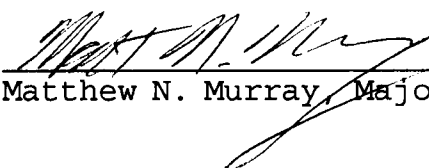
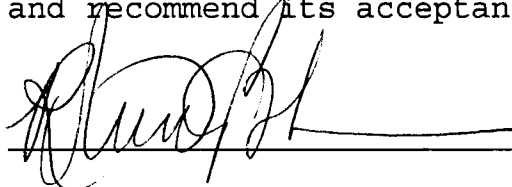


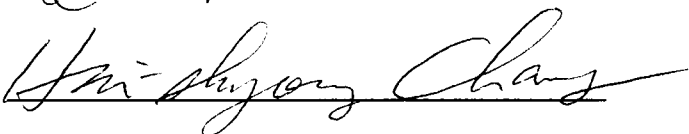
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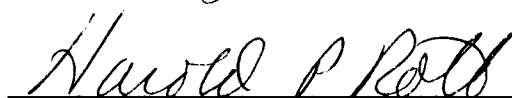
I am submitting herewith a dissertation written by Juei-Chi Shen entitled "Estimating State Expenditures on Public Education: An Econometric Study from Pooled Time-Series and Cross-Sectional Data." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.


Matthew N. Murray, Major Professor

We have read this dissertation
and recommend its acceptance:







Accepted for the Council:


Associate Vice Chancellor
and Dean of The Graduate School

Estimating State Expenditures on Public Education:
An Econometric Study from Pooled Time-Series and
Cross-Sectional Data

A Dissertation
presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Juei-Chi Shen

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ABSTRACT

This study focuses on the estimation of state spending on public education. The purpose of this study is to review previous empirical studies, to formulate a demand model for state public education based on the median-voter approach, and to estimate the demand equations for public education by region and for the U.S as a whole, using pooled time-series and cross-sectional data from 1982 to 1991.

The empirical results of this study reveal several findings: first, the hypothesis testing has verified that the estimation of the demand for public education by region is justifiable. Second, empirical evidence indicates that the dynamic model based on a partial adjustment mechanism pertaining to spending in public education is more desirable than the static one. Third, the GLS method based on a cross-sectionally correlated and time-wise autoregressive model provides better results for analyzing the demand for public education from state government than do the MLE or OLS methods. Fourth, the independent variables for empirical estimation are generally correct with their signs and are consistent with the theoretical expectations. Fifth, the impacts of public educational policies on state spending for public education are examined. Finally, the possibility of achieving complete wealth neutrality by adjusting federal aid is discussed based on the estimated tax-price elasticities.

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CHAPTER I

INTRODUCTION

Government expenditure on public education (elementary and secondary education) has been an important part of public-sector expenditure activity. Many empirical studies of spending on public education have been carried out in the past decades by using cross-sectional data. These cross-sectional estimates vary depending on the year chosen. In addition, most studies have concentrated on explaining the expenditure determination of public education of individual communities in the 1970s. Owing to the different choices of data, time, districts, price and quantity specifications of public education, it seems difficult to compare the results from the previous studies.

In general, public education services are the responsibility of local governments and are usually financed primarily by local taxes. However, the role of state governments cannot be overlooked. In the 1980s, there were 33 states that took an increasing role in financing public education, and there were 26 states whose revenues for public education from state sources exceeded those from local sources. According to Table I-1, the share of public education expenditure financed by states increased from

TABLE I-1
PERCENTAGE DISTRIBUTION OF
REVENUE FOR PUBLIC EDUCATION
(PERCENT)

	Local	State	Federal
1970s	48.6	42.4	9.0
1980s	44.8	48.3	6.9

Source: Digest of Education
Statistics, 1993

42 percent in the 1970s to 48 percent in the 1980s, while the local share decreased from 49 percent to 45 percent. These changes show that state spending has become the dominant feature of public education and suggest that public education demand from state government has been increasing.

This study will focus on how state expenditure on public education is determined. The purpose of this study is to formulate and estimate the demand for public education from state government in the United States as a whole, and by region, using pooled time-series and cross-sectional data from 1982 to 1991.

There are several advantages to this study over previous studies. First, differences in the demand for public education can be investigated through the use of consistent data and an estimating approach. In addition, the use of

state-level spending on public education can avoid a problem with data aggregation since each state government has only one school system to manage or control in the state.

This study is organized as follows. In chapter II, previous studies pertaining to expenditure determination in public education are reviewed. Chapter III introduces the standard theoretical model of the demand for public goods and formulates a demand model for public education. Chapter IV specifies estimatable equations and introduces the estimation method. Empirical results are explained in chapter V. Finally, chapter VI provides an overview and summary of major findings and conclusions.

A particular contribution of this study is that a dynamic model of the demand for public education from state government is formulated and, by using pooled cross-sectional and time-series data, estimated. The impacts of public policies on public education are then addressed, based on estimation results.

CHAPTER II

REVIEW OF PREVIOUS EMPIRICAL STUDIES

The purpose of this chapter is to review and analyze previous studies relating to the determinants of government expenditure on public education. The emphasis of this review is on empirical results and the methodology used to estimate government expenditure on public education. For purposes of this review, it is useful to divide the vast number of previous studies into two groups according to the types of data employed. The first group consists of macro-data-based studies. The data for empirical studies in this group are taken from the expenditure statistics published by government or private organizations. The other group consists of micro-data-based studies, in which the data sources come from surveys.

Macro-Data-Based Studies

There are many empirical studies of the determinants of spending in public education using macro data. These studies can be divided into several subgroups based on the estimation methodology employed.

Ad Hoc Determinants Studies

The early determinant studies generally used a single equation regression model to explain government spending in public education using cross-sectional data. A number of independent variables were used to explain the variation in the expenditure variable: per capita income, population, population density, and other socioeconomic variables. Also, state aid and federal aid were commonly used to explain expenditure in public education. However, in these studies the underlying theoretical model of spending determinants in public education is normally weak or absent. In addition, the own-price variable is absent from the regression equation. The usual assumption is that prices do not vary across units of government at a specific point in time. Most empirical studies of this group were included in the survey by Bahl (1969) and Denzau (1975).

The early determinant studies of public education expenditure focus primarily on measuring the degree between per capita or per student education spending and income, state aid, and other socioeconomic factors. According to the empirical results, the level of income exerts a significant and positive effect on the level of spending for public education. It was interesting that the estimates showed the income elasticity of public education to be less than one.¹

¹See Denzau (1975), p. 244.

Another interesting question in the earliest studies of spending on public education is the investigation of whether state aid is stimulative or substitutive for local expenditure. It was generally approached by regressing per student state aid and other independent variables on per student education expenditure. If the regression coefficient of the state aid variable is less than one, the effect is substitutive. If the regression coefficient is greater than one, the effect is stimulative. Renshaw (1960), in his study of interstate differences in school spending for 48 continental states, found that an additional dollar of state aid tended to raise school spending by \$0.16, or a coefficient of 0.16, which implied substitution. According to Renshaw's results, the flypaper effect seems to exist since an additional dollar of income raises educational spending by \$0.14.² Bishop (1964), in examining the effect of state aid on New England, also concluded that the state aid was substitutive.

Struyk (1970) examined the effects of state aid on local public school expenditure using cross-sectional data for the 1965-66 school year, from 140 school districts in New Jersey. In his study, he specifies a simultaneous model with state aid as an endogenous variable. The coefficient suggests that

²The flypaper effect is that an additional dollar of lump-sum aid increases public spending more than an additional dollar of private income.

a dollar increase in state aid per student results in an increase in per student expenditure of \$0.65. But, this coefficient is not significantly different from zero.

Utility-Maximization Models

The early determinant studies have provided useful information about the major factors related to expenditure on public education, but the absence of a model for the decision-making process leads to the limitation of application to policy. In the late 1960s and 1970s, there appeared important contributions to the theoretic development of the demand for public goods. A number of empirical studies adopted the utility-maximization model from consumer theory as a basis for analyzing public expenditure behavior. The utility-maximization model was used to derive testable hypotheses concerning expenditure determinants, and to specify the functional form of estimating equations. Studies following the utility-maximization approach have overcome some of the problems found in the earlier studies.

Basically, the utility-maximization model involves the decision-making process and the political, economic and institutional constraints upon it. The functional form of the estimating equation is determined by the choice of a specific utility function and budget constraints.

In general, empirical studies based on the utility-

maximization model can be divided into two categories which reflect different views of the decision-making process. The first is the median-voter model, which follows the individual choice theory of optimization to derive demand functions for the pivotal voter. If individual preferences are single-peaked, the utility function of the median voter becomes the community utility function and the median-voter demand becomes the community demand for public education.³ A vast number of studies follow this approach to formulate an operational estimating equation of the demand for public education.

A primary strength of the median-voter model is that community demand can be reduced to observations on a single consumer/voter, which in turn allows one to derive income and price elasticities of demand for public education. The key problem raised by the application of the median-voter model is identifying the characteristics of the median voter. If the median-voter model is appropriate in determining the median voter's demand, one should, among other factors, use the person with the median income, the median house value, and the median tax bill in the community.

The median-voter model generally focuses on the implications for individual fiscal decisions. Barlow (1970) seemed to be the first one to estimate the demand for public

³See Holcome (1980), p. 260.

education by using the median-voter approach. His cross-sectional data consist of 52 school districts in Michigan for the 1961-62 school year. The price variable is defined as the percentage of taxable property that is nonindustrial. The empirical results show that the price and income elasticities are less than one.

In a 1972 paper, Borcharding and Deacon (B-D) developed a demand model for public goods with a theoretical foundation. Based on the theoretical model, B-D derived a logarithmic per capita expenditure equation for estimating the demand for public goods. In order to handle the problem of price measurement, B-D assumed that public services are produced by a Cobb-Douglas production function, and that under some assumptions, the marginal cost of public good can be derived as a function of the wage. B-D used their model to estimate the demand for public education based on aggregated data from 48 states for 1960-64. Their results indicate that demand for public education is price elastic, and the income elasticity is close to one.

Peterson (1975), following the concept of the median-voter model, formulated a demand equation for school expenditure. In his study, the tax price of public education is defined as the ratio of median house value to total property value in the school district. He estimated demand equations using data from California, Michigan, New Jersey,

New York, and Kansas City Standard Metropolitan Statistical Areas (SMSA) for the 1968-1971 school years. All of his price elasticity estimates are less than one. Income elasticity estimates are greater than one except for California.

Ladd (1975), in a study of education in 78 communities in the Boston SMSA, examined how fiscal capacity and the composition of the property tax base affect education expenditure. Basically, Ladd followed and extended the Bergstrom and Goodman (B-G) approach to include the value of housing stock in her model. In her study, the demand for public education is determined by income, tax price, wealth, state aid, federal aid, and other socioeconomic variables. The tax price of the median voter consists of two components: the local tax share (LS), which is affected by the matching rate on intergovernmental aid, and the residential fraction of the revenue base (RB). In an attempt to examine whether the property tax on commercial and industrial property is shifted forward, the RB is defined as $1 - \alpha C - \beta I$, where C and I are the fractions of the property tax base that are commercial and industrial, respectively. The terms α and β represent the portions of the commercial and industrial property tax that are shifted. If α and β are equal to one, then local residents do not pay the commercial and industrial property tax. If they are zero, then the tax burden is on the local residents. In addition, Ladd assumes that there is

complete rivalry in public education and that the marginal cost of public education is the same for all communities.

Ladd searched over various values of α and β to fit the expenditure equation and chose those values that minimize the sum of squared residuals. The estimated values of α are 0.71 and 0.79 and values of β are 0.39 and 0.45. These results imply that local residents bear more of the tax on industrial property than on commercial property, and a larger proportion of the tax burden on industrial property is perceived to be shifted.

In Ladd's study, demand is price inelastic. The income and wealth elasticities are positive as expected and their estimates are less than one. Ladd notes that an accurate income elasticity cannot be obtained due to the positive relationship between income and wealth. State aid and federal aid have positive effects on educational expenditure. Based on state-aid elasticities, the marginal propensity to spend out of an additional dollar of state aid is close to \$0.50. For federal aid, the marginal impact is about \$1.10 based on federal-aid elasticities.

