is proportional to its price.

Mathematically one can state the conditions for equilibrium. Assume a two good economy with goods X and Z. Suppose that the utility function for the i^{th} consumer is

$$U_i = u(X_i, Z_i) \tag{3.1}$$

the consumer maximizes utility U subject to the constraint on income

(3.2) $$Y = P_x X + P_z Z$$

Where P_x is the price of good X, and Y is the consumers total income. To maximize U subject to the constraint, we construct the Lagrangian function;

(3.3) $$L = u(X,Z) - \lambda(Y - P_x X - P_z Z)$$

where λ is the Lagrangian multiplier.

The first-order conditions for maximization are:

(3.4a) $$\frac{\delta L}{\delta X} = \frac{\delta U}{\delta X} - \lambda P_x = 0$$

(3.4b) $$\frac{\delta L}{\delta Z} = \frac{\delta U}{\delta Z} - \lambda P_z = 0$$

(3.4c) $$\frac{\delta L}{\delta \lambda} = Y - P_x X - P_z Z = 0$$

From these equations it follows that;

(3.5) $$\frac{\frac{\delta U}{\delta X}}{P_x} = \frac{\frac{\delta U}{\delta Z}}{P_z} \quad \text{and} \quad Y - P_x X - P_z Z = 0$$

This merely restates the familiar proposition of economic theory, that in order to maximize utility, consumers must allocate their budget so as to equalize the ratio of marginal utility to price for each commodity.

The idea may be extended to a two good - two person economy. Where X is a private good consumed individually as x_1 and x_2, and Z is a public good consumed jointly. The Lagrangians then become;

(3.6) $L_1 = U_2 (X_1, Z) + \lambda(Y - P_x X_1 - P_{z1} Z)$

(3.7) $L_2 = U_2 (X_2, Z) + \lambda(Y - P_x X_2 - P_{z2} Z)$

These can be rearranged such that the demand curves may be summed vertically, as is standard with public goods, rather than horizontally as a typical private good.

Two problems do, however, present themselves when dealing with public goods of this nature. The first is establishing a price for the good or service. This is dependent on the consumer recognizing the link between price and taxes paid. The second problem is defining units for measuring output, both quantitatively and qualitatively. One solution is to assume expenditures map directly into quantity/quality space.

As a consequence, public finance economists have gone from trying to estimate the demand schedule for public goods, to explaining the total expenditures made on them. Utility maximization is still an objective of the expenditure study, and again the issue of aggregating preferences across the group or community must be dealt with. In this, and many other studies, the Median Voter Theorem is used as the public choice model. How economist have approached the problem is detailed in the next chapter.

Decreasing Cost Monopolies.

Like many other public utilities, rural sewage treatment systems tend to operate under monopolistic, decreasing-cost conditions. Only one plant or system is required per community, and cost reductions only come with increased output (ie. more users). Hirsch (1959) found the long-run per capita expenditure function for sewage treatment facilities declined rapidly in a non-linear fashion for systems up to flows of 1.5 million gallons per day. At an average 200 gallons per person per day, marginal costs would begin to flatten when a community reached about 7,500 persons. Small flows technology has admittedly improved in the last 30 years, but there still exist substantial economies of scale. Again, one can demonstrate the situation graphically, and show how government intervention could be used to allocate resources more efficiently (figure 3.3).

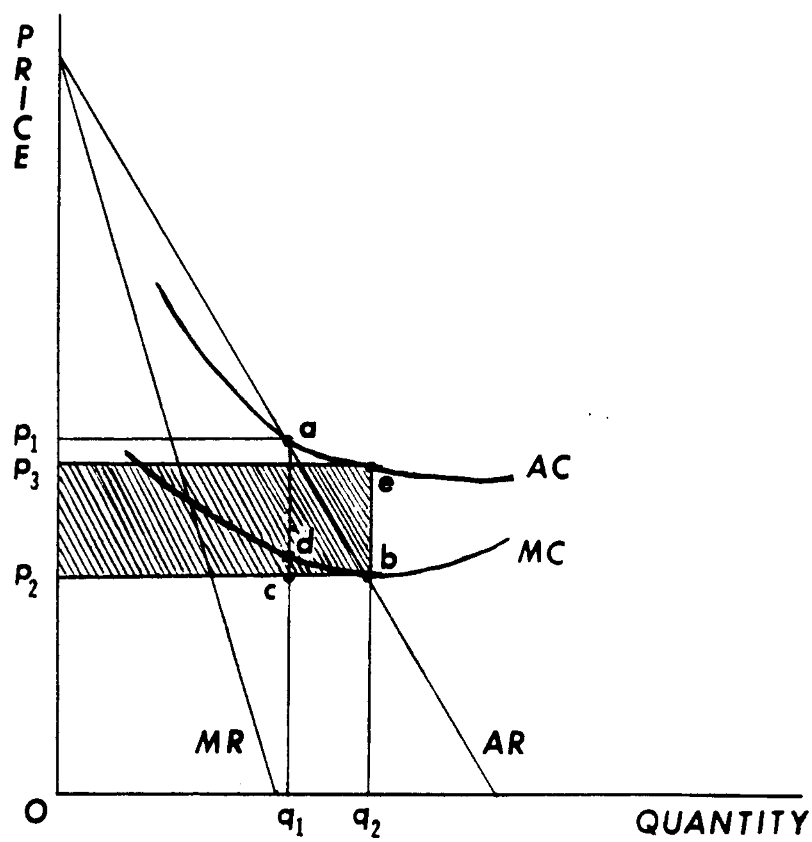


Figure 3.3 - Decreasing Cost Monopoly Model

While equating marginal cost to marginal revenue or price is the rule for efficiency among competitive firms, such behavior by a monopolist leads to an under-allocation of resources. Monopolies are hence regulated to insure adequate service, and a "fair" return on investment. In addition, service rates are typically set at the point where average costs equal average returns (point a). But unless the utility is operating at the lowest average cost, the optimal level of output is instead where marginal costs equal price (point b).

If, at the point at which average cost is equal to price, marginal cost is below price, as it would be if the utility is operating on the downward portion of its average cost curve, additional units of output, up to the point at which price equals marginal cost, will add less in cost to society then the price charged for them. Were the public sector to step in and pay an equivalent of dcb, society would gain the consumer surplus adb. To achieve this production efficiency, however, a lump-sum transfer (bP_2P_3e) is required. Again, it must be recognized that such transfers may cause distortions in other sectors of the economy.

Equity Considerations.

Optimal resource use involves both efficiency and equity considerations. Economists have relied on the concepts of marginalism to define efficiency, but may choose from a number of criteria in assessing distributional justice. The particulars of these concepts are less important here, than the recognition that fiscal inequities exist. And while it is often an argument of degree, government intervention can be a justifiable means of correcting them. In the delivery of sewage services, two arguments are worth mentioning.

First, not all jurisdictions are equally capable of providing public goods and services. Wealthier communities typically produce better services at a lower tax price than poorer ones. Unconditional grants are a common tool for addressing fiscal disparity, yet implementing their use calls for measures of fiscal capacity and fiscal need. These represent, respectively, the tax rate needed to raise a given level of revenue, and the cost of providing a given level of service. Fiscal strength, can be measured by the ratio or difference of the two. Through the use of grants and progressive taxation, transfers can be made from jurisdictions with high-capacity and low-need to those with low-capacity and high-need. The objective may be to reduce the tax price, raise the level of service, or both.

The effectiveness of this transfer system is controversial at best. National measures of average tax capacity may be inappropriate when applied to individual states, or to the same state in different years. Inter-community measures of need may in no way reflect intra-community needs. Further, a jurisdiction may show a high tax effort, but in fact be "exporting" the tax burden. Finally, the phenomena of capitalization can defeat any meaningful comparison of community effort.[3]

A second equity rationale for intervention is to encourage the consumption of goods that are in the view of the grantor "merit goods". Such goods, whether public or private, are often justified in the name of national interest, or as a way of protecting some minority group. For instance, poor, uneducated people may not see the health or economic value of clean water. The concept of a merit good, however, is in itself controversial, and viewed by many as an affront to the ideals of consumer sovereignty.

Endnotes.

1. When the number of jurisdictions involved is small, voluntary collective action, and institutional changes such as redrawing boundaries or establishing special districts are alternatives. As the number of participants increases, however, so do the problems of coordination and free-riding, and with them the need for central government intervention.

2. In the analysis of private goods, the following assumptions are made about consumers and their behavior. a) Consumers are thought to be selfish, utility maximizers. They can examine choices in the market place, and bundle goods of increasing utility. b) Private goods are measurable by infinitely divisible units, and consumers know the utility value of each. Utility curves are smooth, continuous, and concave. There is in addition, no interdependence among goods.

3. If community A, has some comparative advantage over B in providing a service, all other things being equal, the advantage will be capitalized into the property value of community A. Therefore, while B appears to be maintaining a greater tax effort, residents of A have already paid a price for the service in higher property costs.

CHAPTER 4. PUBLIC EXPENDITURE ANALYSIS

Individual preferences for public services are translated into budgetary decisions through the political process. The desires of the electorate are then brought to fruition by public officials and bureaucrats at the various levels of government. Often, the most influential actions are taken at the federal level, and one important tool is the intergovernmental grant. To better understand this path, the following topics are examined; the median voter public choice model, fiscal federalism, and the expenditure effects of grants-in-aid.

Modeling Public Choice.

Median Voter Theorem.

Economic theory can be used to predict or explain actual budgetary behavior. But as was shown in the last chapter, public goods present analytical problems, primarily due to their collective nature. Assumptions need to be made about producers and consumers to maintain consistency between application and theory.

An important element of the community decision model is in defining the representative utility function. In early public expenditure studies the social welfare approach was used. According to this theory, elected officials were thought to reflect in their decision making the utility maximization of the community. All individuals were assumed to be identical, and members of a representative democracy.

As public finance theory has progressed, however, ideas about the motivations of elected officials have changed. Public participation in decision making has increased, and in legislative bodies such as Congress, power has became more dispersed. What truly mattered to the elected official, others contend, is not the welfare of the collective society, but the satisfaction of the voter who would be decisive in the politicians election bid. Known as the Median Voter Theorem, it asserts that the outcome of a single issue, majority rule, referendum will reflect the preferences of the median voter.[1] The strategy for an elected official (or someone seeking election) is to align themselves with the issues in accordance with the wants of the median or decisive voter, thereby assuring majority support.

Supply/Demand Assumptions.

Bergstrom and Goodman (1973) outlined four assumptions, which in addition to the Median Voter theorem, allow investigators to estimate the demand for local services. A fifth is made about supply. These are listed below, along with justifications for their application to this study of wastewater treatment.

1. <u>Costs are shared equally among users</u>. This holds better for toll goods, like wastewater treatment, than most other public services. User fees are a common funding device, indeed when federal dollars are involved they are a required cost recovery method. Where metering does

not exist - typically in small towns - assessments are made uniformly across households.

2. The maximizing consumer is aware of the goods price. Public participation in the decision process, and knowledge of project costs can be more easily assumed in a small community, than large. Again, federal regulations require public meetings and public notification of project costs as a part of the grant process.

3. The quantity supplied is equal to the quantity demanded by the median voter. This assumption provides the link between the electorate's preferences, and the politician's platform. Vote-maximizing politicians will offer, as best they can assess, the quantity demanded by the median voter. At this level, the average or median citizen will get what they want (ie. they are in equilibrium).

4. Median quantity demanded is the quantity demanded by the median income voter. This assumption combined with (3) says that the quantity supplied is that demanded by the median income voter. This allows one to treat the equilibrium supply/demand position as a point on the demand curve for the median income voter.

If assumptions (1) through (4) hold, a Bowen Equilibrium is said to exist. This by definition is the price and quantity combination of output where the median voter is at an equilibrium position. Since supply exactly equals demand, any other allocation would be sub-optimal.

5. Constant cost scale economies exist. This assumption has two points. First to account for price variation across communities, we assume identical, homothetic production functions. Second, it is assumed that all communities face a horizontal or perfectly elastic input supply curve. If there exist constant returns to scale, any change in output will result in a proportional change in total costs. So while unit costs may differ among communities, costs in each community are constant with respect to output. Perkins (1972) adds to these supply assumptions, that if labor and capital are the only factors of production, we may assume capital is mobile, but not labor. The advantage is in allowing one to measure marginal costs without measuring the rental rate on capital services, or that interest rates are constant across communities.

Intergovernmental Relations.

Federalism.

The need for intergovernmental fiscal relations is often explained using Musgraves trichotomy of public sector functions; resource allocation, income redistribution, and economic stabilization. Defining the level of government responsibility for each function and the method for implementing it, is the essence of fiscal federalism.

In its simplest form, the traditional division of responsibilities among levels of government calls for the centralized management of redistribution and stabilization programs, and the decentralized allocation of resources, except in the special case of national goods such as defense.[2] A compromise between unitary government and complete decentralization, Oates (1972) calls federalism, in economic terms, the optimal form of government. Aptly pictured by Grodzins marble-cake analogy, no simple model does justice to the complex sharing of responsibilities found in the American federalist system. The interrelatedness of each function leads to conflicts and compromises in achieving social, political, and economic goals. Never the less, Musgraves framework is a useful starting point.

The decentralization of the allocation process is typically justified efficiency grounds. While some publicly provided goods are national in scope, most produce localized benefits. To the extent that communities differ in their preference level for a public good, local governments are considered more capable of detecting and responding to local needs. Decentralization therefore leads to more efficient decision-making due to both the direct knowledge available to those intimate with the situation, and their subsequent recognition of the real resource costs involved. Additionally, efficiencies from innovations and experimentation are more likely when competition exists between jurisdictions to provide the least cost service.[3]

The decentralization theorem (Oates 1972) offers one conceptual framework for judging the optimal size jurisdiction to provide a parieto-efficient level of public service. Combining concepts from Tiebout's consumer choice model (1956), and Brenton's "perfect mapping" (1965), Oates reasons the optimal size jurisdiction for producing a particular good is that which covers the smallest area over which benefits are distributed.[4] The ideal is a balance between the welfare loss from taste differences and the efficiency gains from benefit spill-overs. The theorem is conditioned on a lack of sufficient economies of scale from centralization, and some indifference among jurisdictions to a uniform level of the good. Application of the theorem is complicated by the costs of decision-making, organization, and consumer mobility.

Fiscal Relations.

A system of intergovernmental fiscal relations can develop in which revenue-raising is centralized and expenditure decisions decentralized. Often, the result is an imperfect correspondence between the two, leading to the need for budget balancing transfers. Hirsch (1970) outlines three methods by which higher level governments can share revenues with lower levels; tax coordination, tax base sharing, and direct transfers.

Tax coordination is a procedure for eliminating inefficiencies and inequities brought about by either a horizontal or vertical tax overlap. Horizontal overlaps exist where individuals or firms are taxed repeatedly at the same level of government, such as with interstate commerce. Vertical overlaps result with multi-level taxing of the same individual; for example, federal and state income tax. State and local fiscal positions can be improved, and a more optimal welfare solution attained by coordinating tax collection efforts. One technique is for each jurisdiction to adopt a uniform tax code; another is to further centralize tax administration and collection; another still is through some system of tax credits.

Equally important to achieving fiscal balance is a sharing of the economy's tax base. The federal government relies on a progressive income tax structure, one which tends to be less responsive to income changes. In general, State tax structures rely on income, plus sales and excise taxes, while local government revenues are based on property tax revenues and user fees. Sales and property tax bases are generally less elastic than the federal tax base, and the state-local tax structures are more regressive.

One method of sharing the economy's fiscal capacity among levels of government is to vacate specific revenue sources. Such is the case with federal relegation of certain sales and excise tax receipts to state coffers. Tax deductions and allowances against otherwise taxable income are another common, and controversial, method for sharing the tax base. The fairness, and inefficiency of such provisions are the source of heated political and economic debate.

Both tax coordination and tax base sharing are important policy tools for correcting fiscal imbalance, but the most popular and widely used is the direct transfer of funds. Loans with subsidized interest rates, or generous repayment schedules, are other common instruments.

Such loans are really a direct transfer, amounting to the difference between the market interest rate and the subsidized rate. Most carry stipulations on how the funds may be used, a characteristic found in many grants as well. By setting conditions on how, where, and when funds can be used, grantor's can influence spending decisions, and better achieve their goals.

The Theory of Grants.

Grants and Their Use.

Intergovernmental grants are a way to make the federal system more efficient than a centralized or decentralized one. Grants can be designed to raise community income levels, or to redirect consumption by altering relative prices. The appropriate type of grant depends on the problem society faces.[5]

Three types of grants-in-aid are common; unconditional, and open- and closed-end conditional grants. The most widely used are the latter two conditional matching grants. The choice of open and closed-ended depends on whether the grantor's support is limited. For either, the funds use is clearly defined by the grantor. Thus, they are often referred to as categorical grants. Some matching funds are required to be provided by the recipient. Open-ended grants are confined mainly to welfare and medicare programs, while closed-end matching grants serve a variety of programs including transportation, education, and the environment.

The appropriate use of conditional grants, according to Break (1980), should depend on some assessment of the community's price elasticity of demand for the aided good. If it is low he argues, benefits to the grantee may not be significant enough to keep grant funds from being diverted to other purposes. A less costly and perhaps equally effective alternative, therefore, may be a direct income support grant.

An important issue with matching program grants is their fungibility. In the absence of effective maintenance efforts, or when funds are more discretionary as with block grants, local authorities may use grant monies to fund a community's own priorities, or take the opportunity to displace their own spending on the aided good. McGuire (1979) suggests a number of other ways locals can defeat program intentions; by trading, selling, or renting the aided good or a substitute; reallocating overhead costs; or redefining activities to fall under grant-eligible criteria.

Unconditional grants, such as revenue sharing, are a third type. These amount to an income transfer, typically made on a per capita basis with perhaps some regard for need. No restrictions are put on the use of the funds transferred, allowing recipients greater buying power without interfering with freedom of choice. Block grants are a cross between revenue sharing and categorical grant, in that they may or may not require matching funds, and their use is restricted to broadly defined categories.

Expenditure Effects.

Using the standard theory of rational choice, a recipient's budgetary response to various grant designs can be shown graphically (figure 4.1). Units of the aided good are measured on the horizontal axis, all other goods on the vertical axis. Line segment ab shows the pre-grant budget constraint. Either quantity Oa of the non-aided good can be purchased, or Ob of the aided good. Side stepping the complications of defining the utility function, we begin with a initial equilibrium e at the tangency of the indifference curve I_1 and budget line ab. (For the sake of clarity, only indifference curve I_1 will be shown.) Prior to initiating grant-aid, local resources are allocated to x_1 of the aided good and y_1 of all other goods.