Billings and Folsom, in a 1980 study, estimated educational expenditure using 1972-73 data from Arizona, based on equations specified by Ladd. The results show that the voter-perceived fiscal capacity of Massachusetts is different from that of Arizona. Price and income elasticities

are less than one. But, the coefficient of income has a negative sign. State aid and federal aid have positive effects on educational expenditure; and the marginal impact from state aid is less than one, while marginal impact from federal aid exceeds one. These findings are similar to those from Ladd.

Feldstein (1975) also used Massachusetts data for 1970 to estimate the demand for public education. He tried to look at the wealth neutrality implication of a power equalizing aid scheme. In his study, the log-linear expenditure equation is implicitly based on the median-voter model. The independent variables include price, income, wealth, state aid, federal aid, and some demographic factors. The price term is equal to one minus the marginal matching rate.

Feldstein's empirical results show that income and wealth elasticities are positive and less than one. The price elasticity is quite large, which implies that a grant program can effectively neutralize the influence of wealth in local education expenditure.

Perkins (1984) also tried to examine the wealth neutrality issue using the same approach as Feldstein's from Massachusetts data. His study relies on a larger sample size. The econometric results indicate that demand for public education is price inelastic and all various estimates (absolute values) are much lower than those from Feldstein.

These results, contrary to Feldstein, show that the influence of wealth in public education cannot be effectively neutralized by the grant program.

Perkins (1977), in a study of the demand for local public goods using 1970 data for 38 Massachusetts communities, specified an extended B-D model. Ten public goods and intergovernmental aid are included in his model. Aid is taken into consideration from two ways: (1) all aid enters price term, and (2) all aid enters income term. His econometric results show that public education is price inelastic. The income and aid elasticity estimates are close to one.

Inman (1978) followed the B-G approach and specified a theoretical model to estimate the demand for public education using a sample of 58 Long Island school districts. In his study, price term incorporates income tax deductions from the property tax. The tax price is determined by the net burden of property tax to a median-income family and the ratio of median-income home value to total property tax base per student. Four versions of the empirical models are estimated by ordinary least squares (OLS) and two-stage least squares (TSLS). All estimates of price, income, and aid elasticities are less than one.

Lovell (1978) used Connecticut data to estimate the demand for public education by assuming that a household's

utility function was of the constant elasticity of substitution (CES) form. In his study, the tax-price term incorporates the skewness of the income distribution, owner-occupied houses, dwelling-house value as a fraction of the total house value, and marginal state aid. His econometric results show that price and income elasticities are less than one. But, Lovell's results provide further evidence that the tax price is a fundamental factor in the determination of spending on public education.

The studies described above are implicitly or explicitly based on a median-voter model and hence rely on aggregated data. The major difference among these studies lies in the formulation of the tax-price term. The purpose of these studies is to discover the importance of various factors in the determination of public educational expenditure through econometric analysis. These studies are usually based on different data and model formulations. Except for a few studies, demand for public education is generally found to be price inelastic. Income elasticities are also found to be less than unity. As for aid elasticities, it is found that they are positive and less than one. Some demographic factors are used for empirical analysis, but the results are found to be inconclusive.

The second group of utility-maximization studies is based on the assumption that the school board tries to

maximize its objective function. It is usually assumed that the school board maximizes a utility function with educational expenditure and tax burden as the major arguments, subject to a budget constraint for the district. Community taste and demographic variables may also enter the utility function.

Barro (1972) examined public school expenditure using aggregated cross-sectional data from local school districts for 48 states. In his study, nine multiple regression equations for school years 1951-52 to 1967-68 are estimated. The budget constraint specifies that total expenditure by the district must be equal to the sum of local school tax receipts plus lump-sum state and federal aid. The price index of school input is measured by salary component from instructional staff and other inputs into schooling.

Barro's empirical results show that the estimated price elasticity of demand for educational expenditure is found to be between 0.5 and 0.9. A dollar increase in personal income will lead to a \$0.05 increase in expenditure. An additional dollar of state and federal aid is found to increase total school expenditure by about \$0.25 to \$0.30, which implies a stronger expenditure impact for intergovernmental aid relative to income.

Stern (1973) tried to explain public education expenditure in 157 Massachusetts school districts for the

school year 1968-69 by maximizing school board utility. Local school tax rates were determined by state aid, federal aid, property value, and local expenditure level. Independent variables consist of mean income and some demographic factors; a price term is not included. Stern concludes that an extra dollar of lump-sum aid will reduce \$0.50 from local expenditure. The estimated income coefficient is found to be 0.029.

Grubb and Osman (1977), based on a model of school district behavior, investigated the determinants of school revenue and expenditure variation using 1971-72 cross-sectional data of 242 California school districts. The dependent variables used in his study include local revenue and total expenditure per student. Property valuation, income, state aid, federal aid, and other socioeconomic variables are included as the independent variables. It is found that the property valuation is the most important variable to explain local revenue and total expenditure per student. Income is the second-most important variable. Approximately 40 percent of lump-sum state aid is used to reduce local revenue, compared to 50 percent of federal aid. Grubb and Osman also find that the degree of substitution is stronger for large school districts than for small school districts.

Tresch (1974) estimated eight state expenditure

functions, including public education, by using pooled time-series and cross-sectional data. In his study, it is assumed that states act as consumers and maximize a state utility function. In the specification of education equation, the education share depends on percentage of children, state per capita income ratio, percentage of low-income families, and the ratio of grants-in-aid to income. The econometric results indicate that the estimated cross-sectional coefficients may not be reliable due to slope heterogeneity through the sample period.

According to the studies described above, both groups of utility-maximization models are quite similar in terms of methodology. Both approaches assume if decision-makers are trying to maximize utility subject to a budget constraint based on the decision-making process. However, there are some differences in the specification of models between these two approaches. In the median-voter model, public education is supplied in a competitive manner in response to the preference of the median voter. The school-board-behavior model, on the other hand, does not always respond competitively to citizen's preferences. The median-voter model generally uses median income as an explanatory variable, while personal income is the relevant income variable in the school-board-behavior model. Furthermore, the school-board-behavior models seem to focus on the impact of

intergovernmental aid, while the median-voter models place emphasis on tax-price and income elasticities. Both approaches may use the same variables and methods to estimate spending in public education, but the results may have different implications. In general, based on the median-voter approach, the demand elasticity for public education can be obtained. However, the school-board-behavior models can only derive expenditure elasticities.

Hedonic Prices Approach

The utility-maximization studies provide little insight into the magnitude of the income elasticity of household demand for public good; and tax shares do not reflect the price to the consumer of additional units of public output.⁴ Hedonic price methods can be used to solve these two problems.

McDougall (1976) used the hedonic price approach to estimate the demand for public education from Los Angeles data for 1970-71. In his study, it is assumed that public education service differentials are reflected in house values. McDougall uses the sum of grade-twelve median scores on the Iowa Tests of Basic Skills as the measurement of public education service. The demand function for public education is estimated through a two-step procedure. The

⁴See McDougall (1976), p. 266.

first step estimates the hedonic relationship between house value and house characteristics to obtain price functions and an implicit price series for public education service. The second estimates the demand function by regressing public education service on the implicit prices and other socioeconomic variables. The econometric results show that the price elasticity is 1.678 and income elasticity is 1.224.

The hedonic price approach can be used to measure the implicit price of public education and then identify the demand curve. However, in practice, the application of the hedonic pricing technique may have some limitations.⁵ For example, the data for a hedonic study are not exacting. In addition, sufficient market data for reliable estimations may be difficult to obtain.

Recent Studies

There have been several utility-maximization studies of public education that have appeared recently in the literature. Baum (1986) estimated the demand for and production of educational output for 46 Los Angeles County school districts by using a simultaneous model. In his study, educational service is assumed to be produced by a production function with capital and labor as inputs and test scores or output are determined by instructional services and student

⁵See Mitchell and Carson (1990), pp. 80-81.

characteristics. From this, Baum derives the test score output or cost function.

The demand function for test scores is obtained from the assumption that individuals maximize a utility function with a private good and test scores as the two key arguments. The tax-price term incorporates the household's tax share and instructional expenditure. Econometric results indicate that the demand for test scores is affected by the median voter's income and tax price. The price and income elasticities are found to be significantly less than one. When, like most studies, expenditure per student is used as a proxy of educational output, income and price elasticities are also found to be less than one.

Dynarski, Zampell, and Schwab (1989) examined the role of local characteristics in the production of education. They derived an output-maximization model to explain the production of education by a sample of California school districts for 1979-80. In their study, the educational output is measured by the district third grade total score on the California Assessment Program test battery. Income, purchased inputs, and local characteristics are included as independent variables. Econometric results imply that the demand for education achievement may be much more income-elastic than the demand for educational expenditure. The reason is that Dynarski et al. allow income to enter price term and then to

affect the cost of providing the public education service. When income lowers the cost of education production (environmental effect), the income elasticity of quantity demanded will be greater than income elasticity of expenditure if the price elasticity of demand is less than one. Without considering the impact of income on price, the income elasticity of demand may be underestimated.

Todo'-Rovira (1991) investigated the determinants of education expenditure using aggregated local data for 50 states in 1977. In his study, expenditure on public education is the dependent variable. Median income, the dispersion of income, the progressivity of taxes, and some city characteristics are independent variables. His major contribution is that the dispersion of income and the progressivity of taxes, which have not been included in the previous studies, are used to explain the determination of public educational expenditure. The empirical results show that the estimated coefficients for both variables are negative. The median-income elasticity is larger than those usually reported by the median-voter literature when the dispersion of income is included in the estimated equation. Based on the estimate of the population, the crowding coefficient is equal to one, implying there are no economies of scale in the provision of public education.

These recent studies attempt to use local

characteristics or distributional characteristics to estimate the demand for and supply of public education. These factors seem to have effects on the income coefficient. Especially, when environmental factors are considered, allowing income to indirectly affect the demand for public goods through the tax price will yield a difference between the income elasticity of demand and the income elasticity of expenditure, unless the tax price elasticity is one. Few of these factors have been discussed before in the estimation of public education spending.

Micro-Data-Based Studies

In order to relate public expenditure directly to the individual characteristics of consumers, some studies have used micro-survey data to estimate the demand for public education. The advantage of this approach is that detailed individual characteristics on income, demographic, and other socioeconomic variables can be included. Moreover, survey data also can provide information on how each consumer compares actual levels of provision to desired levels.

Rubinfeld (1977) developed a logit model to study the voting decisions of individuals in a local school millage referendum in Troy, Michigan, in 1973. His logit equation is of the form:

$$(2.1) \quad \text{Log} \frac{\text{Prob}(\text{yes})}{1-\text{prob}(\text{yes})} = \beta_1 + \beta_2 Z_2 + \dots + \beta_k Z_k$$

where the Z_i represents the voting attributes and prob (yes) represents the probability of a voter supporting the millage referendum. In his model, the price of education is measured as the amount of local taxes which the household must pay if school spending per student is raised one dollar. According to the estimated equation, the income elasticity is found to be about one. The demand for public education is found to be price inelastic. All of the coefficients for the number of children in public school are found to be significant and positive.

Bergstrom, Rubinfeld, and Shapiro (1982) also constructed a logit model to examine the demand for public education by using a sample of 949 consumers/voters from a survey in Michigan in 1978. In their studies, four models are estimated using different sets of explanatory variables. In all cases, the price and income elasticities are found to be less than unity. The authors claim that analysis of the Michigan data yields income and price elasticities of demand for public education similar to those obtained in aggregate studies using median-voter models. Demographic variables also show some important effects on public school expenditure. The income elasticity of demand falls as more variables are added, implying several variables added seem to be positively

associated with income and the demand for public education.

The micro-data-based approach relies on surveys of voter preferences. Using this method, it is possible to obtain the effects of many individual characteristics on public education demand. Moreover, one does not need to call upon a median-voter model or any other theory of collective decision making for assistance to estimate the demand for public education. In general, the responses to surveys may be consistent with actual voting behavior. The potential limitation of micro analysis is that respondents to surveys may not exactly report the actual situations. Data from surveys are only qualitative and seldom provide a desired spending level. Furthermore, survey data are much more expensive to obtain than the data for aggregate studies.

Summary

In this chapter, major previous studies of the demand for public education or the determinants of spending on public education have been examined. Government expenditure on public education can be analyzed by one of the following approaches: an ad hoc determinants approach, a median-voter approach, a school-board approach, a hedonic prices approach, and a micro-survey approach. Each approach has its analysis limitations. Among these approaches, the median-voter approach has been used most widely for estimating the

expenditure on public education. The estimates of price, income, and intergovernmental aid elasticities from selected previous studies are summarized on Table II-1.

According to Table II-1, most previous studies attempt to use 1970s cross-sectional data to explain spending in public education. The demand for public education reveals a confusing array of empirical results and there is a lack of consistent explanation. The price elasticity varies from 0.14 (Baum, 1986) to 1.68 (McDougall, 1976). The income elasticities are positive except for those from Billings-Folsom, but the estimates have wider variation than price elasticities, ranging from 0.15 by Grubb-Osman (1977) to 3.65 by Dynarsky et al. (1989). Table II-1 also indicates that intergovernmental aid elasticities are generally smaller than price and income elasticities but still display a wide variation.

One explanation for the divergence of results noted above, is that studies are based on different set of cross-sectional data. In addition, different behavioral responses are expected from on different consumer groups. Furthermore, variation exists in model specification, estimation, and technique. Other factors, such as changes in policies for school finance, changes in demographics, or changing trends in school performance also may cause the divergence of results. The predominance of cross-sectional studies about

TABLE II-1

COMPARISON OF PRICE, INCOME, AND AID ELASTICITIES
OF DEMAND FOR LOCAL PUBLIC EDUCATION

Study	Sample	Elasticity		
		Price	Income	Aid SA/FA
Barlow (1970)	Mich. (1960)	-0.34 (-8.5)	0.64 (6.4)	
Barro (1972)	48 States (1951-67)	-0.50 (nr) -0.90 (nr)		
Borcherding- Deacon (1972)	50 States (1960-64)	-1.13 (-3.8) -1.21 (-2.3)	0.94 (5.9) 1.04 (5.5)	
Peterson (1975)	Five Samples (1968-1970)	-0.36 to (-6.2) -0.70 (-6.4)	0.84 to (7.9) 1.35 (12.5)	
Feldstein (1975)	Mass. (1970)	-1.0 (-5.4)	0.48 (6.9)	0.07/0.14 (5.4)/(5.2)
Ladd (1975)	Boston SMSA (1970)	-0.31 (-2.7) -0.65 (-3.2)	0.46 (2.9) 0.42 (2.7)	0.03 (0.3) 0.04/0.11 (3.4)/(4.2)
McDougall (1976)	California (1970-71)	-1.68 (-5.1)	1.22 (5.5)	
Grubb-Osman (1977)	California (1971-72)		0.15 (nr)	
Perkins (1977)	Mass. (1970)	-0.29 (-1.7) -0.86 (-2.2)	1.02 (4.5) 1.07 (4.9)	
Lovell (1978)	Conn. (1970)	-0.82 (-5.9)	0.65 (nr)	

TABLE II-1 (Continued)

Study	Sample	Elasticity		
		Price	Income	Aid SA/FA
Inman (1978)	Long Island (1970)	-0.37	0.59	0.25/
		(-5.3)	(6.6)	(2.3)
		-0.46	0.77	
		(-4.2)	(6.4)	
Rubinfeld (1977)	Detroit (1973)	-0.56	0.96	
		(nr)	(nr)	
		-0.69	1.12	
		(nr)	(nr)	
Billings- Folsom (1980)	Ariz. (1972)	-0.25	-0.12	0.72/0.84
		(-8.1)	(-0.5)	(5.4)/(2.1)
		-0.27	-0.75	0.17/0.07
		(-6.2)	(-2.3)	(1.3)/(4.5)
Bergstrom et al. (1982)	Mich. (1978) Mich. (1973)	-0.39	0.64	
		(-1.6)	(1.6)	
		-0.15	0.38	
		(-10.0)	(12.7)	
Perkins (1984)	Mass. (1970)	-0.67	0.88	0.01/0.00
		(-3.2)	(11.0)	(2.2)
		-0.70	0.95	
		(-3.5)	(11.5)	
Baum (1986)	California (1969-71)	-0.14	0.61	
		(-3.9)	(8.7)	
		-0.21	0.32	
		(-7.0)	(2.7)	
Dynarski et al. (1989)	California (1980)		3.65	
			(nr)	
Todo'-Rovira (1991)	US States (1977)		0.93 to	
			(3.9)	
			2.11	
			(5.5)	

Notes: SA and FA indicate state aid and federal aid, respectively.
 Figures in parentheses are t-values and nr indicates that t-values are not reported.

public education may be due to the shortage of good time-series data.

Cross-sectional studies assume that the behavioral structure is constant across all units of observation. It is implicitly assumed that what is true among different districts at a given point in time will be true for a particular district over time. As a matter of fact, the inferences can be misleading. For cross-sectional data, the coefficients provide no information about the temporal variability between educational expenditure and income or other variables. These elasticities only show that at a given point in time, interdistrict differences in education expenditure are smaller or greater than the differences in income or other variables among these districts.⁶

Based on the above survey, except Tresch (1974), most other studies of expenditure on public education have focused on local expenditure or state and local expenditure. The demand for public education from state government has received little attention. In fact, public education has become the most important "industry" for state governments. This study attempts to fill in this gap by using cross-sectional and time-series data combined with the median-voter model to examine the state expenditure on public education (K-12).

⁶See Bahl (1969), p. 198.

CHAPTER III

MODEL SPECIFICATION

The model must be specified at both the theoretical and empirical levels. In this chapter, the standard theoretical approach to local public good expenditure determination specified by Borcharding and Deacon (1972) and Bergstrom and Goodman (1973) is discussed first. Then, based on the standard theoretical approach, an alternative demand model for public education is formulated.

Review of the Standard Theoretical Approach

The Borcharding and Deacon (B-D) and Bergstrom and Goodman (B-G) models are fundamental to the specification of a demand function for public goods. Both models integrate supply and demand factors and are based on a neoclassical framework. Fiscal choices are assumed to be consistent with constrained maximization of the median voter's utility function.

There are five assumptions for the median voter model:⁷
(1) there is a given tax schedule and a single public service.

⁷These assumptions are based on Inman (1978), especially on pp. 45-46.

- (2) Consumers/voters have single-peaked preferences.
- (3) Voters vote their preferences, do not vote strategically and can be ordered along a continuum from low to high demanders of the public service.
- (4) The rule for fiscal choice is to select that service level which will defeat all others in a majority rule election.
- (5) The public service is that demanded by the consumer-voter with the median income.

The structural model specified by B-D focuses attention on the supply side (unit cost) of the local public good problem. In order to specify the price of the public good, B-D consider the share of the marginal cost that is borne by the individual and the amount of the public service that the individual captures from the marginal unit.

In order to derive the marginal cost of the public good (Q), B-D specify a continuously differentiable Cobb-Douglas production function homogenous of degree one. Factor inputs include labor and capital. Under the assumption of efficient production, the marginal cost can be expressed as a function of wages and labor's share, when labor's wages are assumed to vary across jurisdictions, and rental rates for capital are assumed to be constant across all jurisdictions. The public good is supplied at a constant price as perceived by the individual.

Based on B-D the model, the marginal cost and unit cost of the public good can be expressed as

$$(3.1) \quad TC/Q = C = C_q = aW^\beta$$

where TC = total cost;

C = unit cost;

C_q = marginal cost;

a = a constant;

W = labor wages; and

β = labor's share.

In general, a private good can be completely parceled out to individuals and independently consumed while a public good is provided in such a manner that each unit produced must be consumed equally by each individual within a society without diminishing its quality or quantity. However, in practice it may not be this easy to distinguish between public goods and private goods. In order to specify the price of the public good, the B-D model introduces the amount of the service that the individual can capture from the marginal unit supplied via the concept of a capturability (congestion) parameter. B-D assume that the amount of public output to the individual is determined by the amount of output produced and the number sharing that output as follows:

$$(3.2) \quad q = Q/(NP)^\alpha$$

where q = the quantity of public good consumed by an individual;

Q = the number of units of public good produced;
 NP = the population; and
 α = the degree of privateness for the public good
 (capturability parameter).

The term α is used to measure the degree to which the public good is nonrival. If α is equal to zero, then the public output is a pure public good and $q=Q$. If α is equal to one, then the public output is completely rival and like a pure private good. Intermediate values ($0 < \alpha < 1$) imply quasi publicness/privateness.

The specification of (3.2) implies that for $\alpha > 0$, capturability is decreasing at the margin. In addition, note that the capturability elasticity $\alpha = (dQ/dNP)/(Q/NP)$ will be constant in this specification. The degree of rivalness of the public good has implications for the unit price of the public good. If the marginal cost of providing an extra unit of the public good is a constant C_0 and each individual pays a per capita tax share, then each individual will pay $C_0 Q/NP$ for the local public good. The tax price per unit of the public good received for the individual is

$$(3.3) \quad S = C_0 Q / (NP) q = C_0 (NP)^{\alpha-1}.$$

If the demand for the public good is a constant elasticity multiplicative function of price and income, then the specified demand function will be

$$(3.4) \quad q = AS^{\delta} (YM)^{\eta}$$

where A is a constant and YM is median income.

The quantity of public good (q) is unobservable. Based on (3.1), (3.2), (3.3), and (3.4), the per capita public expenditure will become

$$(3.5) \quad E = Sq = A' W^{\beta(\delta+1)} (YM)^{\eta} (NP)^{(\alpha-1)(\delta+1)}.$$

This completes the theoretical development of the demand for public goods based on B-D approach. Equation (3.5) can be estimated since all variables are observable.

The structural model developed by B-G is complementary to the B-D approach, emphasizing the demand side of the public service. There are five basic assumptions underlying their model:

- (1) Unit costs are constant within each jurisdiction.
- (2) Each member has a tax share.
- (3) Any member living in a jurisdiction faces a tax price.
- (4) In each jurisdiction, the quantity supplied of the public good is equal to the median of the quantities demanded by its members.
- (5) The jurisdiction chooses the level of production of public good that corresponds to the tastes of the members with median income.

B-G first develop the conditions for optimal individual choice between private and public goods, then specify a demand function, and finally define the public good expenditure function. An individual's utility (U) is a

function of private goods consumed (X) and public good q.
That is,

$$(3.6) \quad U = U(X, q)$$

and the budget constraint is

$$(3.7) \quad YM = X + \tau CQ$$

where the price of X is one, τ is the tax share of the person, and C is the unit cost of Q. In addition, B-G also incorporate the degree of publicness in good Q in a manner similar to B-D as:

$$(3.2) \quad q = Q/(NP)^\alpha$$

According to (3.7) and (3.2), the budget constraint can be revised as

$$(3.8) \quad YM = X + \tau C(NP)^\alpha q$$

where $S = \tau C(NP)^\alpha$ is the price per unit of q to the individual.

The demand is assumed to be Cobb-Douglas with constant price and income elasticities. The demand for q is:

$$(3.9) \quad q = a(\tau C(NP)^\alpha)^\delta (YM)^\eta$$

Based on (3.2), the total public good produced can be defined in terms of individually consumed good as:

$$(3.10) \quad Q = q(NP)^\alpha$$

and the demand for Q is :

$$(3.11) \quad Q = a(\tau C(NP)^\alpha)^\delta (YM)^\eta (NP)^\alpha$$

Finally, total expenditure is

$$(3.12) \quad TE = CQ = a\tau^\delta C^{\delta+1} (NP)^{\alpha(\delta+1)} (YM)^\eta$$

The total public expenditure can be expressed as a function of four exogenous variables: tax share, unit cost, population, and income. For empirical applications, other socioeconomic factors that may affect the demand for public service can be added to the equation: for example, urbanization and land area in the B-D estimatable equation. When unit cost is a function of wages and the tax share is equally distributed, i.e. $\tau = 1/NP$, the B-G model is the same as the B-D model. Additionally, in empirical studies, it is usually assumed that the unit price of public good is the same across all jurisdictions.

A major advantage of the median-voter framework lies in its use of tax price, so that price elasticity of demand can be obtained. The median-voter model also provides a method whereby the complex process of public finance can be related to consumer behavior and reduced to a choice of a single consumer.

Aubin et al. (1988) suggest that

The public sector behavior should be analyzed in terms of both the demand side and the supply side. However, it is not necessary to build a structural model which explicitly dichotomizes between these two sides....⁸

They, too, note that

⁸See Aubin et al. (1988), p. 207.