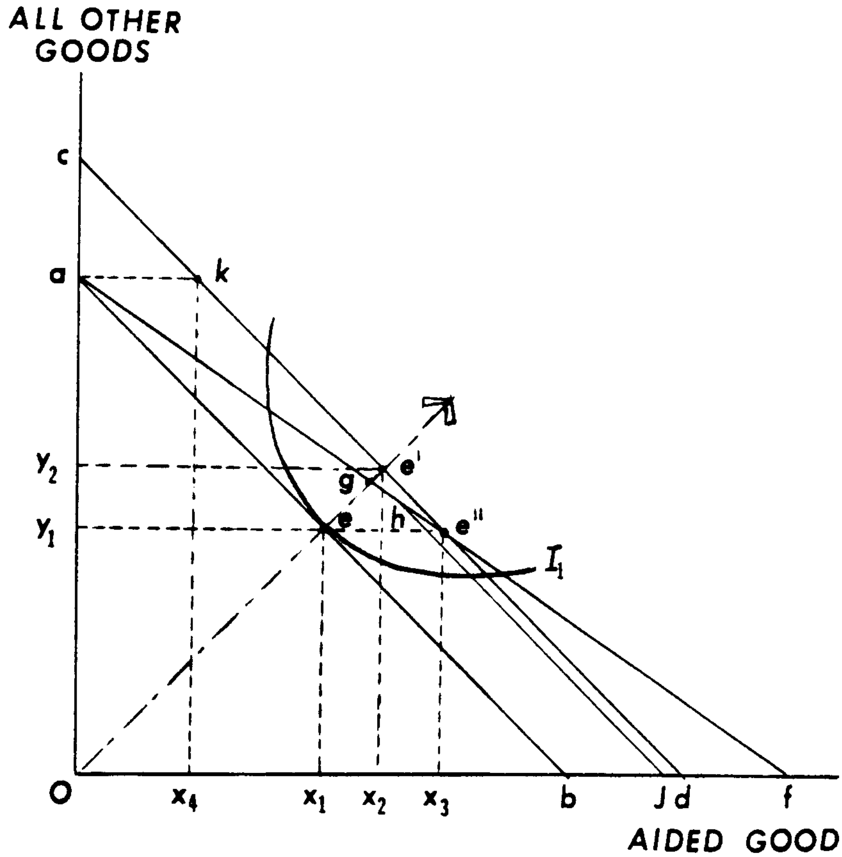


Figure 4.1 - Expenditure Effects of Grants

Introducing an unconditional non-matching grant of an amount ac, the budget line is pushed out to cd by a pure income effect. Assuming both goods are normal and income elasticities are positive, consumption moves to a new equilibrium e' on the income-consumption path. The grant results in greater consumption of both goods, indicated by x_2 and y_2.

General Revenue Sharing and other programs use this type of grant mechanism. Studies have focused on the so-called fly paper effect -- that money sticks where it hits. Empirical evidence has indicated that indeed expenditures do rise in the long run by more than would occur with an equivalent increase in personal income. Overall, taxes are reduced and expenditures increased. Not surprisingly, the expenditure increase is less than would occur with a categorical grant.

An open-ended conditional or categorical matching grant is the equivalent of an ad valorem subsidy of the aided good. This changes the relative price scheme in favor of the aided good, and swings the original budget out to af. The slope of the new line is dependent on the matching ratio, where bf/Of is the percentage of expenditure the grantor contributes. In this case, the increase in expenditures depends on the community's elasticity of demand for the aided good. If the partial derivative of expenditures with respect to grants ($\delta E/\delta G$) is unitary, a new equilibrium e'' results from a pure price effect. Consumption of all other goods remains unchanged at y_1, while the aided goods' consumption increases to x_3. When demand for the aided good is elastic ($\delta E/\delta G > 1$), expenditures increase by more than the grant, and that of all other goods declines. This results in a new equilibrium along the segment e''f. The opposite holds when demand is inelastic ($\delta E/\delta G < 1$), and a new equilibrium is established along e''a.

Empirical studies show the latter to be the more likely case for most public goods. Generalizing, the partial of expenditures with respect to (open-ended) grants ($\delta E/\delta G$) is found to be between 0 and 1, implying a price inelastic demand for the aided good. They appear then, to result in local spending of less than the grant amount, or substitute federal for local dollars, instead of stimulate local spending, the intended result.

A closed-ended matching grant limits the grantors budget exposure, as well as the participation of any one grantee. If after some point h, the grantor will no longer subsidize the aided good, the budget line becomes kinked as in segment ahj. To the left of h, or along segment ha, the new constraint is non-binding and the effect is the same as the open-ended grant. A new equilibrium to the right of h, however, increases the consumption of the aided good, but by less than is the case with the open-ended grant.

Gramlich compiled results for 24 of the numerous studies on expenditure effects from federal closed-ended conditional grants. Estimates (for the partial of expenditures with respect to grants), range from 2.45 to .32 with an average response of 1.4. Despite the appearance of a highly stimulative grant instrument, the author notes some inconsistencies in the results. First, the mean effect (1.4) is greater than the 1.3 mandated by the typical 30% matching funds requirement. This response appears to contradict the negative income effects one would expect to find as increasing amounts of own source funding are required. In addition, unlimited conditional grants are found to be less elastic than limited ones. Gramlich attributes this to the latter's application where demand is more elastic, or the existence of more effective effort maintenance provisions. He contends that in general the limited conditional grant stimulates local spending about equal to the grant amount.

Finally, block grants are a fourth type of grant mechanism, which has received little empirical review, but is worth mentioning here. Block grants with no matching requirements, but use restrictions, will allow an equilibrium along segment kd, and at least x_4 is consumed. In the case of a matching block grant, the allocation will be the same as with a categorical matching grant, but the definition of the aided good will be more variable.

ENDNOTES

1. A number of other (unrealistic yet simplifying) assumptions are also made. Voters are thought to be sincere, have single peaked preferences, and single dimensional ranking of political beliefs. Gamesmanship isn't allowed for, nor is preference intensity. Bureaucracies are no impediment to efficient production, hence output is produced at least costs.

2. This paradigm is not without its critics. Gramlich (1985) seriously questions the superiority of centralized monetary and fiscal policy, given the globalization of the capital markets, and the macro-economic evolution of the last decade. He goes on to point out a number of views challenging the dominance of a centralized government redistribution policy as well.

3. Arguments supporting centralized stabilization and redistribution policies cite the openness of local economies, and the efficiencies of collective actions. Allowing for mobility, any jurisdiction's unilateral attempt at redistributing wealth through progressive taxation for instance, would succeed only in attracting a large number of "poor", while repelling the increasingly burdened "rich". Eventually, the redistribution effort would be overwhelmed and defeated. When the objective is stabilization, say to lessen unemployment, mobility again works counter to local efforts. The inability to create money, and restrictions on deficit financing, further limit the options of local governments to conduct redistribution and stabilization policy. Finally, centralization can take advantage of economies in revenue collection, and in some cases a higher degree of administrative competence.

4. Tiebout postulated, that in a mobile society, consumers would choose the jurisdiction offering the bundle of services which maximized their utility. ("A Pure Theory of Local Expenditures." Journal of Political Economy, 1956.) Brenton's "perfect mapping" proposed jurisdictional boundaries to include only those who received benefits from a service. ("A Theory of Government Grants." Canadian Journal of Economics and Political Science, 1965.)

5. Most grants are allocated according to a formula based on population, income, or some other variable, many are made on a project by project basis. This puts a premium on the "grantsmanship" skills of a community and, some argue, unfairly and inefficiently skew the dispersion of funds. Proponents contend the process allows the grantor an easy "first cut" since it identifies interested recipients. The selection of viable applicants is easier and matching ratios, they claim, can be tailored to community demand elasticities.

CHAPTER 5 REVIEW OF THE EMPIRICAL LITERATURE

A number of public sector demand studies have been conducted in the last 30 years. Determinants of public expenditures studies were commonplace through out the 1960's, but they virtually disappeared in the 1970's as more pressing topics dominated the research scene. Yet lately, the determinant study has resurfaced as state and federal budget cuts have put strains on local finances.

This chapter examines six relevant expenditure studies. But before beginning this review, two shortcomings must be recognized. First, a great deal of social, economic, and technologic changes have occurred over the last three decades which leave in doubt the current value of some estimates. And second, research seldom has focused directly on sewage treatment services, but instead combined it with another service, or looked at general expenditures in total.

Henderson (1968) used the Social Welfare approach in one of the first studies to examine the determinants of per capita public expenditures. His model took a two equation form, with local government expenditures and taxes as the dependent variables. Two-stage least squares regression was applied to cross-sectional data from the 1957 Census of Government. One purpose was to differentiate the responsiveness of communities in metropolitan and non-metropolitan places. Critical to Hendersons model is the assertion that communities are homogenous, and more importantly that elected officials are acting to maximize the welfare of the community as a whole. Four major differences were observed, and they bear repeating even though the urban-rural dichotomy has narrowed since 1957.

> All other things held constant;
>
> - Marginal changes in per capita income brought about a larger response in non-metro areas for local public services. The total income elasticity of demand for public goods was .900 for metro counties, 1.224 in non-metro.
>
> - Local public expenditures were preferred in non-metro counties to private expenditure with marginal increases in community income. The opposite was found in metro counties.
>
> - Dollar for dollar, intergovernmental aid was more stimulative in metro areas (1.42) compared to a nearly unitary response (1.037) in non-metro counties.
>
> - Population changes were inversely related to public expenditures in non-metro areas (expenditures dropped $ 0.2734 per 1000 person increase), in metro counties the response was small, but positive ($ 0.0102 per 1000 new residents).

In summary, Henderson found among non-metropolitan places a preference for publicly provided goods to private goods as community incomes rose. This may have been a reflection of the overwhelming need for basic services in rural areas, and perhaps was a factor in the "catch up" seen in rural services since 1957. Intergovernmental aid was found to be neither stimulative nor substitutive, meaning non-metro demand for public services changed proportionally to their price. Finally, per capita expenditures declined as small communities grew, while the opposite occurred in large cities.

Bergstrom and Goodman (1973) used the Median Voter theorem to justify their pooled cross-sectional analysis of 1962 Census of Government expenditure data. This effort produced estimates for three public-services; general administration, police protection, parks and recreation. For each, expenditures were regressed on 11 independent variables. Of particular interest are the elasticity estimates (income, tax share, and population) for general expenditures at the national level, and as they compare to Minnesota (table 5.1).

Nationally, the income elasticity of demand for general expenditures (excluding education and welfare) in 1962 was estimated 0.64. In Minnesota, however, the coefficient was estimated at 1.29, indicating a very strong preference for public goods with marginal changes in income. The tax share elasticity, a proxy for price, was calculated at -.23 for the pooled data, and at -.25 for Minnesota individually. And the population elasticity (the change in general expenditures given a 1% change in population) was estimated nationally at .84, compared to .69 for Minnesota alone. Notably, these estimates (price, income, population) are significant at the 95% level.

Bergstrom and Goodman's model included other variables less robust, but still of interest. Percent population change had a small, negative elasticity in both national and Minnesota estimates, though for the state it was not statistically significant at the 95% level. Percent owner occupied housing was large and negative (-3.21) for Minnesota, small and negative (-.77) for the national data.