Such an approach is implicit in the median-voter model which outlines demand factors but which is also a supply model, since it assumes the willingness of government to comply with the median voter's preferences in order to stay in power.⁹

As described above, the median-voter models developed by B-D and B-G consider not only demand side factors but also the supply side of public sector behavior. Hence, public expenditure can be explained as a reduced form. Both models have been most commonly used for cross-sectional analysis of local or state-local public expenditure including public education. However, since 1980, the median-voter model also has been used for estimating federal or general government expenditure from time-series data.¹⁰

A Formulation of the Demand for Public Education

The purpose of this section is to formulate an alternative demand model for public education from state government, based on the standard approach and provide discussion regarding outcomes and costs of public education.

⁹See Aubin et al. (1988), p. 209.

¹⁰These studies include Provopoulos (1982), Aubin et al. (1988), Diamond (1989), or Tridimas (1992).

Determination of Demand

In order to derive the demand for public education from state government, the model is based on the assumption that the representative individual will maximize his/her utility function subject to budget constraint. It is also assumed that state government is to set expenditure in response to the preference of the representative individual's demand for public education. The representative individual is decisive in the state budgetary process of public education. For simplification, only private goods and public education from state government are considered in the formulation of the model. Based on conventional consumer-choice theory, the individual chooses private goods and a publicly supplied good (public education) to maximize the strictly quasi-concave utility function. The individual's utility function is given by:

$$(3.13) \quad U = U(X, q).$$

The constraints are defined by

$$(3.14) \quad Y = PX + \tau TS,$$

$$(3.15) \quad TS/NS + F/NS = CQ/NS,$$

and

$$(3.2) \quad q = Q/(NS)^{\alpha}$$

where Y = the representative individual's income;

X = the private goods consumed by the individual;

TS = the total state taxes for public education and TS

$$= TS(q, C, F, NS);$$

F = the total unconditional federal aid;

q = the amount of the publicly supplied good (state public education) demanded;

Q = the amount of the publicly supplied good produced;

NS = the number of students in public schools;

τ = the tax share of the representative individual;

P = the price of the private good;

C = the unit cost of producing Q; and

α = the capturability (publicness) parameter.

The above specifications represent the individual's demand for public education service from state government. Equation (3.14) is the individual's budget constraint. It states that total income of the individual is divided into the expenditures on private goods and his/her tax bill. Equation (3.15) is a balanced budget constraint for the state, which indicates that total cost of state public education must be equal to the total tax revenue and the lump-sum aid from federal government. Equation (3.2) is the same as defined by B-D, which shows the relationship between actual output of state public education, the quantity consumed, and population. It is assumed that the capturability elasticity α is constant across states.

Substituting (3.2) and (3.15) into (3.14) gives rise to

$$(3.16) \quad Y + \tau F = PX + \tau C(NS)^{\alpha} q$$

which implies that the per unit tax price of state public education is

$$(3.17) \quad S = \tau C(NS)^{\alpha}.$$

With this transformation, the Lagrangian function for a representative individual is

$$(3.18) \quad \mathcal{L} = U(X, q) + \lambda(Y + \tau F - PX - \tau C(NS)^{\alpha} q).$$

The necessary conditions for an interior solution are

$$(3.19) \quad \begin{aligned} \partial \mathcal{L} / \partial X &= \partial U / \partial X - \lambda P = 0 \\ \partial \mathcal{L} / \partial q &= \partial U / \partial q - \lambda \tau C(NS)^{\alpha} = 0 \\ \partial \mathcal{L} / \partial \lambda &= Y + \tau F - PX - \tau C(NS)^{\alpha} q = 0. \end{aligned}$$

It is assumed that the sufficient condition is satisfied.

This framework suggests a general demand for public education

$$(3.20) \quad q = q(Y + \tau F, P, \tau C(NS)^{\alpha}).$$

Equation (3.20) indicates that the demand for public education is a function of individual's augmented income (individual's income plus share of federal aid), the price of the private good, and the price of public education.

Note that $Y + \tau F$ is the appropriate income measure for the demand function. However, in all studies using the median-voter approach, except Perkins (1977) and Turnbull (1987), the income and aid terms are separated in the specification of the estimation equation in order to examine the effect of aid on public education.¹¹ For a conventional model, the

¹¹The flypaper effect can be used to examine the different responses to changes in income and aid. The specification for augmented income term will become $Y + k\tau L$.

specification of separating income and government aid has little theoretical foundation.¹²

Outputs and Unit Costs of Public Education

The major problem with the estimation of demand for public goods, including public education, is the lack of adequate measures of public output and unit costs. According to the above analysis, the price of public education consumed (q) is $S = \tau C(NS)^a$, which is composed of three components: tax share borne by the individual, unit costs of public education, and capturability. In an attempt to obtain the unit cost of public education, the relationship between output and inputs of public education should be considered. The output-input relationship can be conceptualized by an educational production function.

Some have claimed that the outcomes of public education are test scores, student attitude, ability to cope within society, continuation in schooling, creativity, and so on. Recently, test scores have been used in empirical studies.

If k is greater than one, then the flypaper effect exists, implying aid is more stimulative than income.

¹²According to Turnbull (1985), using the coefficient of tax-share term as the tax-price elasticity will lead to an estimate that is biased upwards if the income and aid are separated terms in the specification. He also shows that in the absence of matching-aid term, the estimate of the tax price elasticity can be directly obtained from the coefficient of the tax share term if the income and aid are not separated.

The reason is that test scores can be measured and are important from the views of students, teachers, parents, and others. However, the lack of external validation may be the most important concern with these test scores.

In fact, educational outputs are different from those of standard production theory. Educational outputs are derived from individuals with different quality attributes, while standard production theory leads to homogenous outputs. For this reason, most studies do not show what educational output should be, and some studies even rely on test scores as proxies. This concept of educational output has been used by some of the studies described in Chapter II.

For an educational production function, the inputs may include instructional staff, managers, parents, students, and equipment. These factors make contributions to outputs of public education. However, no matter what the output may be, instructional staff is the primary concern in the educational production function and is generally considered as the most important labor input for educational outputs. It has been claimed that labor costs of instructional staff reflect most closely the actual services of public education. Therefore, most studies have used average instructional staff wages in schools or per student labor cost as a proxy for the unit cost of local public education, as with Borcharding and Deacon (1972), Perkins (1977), and Baum (1986). But Baum

links labor cost to output or test scores.

As mentioned above, both the demand side and supply (cost) side should be included in estimating public goods. However, some studies have not mentioned the production function in estimating spending in public education or other public goods (see B-G, Ladd, and Inman). These studies implicitly assume that the unit cost of the public good is the same across all jurisdictions using cross-sectional data. If the choice of observational unit for empirical purpose is local governments within a given state, then little or no estimation bias results because it is reasonable to assume little or no intra-area variations in production costs of a public good within a state. If the data are chosen from different states, however, production costs should not be ignored. Labor costs are the most prominent source of interstate differences in the costs of producing public education services.

In this study, interstate data will be used to estimate spending in public education. In order to specify the unit cost, as in the B-D model, assume that state public education is represented by the Cobb-Douglas constant return production conditions, elastic factor supply, and a homogenous rate of return on capital across states. Therefore, unit cost will be a function of wages and can be expressed as

$$(3.21) \quad C = aW^b$$

and the price of q will be

$$(3.22) \quad S = \tau (aW^{\beta}) (NS)^{\alpha}.$$

These equations provide the basis for the estimation described in the next chapter.

CHAPTER IV

ESTIMATION MODELS AND METHODOLOGY

The purpose of this chapter is to specify the equations for estimating the demand for public education based on (3.20) and (3.22), and to describe the estimation method.

Specification of the Estimation Equation

According to the demand function for public education mentioned above, when using pooled time-series and cross-sectional data, the demand for public education (3.20) can be expressed as

$$(4.1) \quad q_{nt} = q(P_{nt}, S_{nt}, (YM + \tau F)_{nt})$$
$$n = 1, 2, \dots, N \text{ (states)}$$
$$t = 1, 2, \dots, T \text{ (periods)}.$$

where q_{nt} = the individual quantity demanded for state n at time t ;

P_{nt} = the price of the private goods for state n at time t ;

S_{nt} = the tax price of public education service, where

$$S_{nt} = \tau_{nt} (a w_{nt}^b) (NS)^a;$$

F_{nt} = the total federal aid for state n at time t ; and

YM = the median income.

It is assumed that the demand is a multiplicative

function of tax price, augmented income (median income plus share of federal aid), and the price of the private good. Therefore, (4.1) implies that the specific demand function for public education is of the form:

$$(4.2) \quad Q_{nt} = AP_{nt}^{\rho} S_{nt}^{\eta} (YM + \tau F)_{nt}^{\delta} e^{\varepsilon_{nt}}$$

where ρ is the cross-price elasticity, δ is the augmented income elasticity, η is the price elasticity, ε is the error term, and A is constant.

Substituting $S_{nt} = \tau_{nt} (aW_{nt}^{\beta}) (NS)_{nt}^{\alpha}$ into (4.2) and taking the natural logarithm yields a double-log form:

$$(4.3) \quad \ln Q_{nt} = \text{const} + \rho \ln P_{nt} + \delta \ln (YM + \tau F)_{nt} + \eta \ln \tau_{nt} \\ + \alpha \eta \ln NS_{nt} + \eta \ln W_{nt}^{\beta} + \varepsilon_{nt}.$$

It is assumed that the tax share is measured by $\tau = YM/YP$,¹³ where YM is median income and YP is personal income, which implies that the tax burden of the median voter is the ratio of median income to personal income. Substituting the tax share $\tau = YM/YP$ into (4.3) yields

¹³In a median-voter model, the tax share (τ) should be able to reflect the median voter's tax burden. But, there are some difficulties in accurately measuring τ , especially in state and time-series data. In this study, τ is measured as the ratio of median income to personal income, indicating personal income is considered as tax base. The reason of using personal income as a proxy of tax base is that there exists a high relationship between sales taxes or total state taxes and personal income.

$$(4.4) \quad \ln q_{nt} = \text{const} + \rho \ln P_{nt} + \delta \ln \{YM + (YM/YP)(F)\}_{nt} \\ + \eta \ln (YM/YP)_{nt} + \eta \ln w_{nt}^p + \eta \alpha \ln NS_{nt} + \varepsilon_{nt}.$$

The individual's demand is homogeneous of degree zero in price of the private goods (P), augmented income (YM+ τ F), and the tax price of public education (S), which implies

$$(4.5) \quad \rho + \delta + \eta = 0.$$

Based on (4.5), $\rho = -(\delta + \eta)$. Therefore, (4.4) will become:

$$(4.6) \quad \ln q_{nt} = \text{const} + \delta \ln \{ym + (YM/YP)(f)\}_{nt} + \eta \ln (YM/YP)_{nt} \\ + \eta \ln w_{nt}^p + \alpha \eta \ln NS_{nt} + \varepsilon_{nt}$$

where ym = real medium income after being deflated by P;

f = real federal aid after being deflated by P;

w = real public wage after being deflated by P.

Since q in (4.6) is unobservable, utilizing real $c = a'w^p$ and $q = Q/(NS)^\alpha$, equation (4.6) will become:

$$(4.7) \quad \ln E_{nt} = (\ln q_{nt} + \alpha \ln NS_{nt} + \ln c_{nt}) - \ln NS_{nt} \\ = \text{const} + \eta \ln (ym/yp)_{nt} + \beta(\eta+1) \ln w_{nt} \\ + \delta \ln \{ym + (YM/YP)(f)\}_{nt} + (\alpha\eta + \alpha - 1) \ln NS_{nt} + \varepsilon_{nt}$$

where E_{nt} is per student real expenditure on public education. Equation (4.7) is an estimatable equation since all variables are observable. Per student real expenditure is determined by tax share, public wages, augmented income, and the number of students in public schools.

In addition to the factors mentioned in equation (4.7), there are socioeconomic factors which should be considered in

the determination of state expenditure on public education. These factors may consist of private school education and local public education services. Private school education is a substitute for public education. Since local public education service is a key complement to state education service, state education spending will be affected by local education spending.