Table 5.1 Elasticity Estimates for General Expenditures (Bergstrom and Goodman)

VARIABLE	MINNESOTA	NATIONAL
Income	1.29 *	0.64 *
	(.38)	(.07)
Tax share	-0.25 *	-0.23 *
	(.11)	(.03)
Population	0.69 *	0.84 *
	(.19)	(.03)
Crowding	0.92	1.09 *
	(-)	(-)
% Population Change	-0.03	-0.04 *
	(.02)	(.01)
Work/Live	-0.13	0.12 *
	(.11)	(.02)
Percent Owner Occupied Housing	-3.21 *	-0.77 *
	(1.01)	(.13)
Percent Non-white	12.79	0.84 *
	(10.92)	(.19)
Density	0.03	-0.07 *
	(.08)	(.02)
Percent 65 Yrs or Older	1.49	1.75 *
	(2.01)	(.45)
Percent In Same House	-1.48 *	-.65 *
	(.66)	(.17)
Intercept	-6.08	-
# observations	36	-
R-squared	.89	-

standard errors in parenthesis
* statistically significant at 95% confidence level.

Population density was small and negative nationally, small and positive for the state. The elasticity for percent elderly was in both cases large and positive. The signs on all of Bergstrom and Goodman's estimates were "correct", where the estimate was statistically different from zero. Notably, the r-squared (.89) on the Minnesota regression is quite high for cross-sectional data.

The crowding parameter is an attempt at revealing the Samuelson characteristics of public services. An estimate of zero would indicate a purely public good. If the estimate is one, the service has private good features. Empirical estimates tend toward the latter.

Borcherding and Deacon (1972) paralleled Bergstrom and Goodman both in timing and theoretical framework. They examined expenditure decisions based on pooled cross-sectional data from the 1962 Census of Government. In their analysis, state and local government expenditures from 44 states were observed for eight public services. Of the greatest interest here are the finding for sewer-sanitation services. To address the problem of maintaining constant-cost supply assumptions across such a broad geographic sample, subgroups were created for certain services according to their labor intensity.

Table 5.2 ELASTICITY ESTIMATES FOR SEWER-SANITATION SERVICES (Borcherding and Deacon)

MODEL	Constant	Price	Income	Pop.	Capturability	R^2
GROUP 1	(Labor's share of expenditure = .2775)					
Coef.	-10.061 (4.58)	-1.495 (2.56)	.733 (.811)	.154 (.108)	.989 (.060)	.09
GROUP 2	(Labor's share of expenditures = .4175)					
Coef.	-12.372 (2.61)	-4.658 (1.61)	2.006 (.448)	.261 (.032)	.940 (.081)	.56

Standard errors shown in parenthesis

Since most rural systems are a non-mechanical, requiring low-labor, we might expect rural areas to more closely resemble the responsiveness of group 1. The poor r-squared for this equation, however, brings into doubt its statistical significance. In either case, demand for sewer-sanitation services is positively related to changes in population and community income. And as expected, price is inversely related to expenditures. While the signs on the coefficients are correct, the reliability of the estimates are soft, and in some cases more highly responsive than one might expect (eg. income elasticity of 2.00).

Borcherding and Deacon include a capturability parameter much like Bergstrom and Goodmans crowding variable, and reported similar results. Thus supporting the view of sewer-sanitation services as quasi-private goods. Additional regressions were run to show the impact of land area and urbanization on local expenditures decisions. In neither case was the model improved significantly, nor were the individual coefficients of any explanatory value.

Perkins (1977) built on Borcherding and Deacon's study and produced own-price, cross-price, and income elasticity estimates for 10 public services. Data was examined from 14 small cities and 24 towns within a 50 mile radius of Boston. Perkins tried to improve the quality of his estimates by narrowing the sample universe to a more homogeneous group. Four factors were considered important, and are relevant to the sampling approach taken in this study. These are discussed in the sample selection part of chapter five. Despite Perkins efforts to improve the quality and consistency of his estimates, the results were less than impressive.

Demand determinants were estimated for eight specific services; local education, higher education, highways, health and hospitals, police, fire, sewers and sanitation, and parks and recreation. Both conditional and unconditional grants were examined for their expenditure effects. Overall, seven of ten own-price elasticities were found to be negative -- only one (education) was statistically significant.

The price elasticity of demand for sewer-sanitation services, was estimated at 22.14; highly responsive, but of the wrong sign for a normal good (table 5.3). Perkins notes that for some jurisdictions, sewer-sanitation services are provided by private or quasi-government organizations. This may explain in part some of the variability in his estimates. The income elasticity was estimated at .15, all other things equal, but is not significantly different from zero. When income grants going to sanitation services were considered, the elasticity estimates were 23.97 and .21, respectively.

Table 5.3 Elasticity estimates for Sanitation Services (Perkins)

GRANTS EFFECTING PRICE AND INCOME

Variable	Coefficient	T-Value
Own-price	22.14	2.05
Income	.15	.14
Cross-price		
Water	-22.85	2.10
Health	11.43	2.35
Constant term =.27	R-squared =.24	

GRANTS EFFECTING INCOME ONLY

Variable	Coefficient	T-Value
Own-price	23.97	2.64
Income	.21	.19
Cross-price		
Water	-23.62	2.10
Health	10.24	2.09
Constant term =.29	R-squared=.25	

The cross-price elasticity for sanitation services with respect to domestic water supplies is -22.85, when grants have price affects. The greater price responsiveness (particularly water and sewer), left Perkins concluding matching grants the more effective mechanism for eliciting a local expenditure response.

Holtz-Eakin (1986) used the median voter model in a study that argued taste differences among communities were not being fully accounted for in cross-sectional analysis. Specifically, that there is the potential for large tastes differences across communities, if as

Tiebout hypothesized communities are comprised of equally like minded people when it comes to public service demands. Without accounting for the variation between communities the estimated coefficients will be biased and misleading. One method offered for data correction is to average over two or more years.

With panel data, Holtz-Eakin calculated expenditure changes (1972-1980) and analyzed the within and between variance for seven public services, plus an aggregate. Despite his efforts, few estimates were statistically significant (table 5.4). Income has the only expected sign to stay constant both between and within, yet the coefficients are more responsive than expected. Only the within income estimate, and the within population estimate are statistically different from zero at a .95% confidence level.

Table 5.4 Elasticity Estimates Sewer Services (Holtz-Eakin)

	Tax price	Income	Pop.	Grants	Crowding
Between Communities	-.353 (.633)	1.636 (3.061)	-.258 (.727)	.617 (.702)	1.15
Within Communities	.133 (.342)	4.949 (2.099)	4.008 (1.456)	-.009 (.208)	4.41

standard errors in parenthesis

Holtz-Eakin concluded, however, that the demand for public services is less sensitive to price, and slightly more sensitive to income than previous studies had indicated. Crowding appears to be less of a problem as well.

Jondrow and Levy (1984) was the only study found which examined directly the responsiveness of local government to federal grants-in-aid for wastewater treatment facility construction. It differs from the other studies in two ways. Time-series data (1949-1981) was analyzed, and capital stocks were used as the dependent variable, instead of expenditures or flows. The studys primary concern was the issue of displacement -- federal grants for local funds. Two measures were analyzed; temporary and permanent displacement.

Temporary displacement is a function of unspent federal budget authority. It is due to start-up and procedural delays, or simply by communities waiting to see if they are eligible for grant monies. Permanent displacement results from jurisdictions substituting federal dollars for funds they themselves would have otherwise provided.

The study's preliminary results indicate two-thirds of all local spending for sewage treatment facility construction was permanently displaced by federal funds. Postponements, or temporary displacement amounted to $.28 for every dollar of unspent budget authorization of the program. Variations on the original model indicate the same basic results. Permanent displacement is at least 50%, and when sewer lines alone are considered displacement is complete.

SUMMARY

Price, income, and population have emerged as the dominant factors in public service demand studies. Some generalizations can be made about expenditure elasticities from the studies reviewed here, and the previous observations made by Gramlich.

Table 5.5 Summary of Previous Elasticity Estimates

	Price	Grant	Income	Pop.
Henderson	-	1.037	1.224	-
Bergstrom & Goodman	-.25	-	1.29	.69
Borcherding & Deacon	-1.49	-	.733	.154
Perkins	22.14	-	.15	-
Holtz-Eakin (between)	-.353	.617	1.636	-.258
(within)	.133	-.009	4.949	4.008

Price, according to Gramlich, tends to be slightly less than unitary with income grants, slightly more with many conditional grants. This narrow set of studies gives no indication about size or sign. The coefficient for grant affects, is equally less enlightening.

The income elasticity coefficient is somewhat more consistent, always positive, and among this group generally elastic. Population may be more sensitive to the particular service, or size of the communities studied, than the other variables. Generalizing, one might expect the population coefficient to be positive, and small.

CHAPTER 6 DATA AND ESTIMATION METHODS.

This chapter defines the study's sample, and explain briefly the statistical techniques used -- Probit and Tobit, and describes the variables used in the analysis. The estimation methods chosen are slightly more complicated than ordinary least squares. The first (Probit) estimates the probability of observing a community sewage treatment expenditure. The second (Tobit) calculates their responsiveness once the choice to spend is made.

Data.

Criteria.

The typical expenditure study has used data aggregated across communities of differing size and geographic location. While this is fine for illustrating a technique or examining the "bigger picture", critics fault such data sets for their lack of focus when policy interpretations follow. Perkins (1977) made this point in his expenditure analysis of 38 small towns and cities within a 50 mile radius of the Boston area. He offered four advantages to his sampling criteria, which were applied to data selection in this study.

1. Perkins examined expenditure categories that were uniformly defined across the sample communities. A common problem with cross-sectional data is the lack of homogeneity. Eliminating significant geographic, topographic, or climatic differences between municipalities should improve results. For the sewage treatment needs of rural Minnesota communities this assumption holds fairly well.

2. The relative proximity of sample jurisdictions supports the idea of homogeneous tastes and preferences. An implicit assumption is that utility functions remain unchanged over the sample space. This is difficult to maintain with national or multi-state expenditure data, but limiting the analysis to rural Minnesota, as Perkins did to the Boston area, substantially improves its validity.