Taking private school education and local public education into account, Equation (4.6) will become:

$$\begin{aligned}
 (4.8) \quad \ln q_{nt} = & \text{const} + \eta \ln(ym/yp)_{nt} + \delta \ln\{ym + (ym/yp)(f)\}_{nt} \\
 & + \eta \ln w_{nt}^p + \alpha \eta \ln NS_{nt} + \gamma \ln(tl)_{nt} + \mu \ln(prt)_{nt} \\
 & + \varepsilon_{nt}
 \end{aligned}$$

where tl = per student real local revenues for public education, and

prt = the real tuition in private schools.

After taking the same procedures as above, the estimation equation will become:

$$\begin{aligned}
 (4.9) \quad \ln E_{nt} = & \text{const} + \eta \ln(ym/yp)_{nt} + \beta(\eta+1) \ln w_{nt} \\
 & + \delta \ln\{ym + (ym/yp)(f)\}_{nt} + (\alpha\eta + \alpha - 1) \ln NS_{nt} \\
 & + \gamma \ln(tl)_{nt} + \mu \ln(prt)_{nt} + \varepsilon_{nt}.
 \end{aligned}$$

Dynamic Specification of the Demand for Public Education

Equation (4.9) allows only a static relationship between the economic variables. A more appropriate behavior should

allow for the possibility of differences between short-run and long-run responses of demand through a dynamic specification. Except Tridimas (1992),¹⁴ no other studies consider dynamic behavior by using the median-voter model to estimate public expenditures.¹⁵ As a matter of fact, any public expenditures may change over time. For analyzing government expenditures, a dynamic specification is more appropriate than a static one.

In order to specify a dynamic model of education demand, it is assumed that desired demand for public education is explained by current income and other factors and the demand for public education is adjusted over time to some desired level. When the explanatory variables change in a given year, the actual realized change in demand for public education is only a fraction of the desired change because of institutional rigidity, legislative lags, the administrative

¹⁴Tridimas examines the relationship between government expenditure and budget deficits by using U.K. data and the median-voter approach. He assumes permanent income will determine the pattern of public expenditure. Therefore, combining adaptive expectation and partial adjustment yields a dynamic demand equation for public expenditure.

¹⁵In a recent article, Downes and Pogue (1994) claim that it is necessary for a median-voter model to specify how actual output is related to desired output. But, they seem not to have addressed the adjustment mechanism and lag response of spending on public education. In their study, the differences between actual and desired expenditures are reflected in the error term of an expenditure equation. They just use cross-sectional data on both levels and changes (first differences) to examine if the dependent variable adjusts fully with the period of observation.

and financial problems associated with government spending. This adjustment can be described as the partial adjustment model.

There are two specifications of the partial adjustment model to be considered. One is an adjustment for the amount of public education demanded, which can be expressed as follows:

$$\begin{aligned}
 (4.10) \quad \ln q_{nt}^* &= \text{const} + \delta \ln\{ym + (YM/YP)(f)\}_{nt} + \eta \ln(ym/yp)_{nt} \\
 &+ \eta \ln w_{nt}^p + \alpha \eta \ln NS_{nt} + \gamma \ln(tl)_{nt} \\
 &+ \mu \ln(prt)_{nt} + \varepsilon_{nt}
 \end{aligned}$$

and

$$(4.11) \quad \ln q_{nt} - \ln q_{n,t-1} = \pi (\ln q_{nt}^* - \ln q_{n,t-1})$$

where q represents actual per student amount, q^* per student desired amount of public education service and π is the adjustment coefficient, with $0 < \pi < 1$. Other variables are the same as defined above.

By solving (4.11) for $\ln q_{nt}^*$ and substituting the solution into (4.10), the estimating equation can be obtained as follows:

$$\begin{aligned}
 (4.12) \quad \ln E_{nt} &= \text{const} + \pi \eta \ln(YM/YP)_{nt} + \beta(\pi\eta+1) \ln w_{nt} \\
 &+ \pi \delta \ln\{ym + (YM/YP)(f)\}_{nt} + \pi(\alpha\eta+\alpha-1) \ln NS_{nt} \\
 &+ \beta(\pi-1) \ln w_{n,t-1} + (1-\alpha)(1-\pi) \ln NS_{n,t-1} \\
 &+ \pi \gamma \ln(tl)_{nt} + \pi \mu \ln(prt)_{nt} \\
 &+ (1-\pi) \ln E_{n,t-1} + \pi \varepsilon_{nt}.
 \end{aligned}$$

The other specification involves an adjustment pertaining to government expenditure on public education, assuming that the path of adjustment of actual government expenditures to its desired level is described by the partial adjustment mechanism. The specification is described as follows:

$$(4.13) \quad \ln E_{nt}^* = \text{const} + \eta \ln(YM/YP)_{nt} + \beta(\eta+1) \ln w_{nt} \\ + \delta \ln\{ym + (YM/YP)(f)\}_{nt} + (\alpha\eta + \alpha - 1) \ln NS_{nt} \\ + \gamma \ln(tl)_{nt} + \mu \ln(prt)_{nt} + \varepsilon_{nt}$$

and

$$(4.14) \quad \ln E_{nt} - \ln E_{n,t-1} = \theta (\ln E_{nt}^* - \ln E_{n,t-1})$$

where E_{nt}^* is per student desired government expenditures in public education; θ is the adjustment coefficient whose value is between one and zero; and the other variables are the same as mentioned above. From (4.14) and (4.13), the estimating equation can be expressed as:

$$(4.15) \quad \ln E_{nt} = \text{const} + \theta \eta \ln(YM/YP)_{nt} + \beta \theta (\eta+1) \ln w_{nt} \\ + \theta \delta \ln\{ym + (YM/YP)(f)\}_{nt} + \theta (\alpha\eta + \alpha - 1) \ln NS_{nt} \\ + \theta \gamma \ln(tl)_{nt} + \theta \mu \ln(prt)_{nt} \\ + (1-\theta) \ln E_{n,t-1} + \theta \varepsilon_{nt}.$$

Equations (4.12) and (4.15) specify government spending in public education as a function of the tax share, public wages, augmented income, students in public schools, local

tax revenue for public education, and lagged values of the dependent variables. These specifications show the dynamics of the economic relationships and allow the estimation of long-run and short-run elasticities as contrasted with the static formulation (4.9). The estimated values of η , δ , γ , and μ , are long-run elasticities from equation (4.12) and (4.15). The short-run elasticities are $\pi\eta$, $\pi\delta$, $\pi\gamma$, and $\pi\mu$ from (4.12) or $\theta\eta$, $\theta\delta$, $\theta\gamma$, and $\theta\mu$ from (4.15).

Comparing equation (4.12) and (4.15), it is found that equation (4.12) reduces to equation (4.15) when $\ln NS_{nt}$ and $\ln w_{nt}$ are equal to $\ln NS_{n,t-1}$ and $\ln w_{n,t-1}$, respectively. Therefore, if there exists an extremely high degree of multicollinearity between $\ln NS_{nt}$ and $\ln NS_{n,t-1}$ and between $\ln w_{nt}$ and $\ln w_{n,t-1}$, then equation (4.15) can be an appropriate specification.

Based on the elementary demand theory that the quantity purchased decreases as the price of a good rises, the sign for the tax-price elasticity (η) is negative. Assuming public education service is a normal good, as consumers' income increases, more public education services will be purchased, indicating that the augmented income elasticity (δ) is positive. The elasticity of the state demand for public education with respect to local revenue (γ) is expected to be negative, since greater local resources reduce the need from the state. As for elasticity of demand for public education

with respect to private tuition (μ), it is expected to be negative since private school education is seen as a substitute for public education. Finally, the values for labor's share (β), publicness (α), and adjustment coefficients (θ and π) are expected to be between 0 and 1.

Estimation Method

Pooled time-series and cross-sectional data are used to estimate (4.9), (4.12), and (4.15).¹⁶ In general, the cross-sectional units (states) may not be mutually independent. The behavior of the disturbances over cross-sectional units is likely to be different from the behavior of the disturbances of a given cross-sectional unit over time. Especially, the relationship between the disturbances of two states at some specific time may be different from the relationship between the disturbances of a specific state at two different periods of time. Therefore, when considering the differences in the disturbances over states and over time, estimates using the ordinary least squares (OLS) method may be inefficient.

There are several approaches to obtaining more efficient estimates from pooled time-series and cross-sectional data.

¹⁶Equation (4.12) is a case of overidentification, and the estimates can be obtained from maximum likelihood estimation (MLE), which is equivalent to nonlinear ordinary least square method.

One approach is the application of the cross-sectionally correlated and time-wise autoregressive model. Another approach is the error components model. However, when there are lagged dependent variables in the equation, the error component technique is not directly applicable. Therefore, the cross-sectionally correlated and time-wise autoregressive model is adopted in this study. In this model, it is assumed that the disturbances are heteroscedastic for cross-sectional observations and the disturbances are autocorrelated over time. In addition, the disturbances of the cross-sectional data are not mutually dependent. The specification of the behavior of the disturbances v_{nt} in the cross-sectionally correlated and time-wise autoregressive model is as follows:

$$\begin{aligned} E(v_{nt}^2) &= \sigma_{nn} \text{ (heteroskedasticity),} \\ E(v_{nt}v_{mt}) &= \sigma_{nm} \text{ (cross-sectional correlation),} \\ v_{nt} &= \rho_n v_{n,t-1} + u_{nt} \text{ (time-wise autoregression),} \\ u_{nt} &\sim N(0, \phi_{nn}), \end{aligned}$$

where

$$\begin{aligned} E(u_{mt}, v_{n,t-1}) &= 0, \quad m \neq n, \\ E(u_{nt} u_{mt}) &= \phi_{nm}, \\ E(u_{nt} u_{ms}) &= 0, \quad \text{if } t \neq s \text{ and } n \neq m, \\ n, m &= 1, 2, \dots, N \\ t, s &= 1, 2, \dots, T. \end{aligned}$$

Each equation can be expressed using matrix notation:

$$(4.16) \quad H = Z\beta + v$$

where H is an $NT \times 1$ vector;

Z is an $NT \times (K+1)$ vector;

ζ is a $(K+1) \times 1$ vector of coefficients to be estimated;

v is an $NT \times 1$ vector containing error terms v_{nt} .

In such a model, the variance-covariance matrix of the disturbance terms can be expressed as an $NT \times NT$ matrix

$$(4.17) \quad \Omega = E(vv') = \begin{pmatrix} \sigma_{11}A_{11} & \sigma_{12}A_{12} & \dots & \sigma_{1N}A_{1N} \\ \sigma_{21}A_{21} & \sigma_{22}A_{22} & \dots & \sigma_{2N}A_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{N1}A_{N1} & \sigma_{N2}A_{N2} & \dots & \sigma_{NN}A_{NN} \end{pmatrix}$$

where

$$(4.18) \quad A_{nm} = \begin{pmatrix} 1 & \rho_m & \rho_m^2 & \dots & \rho_m^{T-1} \\ \rho_n & 1 & \rho_m & \dots & \rho_m^{T-2} \\ \rho_n^2 & \rho_n & 1 & \dots & \rho_m^{T-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho_n^{T-1} & \rho_n^{T-2} & \rho_n^{T-3} & \dots & 1 \end{pmatrix}$$

$n = 1, 2, \dots, N$

$t = 1, 2, \dots, T$.

If σ_{nm} and ρ_n are known, then the GLS estimates of ζ in equation (4.16) is

$$(4.19) \quad \zeta = (Z' \Omega^{-1} Z)^{-1} (Z' \Omega^{-1} H),$$

with the variance-covariance matrix of ζ :

$$(4.20) \quad \text{Var}(\zeta) = (Z' \Omega^{-1} Z)^{-1}.$$

In order to obtain consistent estimates of the elements of Ω , a two-stage procedure will be used. The first step is to apply the OLS method to all of the pooled data and obtain the fitted residuals, e_{nt} , and a consistent estimator of the first-order autocorrelated parameter can be obtained via

$$(4.21) \quad \hat{\rho}_n = \frac{\sum_{t=2}^T e_{nt} e_{n,t-1}}{\sum_{t=2}^T e_{n,t-1}^2}.$$

Using $\hat{\rho}_n$ to transform the variables in the estimatable equation and applying OLS to the transformed model will yield the new residuals, e_{nm}^* . The variances and covariances in matrix Ω can be estimated by

$$(4.22) \quad \hat{\sigma}_{nm} = \frac{\hat{\Delta}_{nm}}{1 - \hat{\rho}_n \hat{\rho}_m}$$

where

$$(4.23) \quad \hat{\Delta}_{nm} = \frac{1}{T-K-1} \sum_{t=1}^T e_{nt}^* e_{mt}^*.$$

CHAPTER V

EMPIRICAL RESULTS

This chapter presents the empirical results obtained from OLS, MLE, and GLS methods based on equations (4.9), (4.12), and (4.15). The chapter begins with a discussion of the data that underlay the estimation. Attention then turns to hypothesis testing in order to see if regional differences exist in the demand functions for public education from state government. The major emphasis is on the explanation of regional differences with regard to the long-run elasticities of the demand for public education and the policy implications of these differences. The remainder of the chapter explores other factors that influence the demand for public education.

The Data

In this study, annual data (k-12) for 48 states from 1982 to 1991 was collected to estimate the parameters in equations (4.9), (4.12), and (4.15) for the U.S. as a whole, and by region.¹⁷ There are four regions considered in this study: the Northeast (9 states), the Midwest (12 states), the West (11 states), and the South (16 states) according to the classification used by U. S. Bureau of the Census.

¹⁷Alaska and Wyoming were dropped due to lack of private school tuition data.

The variables for the empirical study include per student state government expenditures on public education, tax share, augmented income (i.e., median income plus share of federal aid), private wages in manufacturing industries, number of students in public schools, per student local revenues for public education, and student tuition in private school. The variable definitions and their measurements are listed in Table V-1.

The data used to measure variables for estimation include total state expenditures on public education, total local revenues for public education, total federal aid to public education, student numbers in public education, median income, personal income, cost of living index, and consumer price index. The data sources for these variables are listed in Table V-2. Real variables are obtained from their respective nominal values by deflating both the cost of living index for each state and the consumer price index for each year.

There are some comments on the data. First, it is impossible to directly identify the median voter. One way to determine the median voter's tax share is the ratio of median income to personal income in a state. The tax-share specification assumes that personal income is either the tax base (as it is in numerous states) or a good proxy for the tax base in a state. In general, there exists a high

TABLE V-1

VARIABLE DEFINITIONS AND MEASUREMENT

Variable	Definition	Measurement
E_{nt}	real per student state expenditure on public education	$(TE/NS)_{nt}$
τ_{nt}	tax share	$(ym/yp)_{nt}$
yma_{nt}	real augmented income	$(ym+\tau f)_{nt}$
w_{nt}	real average hourly wages in manufacturing industries	
NS_{nt}	number of students in public schools	
$p_{rt_{nt}}$	real student tuition in private schools	
tl_{nt}	real per student local revenues for public education	$(TL/NS)_{nt}$
$w_{n,t-1}$	real average hourly wages at time t-1	
$NS_{n,t-1}$	student numbers at time t-1	
$E_{n,t-1}$	real per student state expenditure on public education at time t-1	

Notes: n and t indicate state and time, respectively.

TE = total real state expenditure on public education.

TL = total real local revenues for public education.

ym = real median income.

yp = total real personal income.

f = total real federal aid for public education.

TABLE V-2
DATA SOURCES

Variable	Source
Total state expenditure on public education (k-12)	<u>Digest of Education Statistics</u> , Washington, D. C: U.S. Department of Education.
Personal income	<u>Survey of Current Business</u> , Bureau of Economic Analysis, Washington, D. C: U. S. Department of Commerce.
Median income	<u>Money Income of Household, Family, and Persons in the US</u> , Washington, D. C: U. S. Bureau of the Census.
Federal aid	See total state expenditure on public education.
Number of student in public schools	See total state expenditure on public education.
Student tuition in private schools	<u>Private Independent Schools</u> , Wallingford, CT: Bunting & Lyon, Inc. and <u>Handbook of Private Schools</u> , Boston, MA: Porter Sargent Publishers.
Average hourly wages in manufacturing industries	<u>Statistical Abstract of the USA</u> , Washington, D.C: U.S. Department of Commerce.
Total local revenues for public education	See total state expenditure on public education.
Cost of living index	<u>Cost of Living Index</u> , Louisville, KY: American Chamber Researchers Association.
Consumer price index	See Median Income.

correlation between personal income and tax revenue in a state, especially for the sales tax, which is the largest revenue source for most states.¹⁸ Therefore, it is appropriate to use the ratio of median income to personal income as a tax share.

Second, the private wage is chosen as the measure of unit cost for public education since the average wage of teachers in public schools is likely an endogenous variable. Under the assumptions of constant returns to scale production conditions, elastic factor supply, and homogenous rate of return on capital, the estimate for private wage can be used to explain the productivity lag in public education.¹⁹

Third, the private school tuition is an average tuition for all private schools that can be obtained for each state. A more accurate estimate would be the average of total tuition divided by total students in private schools in a state or region. But, such data are not available.

Finally, the rate of return on capital in public schools

¹⁸The elasticity of sales tax with respect to personal income has been estimated at about one in a state. See Guthrie et al. (1988), p. 112.

¹⁹Baumol (1967) seems to be the first person to address the relationship between productivity lag in public sector and private wages. Some studies, such as Niskanen (1978) and Provopoulos (1982), have used Baumol's concept to estimate the productivity lag in federal or central government services. The productivity lag in public sector associated with the private sector wages will be addressed later in this chapter.

is omitted due to being not available. If the rate of return on capital varies overtime, then the estimation results may be biased, although it is not clear in which direction.

Specification Test

Choice of An Appropriate Model

This section will explore the appropriate specification of the empirical model based on equations (4.9), (4.12), and (4.15). The choice of an appropriate model will be based on both econometric theory and empirical results. Since cross-sectional and time-series state data are used in this study, in addition to estimation results, disturbance dependence among states and disturbance autocorrelation over time also are considered for model selection.

Equations (4.9) and (4.15) are the cases of exact identification, in which the restricted parameters can be uniquely identified by the unrestricted coefficients. Therefore, (4.9) and (4.15) can be estimated by the OLS and GLS methods described in Chapter IV. As for equation (4.12), there are more unrestricted coefficients than there are restricted parameters, which is a case of overidentification with no unique solution for the parameters. In the case of overidentification, the maximum likelihood method is commonly used to estimate the restricted parameters.²⁰ The empirical

²⁰See Kmenta (1971), p. 447.

results are tabulated in Appendix A for the U.S. and four regions. For GLS, R^2 is not reported since it cannot be interpreted in the usual sense.

In general, both OLS and GLS estimates yield similar results. But, for some estimates, the estimated standard errors from OLS are relatively high, leading to low t-values that become statistically insignificant for these variables.²¹ If OLS is the only method to estimate the demand for public education from state government by region and for the U.S., these variables might be dropped.

In addition, when applying OLS, it is always assumed that there is no autocorrelation problem for the error terms in the time-series data. But, it is very common for time series observations to have autocorrelated disturbances. According to (4.20) in Chapter IV, the estimate ($\hat{\rho}$) of the first-order autocorrelated parameter can be computed by region and for the U.S.²²

²¹For example, coefficients for augmented income in the regressions of the Northeast, the South, and the U.S. by applying static equations (4.9) or (4.15) are not statistically significant.

²²Based on equation (4.9), the first-order autocorrelated estimates for the U.S. are between 0.211 to 0.998 except for AR (-0.031) and CD (0.038). In the Northeast, they are between 0.320 and 0.996. In the Midwest, they are between 0.417 and 0.840. In the West, they are between 0.659 and 0.895 except UT (0.119). In the South, they are between 0.230 and 0.996. When equation (4.15) is applied, the first-order autocorrelated problem is reduced somewhat. However, the estimates are still high such as CD (-0.737), FL (0.687), and MO (0.637) for the U.S., VT (-0.486) for the Northeast, MN

The presence of autocorrelation does not affect the property of unbiasedness, but it does make the OLS estimators less efficient because the variance of the estimator is affected and the estimate of the confidence interval becomes less reliable. Therefore, OLS is an inappropriate method for this study.

Equations (4.12) and (4.15) are dynamic models for estimating the demand for public education from state government in this study. As mentioned above, equation (4.12) is estimated by the maximum likelihood method. The estimation results show that all estimated values of the adjustment coefficients are between one and zero and are statistically significant at the level of 1 percent except the Northeast and the West. According to the empirical results from equation (4.15), all estimated values of the adjustment coefficients are also between one and zero and statistically significant at the level of 1 percent or 5 percent when applying OLS and GLS methods. These results suggest that the demand for public education involves a dynamic relationship between the economic variables used in this study.

The maximum likelihood method is similar to the OLS method. Comparing the results of MLE in equation (4.12) and OLS in equation (4.15), it is found that MLE appears no

(-0.617) for the Midwest, CD (-0.635) and WA (0.613) for the West, WV (0.957), VA (0.781), and TN (0.849) for the South.

better than OLS in this study. For instance, the adjustment coefficients for the Northeast and the West are not statistically significant. In addition, the value of R^2 by MLE in (4.12) is no better than that from OLS in (4.15) in the Midwest. Moreover, except for the South, there are less than three estimates which are statistically significant. Consequently, MLE is also inappropriate in this study.

According to the above analysis, it is evident that in this study, the dynamic specification (4.15) by GLS method seems to provide better results for analyzing the demand for public education from state government. The GLS method is used to deal with the autocorrelation problem and mutual dependence among states so that the GLS estimator will be consistent, asymptotically unbiased and efficient. Therefore, the following analysis is primarily based on the results from GLS in equation (4.15).

Regional Variations

As mentioned earlier in this chapter, this study will consider the U.S. as a whole and four regions - the Northeast, the Midwest, the West, and the South.²³ In order to better understand the regional variations, the overall average from 1982 to 1991 and the respective average in 1982

²³The ideal way is to estimate state expenditure on public education by state if there is adequate time-series data.

and 1991 for all variables by regions are displayed in Table V-3. There are several major findings worth mentioning:

1. Real per student educational state expenditure (E), real per student local revenues for public education (tl), and per student tuition in private schools (prt) present not only regional differences but an increasing trend over time. Especially, more regional differences exist for per student local revenue for public education and tuition in private schools than for per student state educational expenditure. For example, per student local revenue and tuition in private schools are relatively low for the South. Per student local revenues for public education for the South are only about half of those for the Northeast.

2. The Northeast and the West have relatively high tax shares (τ). The tax share for the South is the lowest among regions and it is only about 50 percent of those for the Northeast or the West. In addition, the tax share presents a decreasing trend over time for all regions, indicating that the tax burden of median voters on public education gradually decreases. An explanation is that real median income (y_m) appears to have a lower growth rate than does real total personal income over time.

3. The degree of the regional differences seems to be lower for median income (y_m) than for per student state educational expenditure, per student local revenues for

TABLE V-3

DESCRIPTIVE STATISTICS OF THE VARIABLES
(PERSON FOR NS; RATIO FOR r ; AND
DOLLARS FOR OTHER VARIABLES)

Variable		Mean				
		Northeast	Midwest	West	South	US
E	OA	1441	1396	1690	1593	1538
	82	1138	1209	1528	1374	1323
	91	1630	1561	1777	1816	1709
r	OA	1.53×10^{-7}	1.07×10^{-7}	1.59×10^{-7}	$.80 \times 10^{-7}$	1.19×10^{-7}
	82	1.70×10^{-7}	1.10×10^{-7}	1.82×10^{-7}	$.87 \times 10^{-7}$	1.30×10^{-7}
	91	1.31×10^{-7}	1.01×10^{-7}	1.36×10^{-7}	$.73 \times 10^{-7}$	1.05×10^{-7}
ym	OA	30583	30693	30437	28154	29768
	82	27945	28135	28984	25902	27550
	91	29607	30871	30174	28396	29650
r_f	OA	59	91	113	108	96
	82	62	72	175	114	107
	91	62	130	105	107	104
yma	OA	30642	30784	30550	28262	29864
	82	28007	28207	29160	26016	27658
	91	29669	31001	30280	28502	29753
w	OA	7.42	9.24	8.61	8.39	8.47
	82	7.58	9.63	8.96	8.46	8.70
	91	7.10	8.61	7.99	8.03	8.00
NS	OA	7402716	9931884	8261099	14279280	39829056
	82	7674219	10139364	7617643	13854192	39285408
	91	7406604	10061952	9258205	14972384	41699136
prt	OA	3827	3066	3212	2710	3123
	82	3226	2274	2459	2052	2421
	91	4368	3756	3807	3289	3726
tl	OA	2084	1769	1103	1076	1446
	82	1801	1410	888	1130	1271
	91	2366	1914	1167	1205	1592

Notes: OA indicates average for years from 1982 to 1991. 82 and 91 indicate averages for year 1982 and year 1991.