3. In Perkins view, small communities are preferred to large because expenditure decisions are more likely to reflect individual preferences in the political process. A well informed electorate is an assumption critical to the median voter theorem. Again, public information about wastewater treatment project costs are a requirement when federal dollars are involved.

4. Perkins also noted the value of having all data from a single year. In this study, where the individual community sewage treatment expenditures were made over a 15 year period, this was not possible. Values were adjusted, however, to capture the decision making environment. For example, if construction began in 1982, the community

data (income, population, etc.) from the year proceeding that in which the decision was likely made -- 1981 in this example -- was used. All financial values were then adjusted to reflect constant 1984 dollars.

Qualifications.

With Perkins' four selection criteria in mind, some specific qualifications can be made of the sample universe. One of the most important is the reliability of the data. The Clean Water Act requires states to conduct a biennial assessment of their wastewater treatment needs. In Minnesota, 923 authorities are surveyed. This includes all cities, towns, townships, regional authorities, and federal government facilities. Construction costs are estimated for the various system components -- treatment plants, collectors, and interceptors -- and because individual systems are in different stages of planning, a measure of reliability is attached to the quality of the cost estimate. Four reliability levels are used.

A reliability level of 0 indicates no existing treatment backlog. (Needs and backlogs are terms used interchangeably, and refer to the cost of bringing a community facility up to federal water quality standards.) This lack of need is either because an adequate facility already exists, or the community simply relies on on-site disposal methods. Minnesota has 305 reliability level 0 communities.

There are 258 communities in Minnesota at a reliability level 1. This group has unmet needs, and their cost estimates are of the highest quality. System plans and specifications are complete, and have been reviewed by the Minnesota Pollution Control Agency. These communities are ready to begin construction.

The final two levels of cost estimate reliability are groups 2 and 3, which are derived by historic cost curve methods, and considered of questionable quality. There are 360 communities at level 2 or 3 in the state. Some of these communities may be within the water quality standards, but are ranked in anticipation of future replacement.

The reliability of cost estimates have become an issue as federal authorities have scrutinized municipal sewage treatment backlogs. Recent national needs summaries have broken out reliability level 1 estimates, claiming they are the only legitimate remaining needs. Whether this is a fair assessment or not, they are the most likely "next" projects, and funding them alone will be a significant challenge.

A common regression analysis procedure would be to sample from the reliability level 0 communities which have completed their project requirements, then use the results to make inferences about remaining projects. But since the statistical methods used here allow for limited dependent variables, information from communities that haven't made expenditures can be used. Because they are the most reliable, level 1 communities are also included in the sample.

Two other restrictions are made on the sample set. First, only places with populations of less then 10,000 are included in the sample.

This keeps technology considerations fairly constant, and improves the likelihood of residents being fully informed about project costs. Not coincidentally, this is the population cut-off for Farmers Home Administration loans and grants.

Second, because the study is interested primarily in small, "self contained" rural communities, the sample universe was restricted to communities outside the seven county Twin Cities metropolitan area. Regional and federal facilities were disregarded as well.

Final Sample Set.

A total of 56 communities from 37 counties were randomly selected as the basis for estimation. Of these, 29 were reliability level 1, or had not made any expenditure commitments. (Five of these were still completely unsewered.) The remaining 27 were from level 0, or have completed facility construction. Seven of these made the expenditures without any outside help.

After collecting the data, however, five level 0 communities were eliminated. These were all Iron Range projects whose price had fallen to zero as a result of IRRRB subsidies. Consequently, the final sample set contained 51 communities from 34 counties. The split between proposed and completed projects thus became 29 and 22 respectively.

Estimation Methods.

Demand Components.

Before looking at the statistical methods, it is helpful to first consider the reason for disaggregating demand into actual and potential consumption. Determinant studies, like those described in the previous chapter, have typically used regression analysis methods such as ordinary least squares (OLS) to estimate elasticity values. The dependent variables are positive, ex post expenditure values, which implies all communities are market participants. A significant element of the expenditure dynamic is lost, however, namely the entrance and/or exit of buyers with changes in prices, incomes, and other independent variables.

Thraen, Hammond, and Buxton (1978) outlined the importance of making this distinctions in consumer demand analysis of cross-sectional data. They begin by defining households and their purchases as,

$\tilde{q} = Q/n$ total purchases over actual number of purchasers

$q^* = Q/N$ total purchases over total possible purchasers

where,

if $n = N$, then $q^* = \tilde{q}$ and if $n < N$, then $q^* < \tilde{q}$

the participation ratio $PT = n/N$, so that $q^* = \tilde{q}\ PT$

For simplicity we look at price alone as the determining factor, of both existing and potential demands. Such that the total elasticity of demand can then be expressed as;

(6.1) $\epsilon q^{*}p = (\delta q^{*}/\delta p)\ (p/q^{*})$

substituting $\tilde{q}\ PT = q^{*}$

(6.2) $\epsilon q^{*}p = (\delta(\tilde{q}\ PT)\ /\delta p)\ (p/(\tilde{q}\ PT))$

the first term on the right can be rewritten;

(6.3) $\delta(\tilde{q}\ PT)/\delta p = ((\delta\tilde{q}\ /\delta p)PT) + ((\delta PT/\delta p) * \tilde{q})$

multiplying through by $p/(\tilde{q}\ PT)$ to get elasticities

(6.4) $\epsilon q^{*}p = [((\delta\tilde{q}/\delta p)(p/\tilde{q})) + ((\delta PT/\delta p)(p/PT))] * (\tilde{q}\ PT)/p$

The total elasticity of demand for a product is a sum of the responsiveness of actual purchasers, and the adjustments in and out of the market by the rest of the community as price changes. These are respectively, the first and second terms on the right hand side. This derivation can of course be extended to other determinants, such as income or population change.

Probit Model.

The objective of the Probit statistical method is to predict the likelihood that an individual will choose one action over another given two alternatives. In terms of a regression model, this means translating the independent variables, which range over the entire real number line, to an interpretation of the binary choice dependent variable.

The resulting probability distribution might be represented as;

(6.5) $P_i = F(\alpha + \beta X_i) = F(I_i)$

where F is a cumulative probability function, and X is random.

We assume there exists a theoretical (but unobservable) index I_i which is determined by the variable X_i. The index I_i is also assumed to be a continuous variable, random and normally distributed. Thus we can write,

(6.6) $I_i = \alpha + \beta X_i$

What makes this problem different is that we assume the observations on I_i are not available, but instead fall into either of the (0,1) binary choice categories. Focusing on the decision to construct a sewage treatment plant, the index I_i would represent the strength of feeling in community i for the project under consideration. If we assume that the index is a linear function of the explanatory variables, then the Probit model can be used to estimate the relationship between the index and the independent variables.

Specifically,

$$
\begin{aligned}
(6.7) \qquad P_i &= F(I_i) \quad \text{if } 0 < F(I_i^*) < 1 \\
&= 1 \quad \text{if } F(I_i^*) \geq 1 \\
&= 0 \quad \text{if } F(I_i^*) \leq 0
\end{aligned}
$$

Appendix A outlines in more detail the transformation from index value (I_i) to probability estimate (P_i). Conveniently, standard normal probability distribution tables exist which relieve the investigator of tedious calculation (table 7.5). The use of this table in deriving probability estimates is demonstrated in the next chapter.

Tobit Model.

Tobit is often described as a hybrid between Probit and Ordinary Least Squares (OLS) regression. The procedure resembles Probit in its use of limited dependent variables, but produces regression coefficients similar to OLS. Instead of a discrete binary choice as in the probit model, the Tobit dependent variable is continuous in our case above the limiting value 0. In general, though, this limit may be any number; an upper bound, lower bound, or both. The model underlying Tobit may be expressed by the following relationship,

(6.8) $Y_i = \beta X_i + e_i$ if $\beta X_i + e_i > 0$ for $i = 1,n$

$Y_i = 0$ (limit) if $\beta X_i + e_i < 0$

Where, Y_i is the dependent variable

X_i is a vector of independent variables

β is a vector of unknown coefficients

e_i is an independent error term assumed to be normally distributed with a mean 0 and constant variance σ .

The expected value of Y_i is estimated as a function of the explanatory variables (X) weighted by the probability $Y_i > 0$. This can be written,

(6.9a) $E(Y_i) = 0$ if $I < I^*$

(6.9b) $E(Y_i) = I-I^* \geq 0$ if $I \geq I^*$

As with Probit, the $E(Y_i)$ can be expressed as an index I_i, and equals the difference between the estimated index (I) and the threshold level (I_i^*), where $I > I^*$ (see Appendix A).

Regression Variable Definitions.

Ten predictor variables were considered in the attempt to explain expenditures. To model as closely as possible the decision making environment, community information was taken from one year prior to construction. For communities where there has been no construction, 1984 data was used. In all instances financial data was adjusted to reflect the constant purchasing power of 1984 dollars.[1]

Dependent variable:

PER CAPITA TOTAL PROJECT EXPENDITURES. Both statistical procedures (Probit and Tobit) allow for limited dependent variables. The probit model makes the discrete, binary choice -- 0 for no action , 1 for expenditure. With Tobit, zero naturally means no expenditure, while the action variable is the value of total per capita project costs. In the latter case, the range is from $138 to $3583. The average is $572.

Independent Variables;

1. PER CAPITA OWN-COST is the price variable. Cross-sectional data typically lacks price variation, an essential element in demand

analysis. Grants, however, are not always evenly distributed -- some communities pay the entire expense themselves, others paid virtually nothing at all. The majority of those in the action group got either a 55% or 75% EPA grant. Non-action communities were assumed to reflect a 55% EPA grant in their thinking, and the full state 15% allotment. No additional funding (FmHA, DEED, or IRRRB) was assumed.

The price variable, in addition, reflects only the residential portion of the projects cost. This was found by subtracting all monies from the total project cost, and multiplying by the percent of non-industrial flows. This is justified since polluters (creameries, meat packers, etc) typically arrange payment with the municipality for a service they would otherwise have to produce. This was a factor in the costs of only a few facilities. Local residential costs ranged from $13.85 to $6369. The latter, not surprisingly, is for a yet uncommitted project. As with total expenditures, MPCA files were the data source.