4. The share of federal aid (τf) for the median voter is public education, or tuition in private schools.

less than 0.5 percent of the augmented income (y_{ma}). The Northeast has the lowest share of federal aid, although its tax share is the highest among the four regions.

5. In the 1980s, the number of students in public schools (NS) increased about 22 percent and 8 percent for the West and the South, respectively, while the Northeast and the Midwest present a decreasing trend.

6. Differences exist for the real private hourly wages in manufacturing industries (w) among regions. In addition, real private hourly wages also present a declining trend for all regions. The decrease in real private hourly wages may be due to a decline in manufacturing sector productivity.

According to Table V-3, the descriptive statistics show that for all data, regional differences and time trends do exist. Nevertheless, whether there are different behavioral responses or different demands for public education by region needs to be further examined by econometric methods. If regions do not appear to have significant differences in the demand for public education, then the results from the U.S. as a whole will be used for further analysis. Otherwise, the analysis will be based on regional results.

In order to test for regional differences in the demand for public education, F-values based on the analysis of

covariance technique are used to examine if the intercepts and the slopes of the demand functions as shown in equations (4.9) and (4.15) by the GLS method are the same across the four regions. Under the null hypothesis, the test statistic can be expressed as:

$$(5.1) \quad F_{(KR-K), NT-KR} = \frac{(RSS_{US} - (RSS_N + RSS_M + RSS_W + RSS_S)) / (KR-K)}{(RSS_N + RSS_M + RSS_W + RSS_S) / (NT-KR)}$$

where

RSS_{US} = residual sum of squares from the regression of
the U.S. as a whole;

RSS_N = residual sum of squares from the regression of
the northeastern states;

RSS_M = residual sum of squares from the regression of
the midwestern states;

RSS_W = residual sum of squares from the regression of
the western States;

RSS_S = residual sum of squares from the regression of
the southern states;

K = the number of independent variables;

R = the number of regions;

N = the number of states as a whole; and

T = the time periods.

If the calculated value of F based on (5.1) is greater than the critical value of F from the F table, the null

hypothesis will be rejected, implying it is statistically valid to estimate separately the demand functions by region.

According to Table V-4, all calculated values for equations (4.9) and (4.15) by the GLS method are greater than the critical values of F at the 5 percent level of significance. Therefore, it appears reasonable to estimate and analyze the state expenditures on public education regionally, as is discussed more fully below.

TABLE V-4
CALCULATED VALUES OF F

Equation	Estimation Method	F-Value	Critical F-Value
(4.9)	GLS	9.69	1.57
(4.15)	GLS	2.91	1.52

Notes: GLS = generalized least square

Elasticities of the Demand for Public Education

The definitions of the parameters are listed in Table V-5. As mentioned above, all of the estimated results for specific regions are revealed in Appendix A.

The following analysis of the demand for public education will be based on GLS results from equation (4.15)

TABLE V-5
PARAMETER DEFINITIONS

Parameter	Definition
$\xi_{tp} (\eta)$	elasticity of demand for public education with respect to tax price
$\xi_{yma} (\delta)$	elasticity of demand for public education with respect to augmented income
ξ_{ym}	elasticity of demand for public education with respect to median income
ξ_f	elasticity of demand for public education with respect to federal aid
β	public school productivity-lag
$\xi_{pb} (\alpha)$	elasticity of public school publicness
$\xi_{tl} (\gamma)$	elasticity of demand for public education with respect to local revenue
$\xi_{prt} (\mu)$	elasticity of demand for public education with respect to private tuition
π or θ	adjustment coefficients for equations (4.12) and (4.15)

since the GLS method applied to the dynamic specification produces more reasonable results. These results are summarized in Table V-6. In order to compare the dynamic results and static results, GLS results from equation (4.9) are also summarized in Table V-7.

Adjustment Coefficient

Since the demand for public education involves a dynamic relationship between economic variables, the adjustment coefficients will be first discussed. According to the estimated values of the coefficients for $\ln E_{n,t-1}$ from equation (4.15) by GLS method, it can be calculated that the estimated values of the adjustment coefficients are 0.178, 0.041, 0.105, 0.117, and 0.786 for the U.S., the Northeast, the Midwest, the West, and the South, respectively. These estimated values lie on the theoretical value, $[0, 1]$, and are statistically significant at the 1 percent level. The higher value of the adjustment coefficient implies that the adjustment from the actual to desired educational expenditure is faster. The relatively high value of the adjustment coefficient in the South shows that it takes less time to attain desired spending in public education for the South.

Based on the estimated values of adjustment coefficients, the lag of the response of the dependent variable to a change in one of the explanatory variables can

TABLE V-6

SUMMARY OF GLS RESULTS FROM DYNAMIC MODEL

	Northeast	Midwest	West	South	U.S.
ξ_{tp}	-0.086 (-0.26)	-1.993 ^{***} (-3.03)	-0.680 ^{***} (6.98)	-0.538 ^{***} (-9.32)	-0.675 ^{***} (-18.77)
ξ_{yma}	2.585 ^{***} (2.73)	3.005 ^{***} (3.31)	1.884 ^{***} (5.07)	0.212 ^{***} (3.33)	0.802 ^{***} (5.20)
ξ_{ym}	2.580 ^{***} (2.73)	2.996 ^{***} (3.31)	1.876 ^{***} (5.07)	0.211 ^{***} (3.33)	0.799 ^{***} (5.20)
ξ_f	0.005 ^{***} (2.73)	0.009 ^{***} (3.31)	0.007 ^{***} (5.07)	0.001 ^{***} (3.33)	0.003 ^{***} (5.20)
ξ_{pb}	0.416 ^{**} (1.98)	1.550 ^{***} (17.94)	0.928 ^{***} (5.74)	0.650 ^{***} (14.15)	1.015 ^{***} (61.47)
ξ_{tl}	-1.081 [*] (-1.86)	-1.034 ^{***} (-3.55)	-0.623 ^{***} (-7.20)	-0.043 ^{**} (-1.96)	-0.436 ^{***} (-18.89)
ξ_{prt}	-2.641 ^{***} (3.48)	0.442 ^{***} (3.28)	-0.410 ^{**} (-2.23)	0.187 ^{***} (6.58)	-0.086 ^{***} (-7.09)
β	3.753 [*] (1.75)	-2.229 (-1.55)	1.148 ^{**} (1.96)	-0.189 (-1.24)	1.587 ^{***} (3.75)
θ	0.041 ^{***} (2.94)	0.105 ^{***} (3.41)	0.117 ^{***} (5.95)	0.786 ^{***} (32.61)	0.179 ^{***} (30.86)

Notes: Figures in parentheses are t-values. ***, **, and * indicate that the coefficient is significant at the 1%, 5%, and 10% level, respectively.

TABLE V-7

SUMMARY OF GLS RESULTS FROM STATIC MODEL

	Northeast	Midwest	West	South	U.S.
ξ_{tp}	0.021*** (2.79)	0.134*** (2.97)	-0.395*** (-48.80)	-0.599*** (-15.79)	-0.069*** (-2.71)
ξ_{yma}	0.765*** (11.87)	0.319*** (9.17)	0.462*** (27.86)	0.571*** (15.04)	0.239*** (19.57)
ξ_{ym}	0.763*** (11.87)	0.318*** (9.17)	0.460*** (27.86)	0.569*** (15.04)	0.238*** (19.57)
ξ_f	0.002*** (11.87)	0.001*** (9.17)	0.002*** (27.86)	0.002*** (15.04)	0.001*** (19.57)
ξ_{pb}	1.442*** (48.35)	1.032*** (48.95)	0.736*** (22.63)	0.957*** (38.87)	1.140*** (21.92)
ξ_{tl}	-0.080 (-1.62)	-0.274*** (-34.36)	-0.053*** (-6.94)	-0.153*** (-21.15)	-0.108*** (-13.67)
ξ_{prt}	0.450*** (10.95)	-0.110*** (8.85)	0.170*** (5.41)	0.331*** (25.16)	0.099*** (26.66)
β	-0.168*** (-2.91)	-0.272*** (-6.77)	0.763*** (22.74)	-0.385*** (-3.99)	-0.045*** (-2.96)

Notes: See Table V-6.

be calculated. The response lags are reported in Table V-8.

The mean lag is defined as a lag-weighted average of time. The median lag is the time for which the fraction of adjustment is equal to 1/2. According to Table V-8, half the impact of a change in per student state spending in public education would be felt in six months for the South while it would take about 17 years for the Northeast to have the same impact. The Midwest and the West almost have the same median lags due to very close estimated values of adjustment coefficients for these two regions.

TABLE V-8
RESPONSE LAG IN YEARS

Region	Mean Lag	Median Lag
Northeast	23.4	16.6
Midwest	8.5	6.2
West	7.5	5.6
South	0.3	0.5
U.S.	4.6	3.5

The response lag may be related to institutional, financial, or administrative problems associated with public spending on public education. School finance in a state has

to overcome a wide variety of problems related to the many competing values and interests of parents, students, politicians, bureaucrats, and teachers. If increasing state funding for public education is regarded as making no difference in the performance of schools, then the educational funding would obtain little support. These barriers may become the factors contributing to prolonging the response lag in educational spending.

There is one finding worth noting, which may explain the differences of regional response lags associated with state spending in public education. During the 1980s, the student ratio in private schools seemed to be positively in line with the response lag (see Table V-9). The Northeast has the highest student ratio in private schools among regions and the ratio is almost twice as high as the South. The Northeast appears to be more reliant on private education. The more a region relies on private education, the less public education is demanded. The relatively lower demand for public education could result in a longer legislative lag associated with spending in public education, which would yield a longer response lag for the Northeast.

The relatively short response lag in spending for the South may be due to its relatively high reliance on public education. In addition, some states in the South have made provisions for state takeovers of local public education when

TABLE V-9
THE RATIO OF STUDENT IN PRIVATE SCHOOLS
TO TOTAL ENROLLMENT
(PERCENT)

	Year	
	1980	1989
Northeast	15.6	15.7
Midwest	11.8	12.1
West	9.1	9.1
South	7.9	7.9

Source: Digest of Education Statistics,
1982 & 1992.

there is a academic bankruptcy.²⁴ The active intervention with public education from state governments could reduce legislative lag and administrative problems associated with state spending, which make the speed of adjustment from actual to desired spending faster and the response lag shorter for the South.

The Tax-Price Elasticity

Theoretically, tax-price elasticity is expected to be

²⁴The states include Arkansas, Georgia, Kentucky, South Carolina, and Texas. See Stiglitz (1988), p. 370.

negative: the lower the tax price facing the median voter, the higher the expenditure per student. Based on equation (4.15) by the GLS method, the long-run elasticities of the demand for public education from state government with respect to tax prices are estimated to be -0.086, -1.993, -0.680, -0.538, and -0.675 for the Northeast, the Midwest, the West, the South, and the U.S., respectively. All of these estimated tax-price elasticities are negative except for the Northeast in which the t-value is not significantly different from zero.

When comparing with the estimated price elasticities of demand for local public education in Table II-1 of Chapter II, it is found, for the U.S. as a whole, that the tax-price elasticities in this study are lower than those from B-D's study (-1.13 to -1.21).²⁵ For the West, the tax price elasticity is also lower than that of McDougall's study using California data (-1.68), but much higher than those from Billings-Folsom and Baum (0.26 and 0.18). For the Northeast, the tax-price elasticity of the demand for public education from state government is close to zero. The tax-price elasticities of the demand for local public education appear to be much higher based on Ladd, Perkins, and Lovell who used Massachusetts and Connecticut data.

²⁵The elasticities obtained from cross-sectional data are usually considered as the long-run elasticities.