2. INCOME reflects the community's median adjusted individual gross income, as published in the Department of Revenues Individual State Income Tax bulletin. The range is $8,570 to $15,060, with a mean of $11,710.

3. POPULATION or the size of the facility's user base is a factor in reducing costs for most systems. Communities size ranged from 64 to 8,628. The average community had 1,321 residents. This data is also from MPCA.

4. <u>POPULATION CHANGE</u> gives an indication of community population growth or decline. For action communities this was the period five years prior to construction, for all others it is the 1979-1984 period. The range was from a 75% decline to a 17% increase. The average, however, was nearly unchanged at -1 percent. The State Demographers Office was the source of this data.

5. <u>DEBT TO ASSET RATIO</u> is the quotient of the community's total bonded indebtedness, over total community assessed value. Both are from the Department of Revenue property tax assessment files. The sample average was .23, the range, from near zero to 1.35.

6. <u>REVENUE TO EXPENDITURE RATIO</u> is the ratio of the communitys' total revenue (all taxes, fees, and aids) to its total expenditures (all goods, services, and debts). Each account is reported in the Revenue Departments tax bulletin. Here, the sample mean was 1.06, the range is from a low of .683 to a high of 1.75 dollars of revenue for each dollar spent.

7. <u>PERCENT RESIDENTS 65 YEARS OR OLDER</u> attempts to account for life-cycle behavior. The higher this percentage, the lower the interest one might expect to find in long term investment. This would give the elasticity a negative sign. If, however, the demand for the service didn't diminish with age, but indeed increased, the sign would be positive. Unfortunately, local data is not available so county data

from the 1980 Census of Population is used. Sample data ranged from 8.2 to 21.4 percent elderly, with an average of 15.4 percent.

8. PERCENT OWNER OCCUPIED HOUSING Renters are often said not to the expense of additional services, and are thus more likely than homeowners to vote in support of them. In such a case a negative coefficient might be expected. Again, data only exists at the county level, and is from the 1980 Census of Population. Home owners occupied from 66.1% to 85% of the homes in the sample communities. In the average community the figure was 77.2%.

9. HOUSING STOCK INCREASES come from the difference between the 1970 and 1980 U.S. Census of Housing. This is local data, but the time-frame is limiting. The average community show a 25.4% increase in their housing stock, while the range is from 7% to nearly 60%.

10. POPULATION DENSITY can affect the cost of any rural service, particularly sewer systems. This data is from the State Demographers Office, and is in persons per square mile. The average is 1.70, the most dense community had 12.36 people per square mile.

ENDNOTES

(1) GNP price deflators, adjustment to 1984 dollars
Annual % change in selected prices index 1960 - 1985

Year	rate	factor
1985	-	0.963
1984	3.8	1.000
1983	3.8	1.036
1982	6.0	1.116
1981	9.6	1.221
1980	9.2	1.333
1979	8.6	1.448
1978	7.4	1.555
1977	5.8	1.645
1976	5.2	1.731
1975	9.3	1.892

Source: U.S Dept of Commerce, Bureau of the Census
National Data Book and Guide to Sources, Statistical Abstracts of the U.S. 1986 106th edition.

CHAPTER 7. FINDINGS AND CONCLUSIONS

Two sets of empirical findings are reported in this chapter -- probability estimates for observing an expenditure on public sewage treatment facilities in rural Minnesota, and demand elasticities for these services. In each case, interpretations of the results and implications of policy changes are offered. A summary is made and conclusions drawn about the future of sewage treatment in rural Minnesota, and the likelihood of achieving the Clean Water Acts compliance goals.

Findings: The Probit Model

Despite expectations about the importance of various demand shifters, a fairly simple model emerged from the Probit analysis. Price, income, and the rate of change in community size, best explain the likelihood of observing some capital expenditure on wastewater treatment facilities among rural Minnesota communities. The empirical results and their level of statistical significance are shown below (table 7.1). These coefficients are not probability estimates themselves, but represent marginal changes in the index I_i^*.

The basic Probit equation is,

$$(7.1) \qquad I^* = -.001634\ P + .000044\ Y + 4.776\ G$$

Where, P is the local project cost

Y is the median community income

G is percent change in population growth

Table 7.1 Probit Analysis Summary Statistics

Variable	Coefficient	Standard Error	T-ratio	Sig. Level
Own Price	-.001634	.000619	-2.64	.99
Income	.000044	.000024	1.87	.95
Percent Pop. Change	4.7767	2.565	1.86	.94

Log-likelihood = -26.125 Sig. level = .999

To apply these results, some additional information is helpful.

Table 7.2 Probit Variable Descriptive Statistics

Variable	Mean	Std Dv.	Minimum	Maximum
Own Price	609	1025	13.85	6369
Income	11710	1604	8570	15860
Percent Pop. Change	-.01245	.1350	-75.	17.

To show how this equation is used, we can evaluate the probability of observing a positive expenditure by a community with the characteristics of the sample mean. The calculation yields,

$$I^* = -.001634\ (609) + .000044\ (11710) + 4.776\ (-.01245)$$
$$= -0.539$$

This value (I^*) can be converted to a probability estimate using the equation shown in appendix A, or more simply by referencing the standard normal probability distribution table 7.5. For an index (or Z-score) of -0.539, the area under the curve to the left of the mean (I^* is negative) is approximately .205.

Therefore, the probability PR = .5 - .205 = .295.

This is interpreted to mean the likelihood of observing a rural Minnesota community with the characteristics of the sample mean community will make a positive expenditure on its sewage treatment system is .295, or a little less than 1 in 3.

Price.

The effect of changing the values for any variable can be investigated, holding all other values constant. For example, the impact of reductions in EPA grants from 75% to 55%, can be determined by allowing the per capita local costs to change from 10% above the average to 10% below, a swing of 20%.

The probability of seeing an expenditure at 10% below the average local cost ($609 * .90 = $548) is calculated the same as the example above. The index value is,

$$I^{*} = -.001634\ (548) + .000044\ (11710) + 4.777\ (-.01245)$$

$$= -.440$$

This represents an area under the normal distribution curve (again left of the mean) of .170, implying the conditional probability

$$PR = .5 - .170 = .330$$

Making the same calculation for the average community project at 10% above average costs ($670),

$$I^{*} = -.6388,$$

and

$$PR = .5 - .2389 = .261.$$

This suggests that changes in matching federal rates from 75% to 55% subsidy will reduce the probability of community expenditures by 7%, from .33 to .26.

Income.

Changes in community income may be examined in the same fashion. For instance, what would be the affect on the likelihood of community sewage treatment expenditures given a $1000 increase in the median community income? We know that for the average income ($11,710), the probability is .295. Calculating the index for an income at $12,710, with all other things held equal, yields

$I^* = -.495,$

and

$PR = .5 - .1900 = .310.$

Changes in income (at least of $1000) leave virtually unchanged the likelihood of observing an expenditure on sewage treatment.

Population Change.

Finally, expenditure effects from community growth or decline can also be evaluated with the average sample community of 1321 persons. Once more we know that .295 is the likelihood of a positive expenditure for the average sample community. Calculating I* for a 10% increase in population yields;

$I^* = .0617,$

and

$PR = .5 - .024 = .476.$

This indicates the likelihood of observing an expenditure increases from 30% to 48% with an increase of 10% in the average size community.

Other Models.

Ten independent variables were tested, all but three were rejected. The criteria for selecting the final model was its overall explanatory power, as measured by the significance level of a chi-square test of the log-likelihood function, and the level of significance among the individual coefficients. Also, because of the importance of price and income in demand theory, special interest was taken in these.

Of the demand shifters tried, absolute population size was never significant, nor was the debt asset ratio. Population size and population density, both strongly influenced the income coefficient - changing its sign and significance level.

Revenues to expenditures showed the right sign (positive), and often in the 90% range on significance. It was, however, dropped from the final model to improve the significance of the remaining variables. Neither percent owner-occupied, nor percent elderly, ever had a significant coefficient or added to the overall model. Changes in housing stocks were correlated with population changes, but was less robust and largely negative.

Findings: The Tobit Model.

The results of the Tobit method are similar to those of Probit, with the variables important in explaining local expenditures found to be price, income, and changes in housing stock.

The basic equation is,

(7.2) $\ln E = -3.170 \ln P + 2.416 \ln Y - .171\ H$

where, E is the natural log of per capita total project expenditures.

P is the natural log of per capita local project costs.

Y is the natural log of median community individual income.

H is simply the percent change in community housing stocks.

Unlike the complicated transformations of Probit, Tobit coefficients have a straight forward elasticity interpretation.

Table 7.3 TOBIT VARIABLE DESCRIPTIVE STATISTICS

Variable	Coef	Std Dv	T-ratio	Sig Lvl.
Own Price	-3.170	1.746	-1.816	.94
Income	2.416	1.222	1.976	.96
Percent Change in Housing	-.1713	.095	-1.790	.93

To aid in interpretation, some descriptive statistics are given in table 7.4. Recall, that price and income values are in their natural log form.

Table 7.4 TOBIT ANALYSIS SUMMARY STATISTICS

Variable	Mean	Std Dv	Min	Max
Own Price	5.609	1.251	2.63	8.76
Income	9.359	0.137	9.06	9.67
Percent Change in Housing	31.66	16.09	7.37	68.89

Price.

Price is inversely related to expenditures, agreeing with economic theory and previous empirical studies. The price coefficient is also highly elastic - more so than previous studies have indicated. A 10% increase in the local price of sewage treatment facilities will bring about a 31.7% decline in total expenditures. Therefore, the 20% reduction in EPA funding now in effect is likely to reduce spending by as much as 63.4% at the local level.

Income.

As expected, income is positively correlated with expenditures, and it too is highly elastic. All other factors held constant, a rise in community income of 10% would elicit an 24.16% increase in sewage treatment expenditures. A reduction in community income, such as the loss of General Revenue Sharing, would similarly reduce sewage treatment spending locally.

Housing.

The third variable of explanatory significance in the Tobit model is the percent change in community housing stocks. This coefficient is not in an elasticity form like price and income, but is instead interpreted in the normal regression fashion. A 10% increase in housing units leads to a 1.7% decline in per capita expenditures on sewage treatment facilities.

The inverse nature of this relationship is appealing, as one would expect some economies of scale to be achieve with small system growth. Adding the housing term squared, to test a scale economy hypothesis, however, was unsuccessful. Interestingly, inclusion of the housing variable improved the overall model, plus the individual price and income t-ratios significantly. One reason may be that in addition to the importance of housing stock changes, the variable is acting as a proxy for another, unexplained demand shifter.

The final Tobit results can be used to determine the changes in expenditures for any situation within the confines of the sample set. Remembering, of course, to first take the natural log of price and income, then the natural anti-log of the resulting expenditure calculation. Implicitly we assume the coefficients, here and in the Probit analysis, are valid over the range of sample observations. The weakness of this assumption should be kept in mind as one makes evaluations away from the sample mean values.

Other models.

Variables not specified in the final model behaved much the same as in the Probit analysis. Population, in absolute terms, created a great deal of disturbance in the general model, with the income variable in particular. No transformation, or combination such as a quadratic term, was able to correct this variability. Since changes in community population size could be negative, the term was included in its real form, but to no avail. Unlike the Probit results, population change was not a statistically significant explanatory variable in the Tobit approach.

The two balance sheet variables, debt to assets, and revenues to expenditures, proved to be of little explanatory help. Again, debt to assets was large and positive. Percent elderly, and percent owner-occupied housing created more variability than in the Probit model, and both had statistically insignificant terms. Also as before, population density contributed little or nothing to explaining the demand for local sewage treatment services.

Summary and Conclusion.

This study has explored the interaction between the collective demand for rural wastewater treatment services, and the intervention of government into their decision process. Price, income, and community growth (whether measured in population or housing stock), were found to be the factors most influential in the sewage treatment expenditure decisions of small, rural Minnesota communities. Fulfilling expectations, these results square with economic theory and previous demand studies. Further, they imply some important consequences for rural communities as policy changes outlined in chapter 1 take affect.

Support programs will be appropriating fewer dollars, reducing the ability of rural communities overall to reach compliance standards. The most direct impact, however, is likely to come from the decline in non-local cost sharing levels, and the more restrictive eligibility requirements. Higher local costs will result in fewer communities committing to projects, and a sharply lower willingness to spend local dollars when they do decide to build.

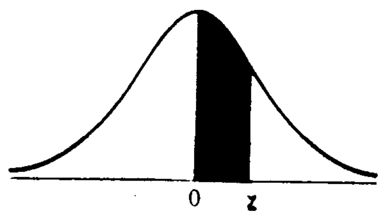
The cost to local residents is understandably a powerful factor in both the decision to build, and the level of spending that follows.

Similarly, one would expect community income to have an equally dramatic affect. But interestingly, though it is not clear why this is the case, expenditures only respond to changes in income after the decision to construct is made. This implies that the loss of one community income source, General Revenue Sharing, may not effect the level of new projects, but will impact the systems ultimate size and capacity.

Finally, a community's rate of growth or decline proved a significant consideration in the decision process. Population growth increased the likelihood of an expenditure. Once the decision was made, however, the growth in housing stock (or number of users) has little bearing on the level of spending. A small, inverse relationship was found between increases in the housing stock variable, and per capita expenditures.

Rural communities in Minnesota, and elsewhere, face a National compliance deadline of July 1, 1988, by which time they must meet or exceed the water quality standards established for their municipal sewage discharge. Clearly, the vast majority of these communities will not achieve this goal. What actions will be taken against them is uncertain. What is certain, however, is that the water pollution problems they generate will remain, if not grow.

Federal policies now in effect will have a predictable result. Fewer federal dollars will mean fewer projects being funded. Lower federal cost-sharing, or inversely, higher local costs have already caused many rural Minnesota communities to simply drop their construction plans. Less visible are the effects of lower community incomes, either due to the lose of general revenue sharing, or the personal income crisis in agricultural and mining areas. In many of these depressed regions people are moving to the larger, regional economic centers, reducing further the economic feasibility of small community projects.



Example If $z = 1.00$, then the area between the mean and this value of z is 0.3413.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2518	.2549
0.7	.2580	.2612	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.49865	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
4.0	.49997									

Table 7.5 Standard Normal Probability Distributions

APPENDIX A - STATISTICAL METHODS

Probit Model.

Kinsey (1984) describes the path from sample response to probability estimation for the simple Probit regression model. To begin, the response frequency of the dependent variable (Y_i) is assumed to be normally distributed with mean 0 and variance 1.

The simple regression model is;

(A.1) $$Y_i = \alpha + \beta X_i + e_i$$

where, Y_i = 1 if the decision is to act
= 0 if no action is taken

X_i = explanatory values, which can be qualitative or quantitative, and are assumed to be nonstochastic, or if stochastic, independent of e_i.

e_i = random error, which has a mean 0 and is independent of e_j ($i \neq j$).

A sigmoid curve (S) is produced when the percentage of observed positive responses are plotted against the (X) predictor variable (figure 5.1). A simple transformation produces the Probit scale, in which the association with X is put in a straight line relationship (L). By assuming the error term (e) is normally distributed about $\hat{Y}$ in equation (A1), the Probit value can be converted to a probability estimate for a positive Y value at any level of X.

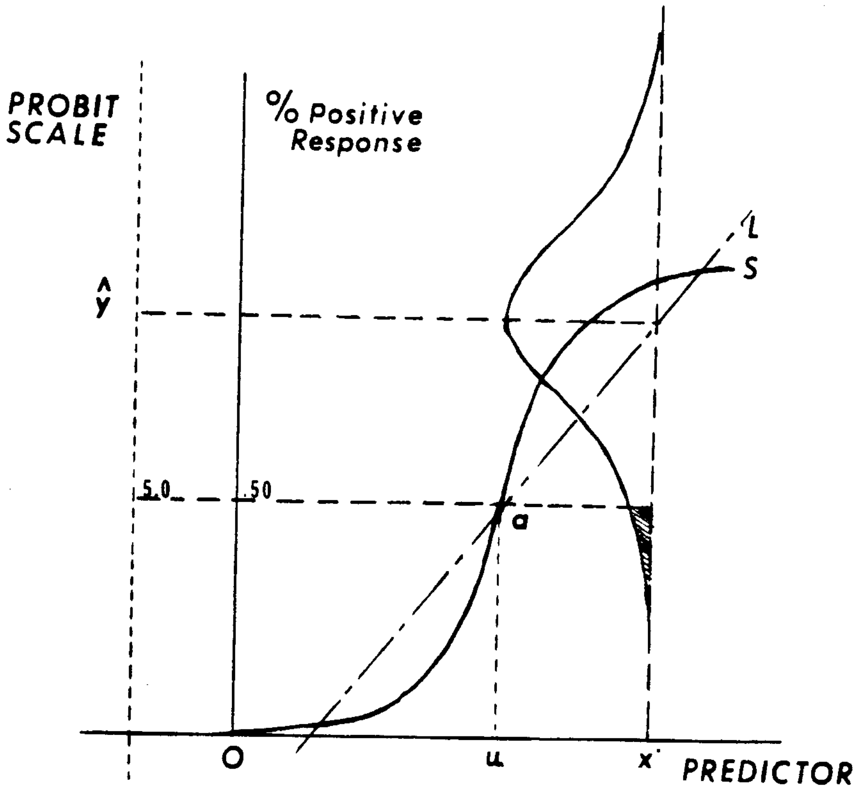


Figure A.1 - Probit Model

It is this transformation which assures the probability estimate is between 0 and 1. The equation for the single independent variable case is,

$$\text{(A.2)} \qquad P = \int_{-\infty}^{\frac{x-u}{\sigma}} \frac{1}{\sqrt{2\pi}} \exp\{-\tfrac{1}{2} e\} \delta e^2$$

where, $\hat{Y} = \frac{x-u}{\sigma}$ and $e = (Y-\hat{Y})$

Relating the normal distribution parameters to equation (A.1),

$u = -\frac{\alpha}{\beta}$ and $\sigma = \frac{1}{\beta}$

such that (A.1) can be rewritten;

$$\text{(A.3)} \qquad Y = \frac{x-u}{\sigma} + e$$

this may be expressed as an index I,

$$(A.4) \qquad I^* = \hat{Y} = \hat{\alpha} + \beta X = \frac{X-u}{\sigma}$$

where I^* refers to the threshold index level at which the response $\hat{Y}$ switches from 0 to 1.

Naturally, this concept can be extended to the multivariable case

$$(A.5) \qquad I^* = \alpha + \beta_1 X_1 + \ldots + \beta_1 X_n$$

The index is assumed to be normally distributed among the sample as a result of factors not included in the independent variables, and can be treated like any multiple regression model -- only differing by the lack of an error term. The transformation equation for converting from the probit scale to a probability estimate becomes,

$$(A.6) \qquad P = \int_{-\infty}^{I^*} \frac{1}{\sqrt{2\pi}} \exp\left(-\tfrac{1}{2} e\right) \delta e^2$$

Coming back to figure A.1, point (A) represents the 50 percent probability of a response at the mean value of X (u). For any other value X^*, the probability of a positive response is the area under the normal distribution curve which lays above the 5.0 level on the probit scale, (unshaded area) and where the mean of the normal distribution is at the estimated value of $\hat{Y}$.

Maximum likelihood methods are used to estimate the unknown I^* parameters. This procedure in effect says, if you are faced with several values of 0 (where 0 is the true parameter value) each of which might be the true value, choose the value which would have made the sample actually observed have the highest probability. The likelihood function is the product of the probabilities at a given index level, that Y = 1 or Y ≠ 1. The log of the joint probability forms of the likelihood functions are maximized with respect to the I^* parameters.

$$\text{(A.7)} \quad L = \prod_{t=1}^{T-n} (P_t)^{Y=0} \prod_{t=n+1}^{T} (1-Pt)^{Y=1}$$

where T = number of participants in the sample
n = number for which Y=0

Kinsey notes that in diagnosing the estimation results, the standard t-tests apply to individual parameters, and the adjusted likelihood ratio test is analogous to the R-squared test for OLS in goodness of fit.

Tobit Model.

The Tobit procedure calculates the expected value of Y_i, again, using a maximum likelihood iteration, and assuming Y_i and e_i are normally distributed. The probability of observing a positive expenditure is expressed as,

$$\text{(A.8)} \quad PR\ \{Y_i > 0 | X_i'\beta\} = F(I)$$

Where, F(I) is the same cumulative normal distribution as in the Probit model. Figure 5.2 shows the expected values of (Y) for Tobit and OLS regression methods. The probability of $Y_i > 0$ is shown as the shaded area under the normal curve between $-\infty$ and the limit 0, with the mean of the distribution falling at the estimated value of Y_i.

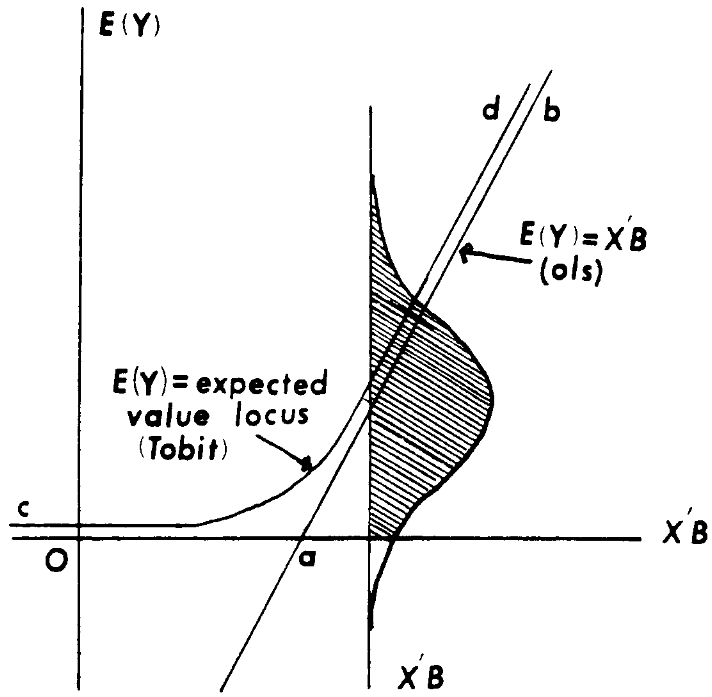


Figure A.2 - Tobit Model

The expected value $E(Y_i)$ for market participants is,

(A.9) $E(\tilde{Y}_i | I \geq I^* \text{ or } e_i > -X_i'\beta) = X_i'\beta + \sigma\, f(Z)/F(Z)$

where, $X_i'\beta$ is the index I

σ is the regression standard deviation

f(Z) is the unit normal density function, or the derivative of F(Z); the cumulative normal probability distribution.

$E(Y_i)$ over the whole sample is;

(A.10) $E(Y_i) = E(Y) * F(Z) = F(Z)Xi'\beta \quad \sigma (f(Z)).$

with $E(Y_i)$ assumed normally distributed mean 0, variance σ^2.

The essential difference between Tobit and OLS is apparent as $E(Y_i)$ approaches the limit 0. The Tobit estimation falls away (line CD), towards the limit, while the OLS estimate (line AB) cuts the horizontal axis to produce negative values for $E(Y_i)$. With Tobit, the $E(Y_i)$ is adjusted to account for the probability of participation, represented by the shaded area under the normal curve. Truncated data in an OLS procedure will bias the B coefficient by the $\sigma(f(Z)/F(Z))$ term in equation (A.10). This bias decreases with increases in the variance of Y_i, a correction adjusted for in the Tobit approach.

BIBLIOGRAPHY

JOURNAL ARTICLES

Bergstrom, T.C., and Goodman, R. P., "Private Demand for Public Goods." American Economic Review (63) 1973 pp 280-296

Borcherding, T.E., and Deacon, R.T., "The Demand for the Services of Non-federal Governments." American Economic Review (62) 1972 pp 891-901

Chernich, Howard A.,"Price Discrimination and Federal Project Grants." Public Finance Quarterly, Oct. 1981. pp 371-394.

Henderson, James M., "Local Government Expenditures: A Social Welfare Analysis." Review of Economics and Statistics (50) 1968 pp 156-163.

Holtz-Eakin, Douglas.,"Unobserved Tastes and the Determination of Municipal Services." National Tax Journal, Dec. 1986, pp 527-533.

Jondrow, James., and Levy, Robert A., "The Displacement of Local Spending for Pollution Control by Federal Construction Grants." American Economic Review. (74) pp 174-178.

Perkins, George M., "The Demand for Local Public Goods: Elasticities of Demand for Own Price, Cross Price, and Income." National Tax Journal. 1977 pp 411-422.

McDonald, John F., and Moffit, Robert A.,The Use of Tobit Analysis." The Review of Economics and Statistics. (62) 1980. pp. 318-321

Ohls, James C., Wales, Terence J.,"Supply and Demand for State and Local Services." The Review of Economics and Statistics, (54) Nov. 1972, pp 424-430.

Smith, David L.,"The Responsive of State and Local Governments To Federal Grants." National Tax Journal. Sept. 1968. pp 349-357.

Stinson, Thomas F., and Vogl, Karen A., "36 Years of Experience: Iron Range Resources and Rehabilitation Board.", Minnesota Agricultural Economist. February 1978.

Stine, William F.,"Estimating The Responsiveness of Local Revenue to Intergovernmental Aid." National Tax Journal, June 1985 pp 227-234.

Thraen, Hammond, and Buxton, "Estimating Components of Demand Elasticities from Cross-Sectional Data.", American Journal of Agricultural Economics. Nov. 1978, pp. 674-677.

Tobin, James.,"Estimation of Relationships for Limited Dependent Variables." Econometrica. (26) 1958.

Todd, Richard., "Note: Understanding TOBIT Analysis." June 1978.

BOOKS

Break, George F., Financing Government in a Federal System, Wash. D.C.: Brookings Institute, 1980

Chiang, Alpha C., Fundamental Methods of Mathematical Economics, New York, McGraw-Hill, 1984.

Due, John F., and Friedlaende, Ann F., Government Finance: Economics of the Public Sector, Homewood, Ill., Irwin, 1973.

Gramlich, Edward M., "Intergovernmental Grants: A Review of the Empirical Literature." in The Political Economy of Fiscal Federalism. ed. Oates, Wallace E., Lexington, Mass.: Lexington Books 1977 pp 219-239.

___________., "Reforming U.S. Federal Fiscal Arrangements.", in American Domestic Priorities, ed. Quigley, John M., and Rubinfeld, Daniel L., Berkley: University of California Press, 1985

Hirsch, Werner Z., The Economics of State and Local Government. New York: McGraw Hill, 1970

Johnson, J., Econometic Methods, New York; McGraw-Hill, 3rd Ed.

Mansfield, Edwin., Micro-economics: Theory and Applications., New York; W.W. Norton 1985

McGuire, Martin C., "The Analysis of Federal Grants Into Price and Income Components." in Fiscal Federalism and Grants-In-Aid., ed. Mieszkowshi, Peter, and Oakland, William, H., COUPE Papers On Public Economics No. 1., Wash: Urban Institute, 1979, pp. 31-50

Musgrave, Richard A., and Musgrave, Peggy B., Public Finance in Theory and Practice., New York: McGraw Hill, 1973

Oates, Wallace E., Fiscal Federalism., New York: Harcourt Brace, 1972.

Rosen, Harvey S., Public Finance., Homewood, Illinois: Irwin, 1985.

Savas, E.S., Privatizing The Public Sector., Chatham, N.J.: Chatham House, 1982. pp. 29-52

GOVERNMENT DOCUMENTS

Federal.

U. S. Congress. Clean Water Act Amendments of 1981. Committee Report on S. 1716, 97th Congress, 1st session, Report No. 97-204, 1981.

____________. Congressional Budget Office. CBO Study. The Federal Budget for Public Works Infrastructure. July 1985.

____________. Congressional Budget Office. Federal Policies for Infrastructure Management. June 1986.

____________. Congressional Budget Office. Efficient Investments in Wastewater Treatment Plants. June 1985.

U.S. Department of Agriculture., Economic Research Service., Economic Development Division. Availability of Selected Public Facilities in Rural Communities. March 1984.

____________., Economic Research Service., Economic Development Division. Characteristics of Projects Funded Under the Farmers Home Administration's Water and Wastewater Disposal Program. January 1982.

____________. National Infrastructure Committee for the Joint Economic Committee. Hard Choices: A Report on Infrastructure . February 1984.

____________., Office of Rural Development Policy. Better Country: A Strategy for Rural Development in the 1980's. April 1983.

U.S. Environmental Protection Agency, Report to the Administrator. Study of the Future Federal Role in Municipal Wastewater Treatment. December 1984.

____________. Office of Municipal Pollution Control. 1984 Needs Survey: Cost Estimates for Publicly Owned Wastewater Treatment Facilities in the United States. February 1985.

____________. Office of Water Programs. 1982 Needs Survey: Cost Estimates for Publicly Owned Wastewater Treatment Facilities. September 1983.

____________. Office of Water Programs. 1980 Needs Survey: Cost Estimates for Publicly Owned Wastewater Treatment Facilities. September 1981.

____________. Office of Water Programs. 1978 Needs Survey: Cost Estimates for Publicly Owned Wastewater Treatment Facilities. September 1979.

U.S. General Accounting Office. Costly Wastewater Treatment Plants Fail to Preform as Expected. November 1980

State of Minnesota.

Minnesota Pollution Control Agency, Division of Water Quality.,Wastewater Disposal Facilities Inventory, State of Minnesota, July 1, 1985.

____________, Municipal Needs List, Fiscal Years 1975-1985.

____________, Municipal Project List, Fiscal Years 1975-1985.

____________, Financial Capability Guidebook, June 1985.

Office of the State Auditor, Report of the State Auditor of Minnesota on the Revenue, Expenditure, and Debt of the Cities in Minnesota for Fiscal Year(s) Ending December 1975 (through 1985).

Commissioner of Revenue, State of Minnesota, Minnesota State Individual Income Tax Year(s) 1975 (through 1985).