The Income Elasticity

Income serves as a measure of the capacity of an individual to consume both private and public goods. It also represents one of the socioeconomic differences across the states. Other things being equal, it is expected that income and demand for public education will be positively correlated. According to equation (4.15) estimated by the GLS method, the long-run elasticities with respect to augmented income are 2.585, 3.005, 1.884, 0.212, and 0.802 for the Northeast, the Midwest, the West, the South, and the U.S. (see Table V-6). These estimates are positive and significantly different from zero at the 1 percent level.

According to the model as specified here, augmented income is the sum of the median income and the share of federal aid. Therefore, the median-income elasticity and the federal-aid elasticity are determined by the respective weight of the median income and the federal aid in augmented income.²⁶

Table V-6 shows that the long-run elasticities of median income are 2.580, 2.996, 1.876, 0.211, and 0.799 for the Northeast, the Midwest, the West, the South, and the U.S., respectively. These estimated income elasticities are found to be much higher than those from estimated static equations

²⁶Median-income elasticity (ξ_{ym}) = $\xi_{yma}(ym/yma)$ and Federal-aid elasticity (ξ_f) = $\xi_{yma} - \xi_{ym}$.

except for the South.

The relatively low value of long-run median income elasticity in the South implies that in the long run, changes in educational expenditure per student are still much smaller than the changes in income. It also implies that in the short run and long run, interstate differences in state spending in public education are smaller than the differences in income among states in the South. As for the Northeast, the Midwest, and the West, the differences in income among states will yield, in the long run, much greater interstate differences in state spending in public education.

The median-income elasticities for the U.S. as a whole appear to be a little lower than the income elasticities of the demand for local public education by B-D and Todo'-Rovira in Table II-1. Except for Dynarski et al., all of income elasticities of demand for local public education are relatively low compared to those from the Northeast, the Midwest, and the West.

The Federal-Aid Elasticity

The long-run elasticities of the demand for public education from state government with respect to federal aid are estimated to be 0.005, 0.009, 0.008, 0.001, and 0.003 for the Northeast, the Midwest, the West, the South, and the U. S. These elasticities are relatively low compared to the

federal aid elasticities of demand for local public education based on Table II-1 of Chapter II. But, they substantially differ by region.

As noted above, augmented income includes median income and the voter's share of federal aid, implying median income and federal aid have the same effect on spending on public education. In an attempt to determine if a dollar's worth of aid increases spending in public education more than a dollar's worth of income, it is common to see if the flypaper effect holds. Considering the flypaper effect in equation (4.15), the specification can be expressed as:

$$(5.2) \ln E_{nt} = \text{const} + \theta \eta \ln(\tau)_{nt} + \theta \beta (1 + \eta) \ln w_{nt} \\ + \theta \delta \ln\{y_{m+\kappa}(\tau)(f)\}_{nt} + \theta (\alpha \eta + \alpha - 1) \ln NS_{nt} \\ + \theta \mu \ln \text{prt}_{nt} + \theta \gamma \ln t_{nt} + (1 - \theta) \ln E_{n,t-1} + \theta \varepsilon_{nt}.$$

If the estimated value of κ in the augmented income term is significantly greater than one, the flypaper effect exists, and implies that aid is more stimulative than income.

The parameters of Equation (5.2) can be estimated by the maximum likelihood method. Examination of the estimated value ($\hat{\kappa}$) shows that the so-called flypaper effect does not exist.²⁷

²⁷The estimated values of κ are -16.4 (-0.1), -2.9 (-0.3), 95.3 (0.1), -37.7 (-1.7), and 32.2 (0.13) for the Northeast, the Midwest, the West, the South, and the U.S., respectively, where figures in parentheses are t-values. Only the Northeast and the West have an estimated value of κ greater than one, but their t-statistics yield no support for

The Productivity-Lag in Public Education

According to the productivity-lag hypothesis in the public sector,²⁸ it is believed that the technology of the private sector, especially the non-service sector, is more liable to productivity improvements than is the labor-intensive public sector. It is assumed that public education is a public service with constant labor productivity and the manufacturing sector has progressive labor productivity. In the manufacturing sector, the wage rate is increased in line with its labor productivity, indicating that the unit cost will remain constant over time. But, if the wage rate in public education is steadily increased with the wage rate (or productivity rate) of the manufacturing sector, the increase in unit cost of public education will completely reflect the increase rate of wage due to its constant labor productivity.

Based on the above concept, the productivity lag in

the existence of the flypaper effect.

The flypaper effect is usually examined by using cross-sectional data with a given time period. In order to examine if income and federal aid at time period $t-1$ have the same effect on per student state educational expenditure at time t , the augmented income term $\ln\{y_m + \kappa(\tau)(f)\}_{nt}$ in (5.2) will be replaced with $\ln\{y_m + \kappa(\tau)(f)\}_{nt-1}$. The estimates of κ are 105.6 (0.5), -28.8 (-1.2), -37.6 (-54.0), -40.7 (-21.2), and -36.2 (-7.9) for the Northeast, the Midwest, the West, the South, and the U.S., respectively. These results also show that the flypaper effect does not exist. At time $t-1$, income appears to have a greater effect on educational expenditure at time t than does federal aid.

²⁸See footnote 19 on page 60.

public education can be obtained from the estimated value of β . The public education productivity lag (β) is an indirect estimate and determined by the estimated value of the coefficients for private wage and tax-price elasticity. If β is equal to one, then there is no increase in public education productivity and a 1 percent increase in private wage will lead to an increase in the unit cost of public education by 1 percent in the long run. If β is greater than zero, then the rate of growth of private sector productivity exceeds that of public education. If β is equal to zero, then public education and the manufacturing sector have the same growth rate of productivity.

According to Table V-6, the parameters (β) are estimated to be 3.753, 1.148, and 1.587, for the Northeast, the West, and the U.S. As for the Midwest and the South, they are -2.229 and -0.189, but they are not significantly different from zero. The estimation results indicate that there is a productivity lag in public education from state government for the Northeast, the West, and the U.S. As for the Midwest and the South, the growth rates of public education productivity seem to be higher than or are at least consistent with the private sector.²⁹

²⁹Usually, the productivity growth rate is lower in the public sector than in the private sector, and the negative estimates are difficult to interpret. But, it is also found that, except for the results from the MLE method, the estimated values of β are negative for the Midwest and the

The Publicness Elasticity

The long-run publicness elasticity is an indirect estimate of the elasticity of per student state expenditure with respect to student size in public schools, the tax-price elasticity, and the adjustment coefficient. The respective long-run elasticities of per student state expenditures with respect to student size are estimated to be -0.610, -2.54, -0.701, -0.677, and -.670 for the Northeast, the Midwest, the West, the South, and the U.S.³⁰ All of the estimated coefficients of student-size elasticities are negative. The negative relationship between expenditure and student size may indicate economies of scale exist in public education.³¹

As far as the parameter for the degree of publicness is concerned, the estimated values based on (4.15), by the GLS method, are 0.416, 1.550, 0.928, 0.650, and 1.015 for the Northeast, the Midwest, the West, the South, and the U.S.³²

South. The derived estimate of public school productivity-lag seems to need further analysis.

³⁰These elasticities are calculated to be $(\alpha + \eta\alpha + 1)$ from dynamic equation (4.15) for the U.S. and four regions.

³¹The concept of economies of scale is based on Bahl (1969). He suggests that economies of scale reflect a negative relationship between per capita expenditure and population. But, Wilensky (1970) points out that the per capita expenditure is not always expected to decline if the demand for the public service is elastic when the economies of scale present.

³²In a recent article, Duncombe and Yinger (1993) present a concept of "economies of population scale" based on the relationship between the per capita cost of public service

The estimated value of the publicness parameter for the U.S. is closer to those of B-D for local education (see Table II-1). These results indicate that state public education is not a pure public good. A value of the publicness parameter equal to one or larger implies that the public education under consideration shares the rivalry characteristic with private goods.

The Local Revenue Elasticity

As described in Chapter IV, state education expenditure can be affected by local education revenue. According to the estimated results, the long-run elasticities of per student state education spending with respect to local educational revenues are -1.081, -1.034, -0.623, -0.043, and -0.436 for the Northeast, the Midwest, the West, the South, and the U.S. It is found that all of these elasticities are negative and statistically significant. They indicate that in the long run, per student state expenditure on public education is expected to decrease by 1.081 percent, 1.034 percent, 0.623

and the number of people. They derive economies of population scale as the product of technical economies of scale and congestion (publicness) elasticities minus one. In this study, technical economies of scale is assumed to be one. So, the economies of population (student) scale will become publicness elasticity minus one, which are -0.584, 0.550, -0.072, -0.350, and 0.015 for the Northeast, the Midwest, the West, the South, and the U.S., respectively. Based on these results, economies of student scale do not exist for the Midwest and the U.S.

percent, 0.043 percent, and 0.436 percent in the Northeast, the Midwest, the West, the South, and the U.S. if the real local revenues for public education are increased by 1 percent. The negative correlation between state expenditure and local revenues also demonstrates that state governments play an important role in financing public education when local revenues become less than adequate. It is interesting to note that the long-run elasticities of state expenditure on public education with respect to local revenues seem to be positively related to the degree of local share of educational revenues. From 1982 to 1991, the average local shares of revenue for public education were 53 percent and 52 percent for the Northeast and the Midwest, respectively, which corresponds to relatively high elasticities of local revenues in these two regions. The respective local shares of revenues in the West and the South were 31 percent and 40 percent.

The Tuition Elasticity

Tuition in private schools is also a determining variable affecting expenditure per student from state governments. The long-run elasticities of expenditure per student with respect to tuition in private schools are -2.641, 0.442, -0.410, 0.187, and -0.086 for the Northeast, the Midwest, the West, the South, and the U.S., respectively.

These estimated values are statistically significant different from zero.

In general, spending in private schools is determined by the tuition received. More spending through higher tuition may improve the educational quality in private schools through better quality services or better students that improve the environment. In order to maintain public schools' competitiveness with private schools, expenditures per student for public education may increase when tuition in private schools rises, which will result in positive elasticities of expenditure with respect to tuition in private schools. This may explain results for the Midwest and the South.

As for the Northeast and the West, they have negative elasticities of tuition in public schools. The explanation may be that these two regions rely more on private education as a substitute for public education than do the Midwest and the South. An increase in private school tuition may result in less demand for private schools and more transfers to public schools. Due to economies of scale in public schools, per student state spending in public education would decrease.

Summary

According to the above analysis, the empirical findings

can be summarized as follows:

- A lagged response of per student state expenditure on public education to its determinants has been revealed for each region. The results from the dynamic model show that the median lag of the response for the U.S. is about four years, with the longest response lag (about 16 years) for the Northeast, and the shortest response lag (about six months) for the South.

- All of the long-run tax-price elasticities of the demand for state public education are negative. The tax price is highly elastic for the Midwest. The high tax-price elasticity seems to be a powerful determinant of per student state expenditure on public education in the Midwest.

- The long-run income elasticities of demand are very high except for the South. These high income elasticities lead to the conclusion that income is a powerful source of the growth of state spending in public education in the Northeast, the Midwest, and the West.

- The empirical evidence suggests that a sizeable productivity lag of the state public education may exist in the Northeast and the West compared with the private sector. For the Midwest and the South, the estimation results show that the growth of public education productivity seems to be in line with the growth in private sector productivity.

- The publicness estimates show that public education

provided by state government is not a pure public good. It appears that there exists a stronger crowding effect for the Midwest and the West than for the Northeast and the South.

- All of the demand elasticities with respect to local revenue for public education are negative. The empirical results demonstrate that the state has to assure enough money to provide public education when the local revenue is less than adequate in order to meet the equality goal of public education.

- The private school tuition is also a contributing variable affecting per student state spending in public education. But, the empirical results show that the private school tuition yields negative effects for the Northeast and the West, and positive effects for the Midwest and the South. Especially, for the Northeast, the long-run demand elasticity with respect to private school tuition is relatively high, implying it is an important determinant of state spending in public education in the long run.

Policy Implications

In general, a public policy will yield its impact on government expenditure through its determining variables and the influence of the median voter. In the following text the impact of public policy on per student state spending in public education is examined by means of the estimation

results. Specifically, the public policies consist of federal aid to public education, tuition tax credits, and school vouchers. The discussion also explores the issue of wealth neutrality.

The federal role in public education has always been a relatively minor one. But, it certainly has yielded effects on the state spending in public education. According to the model specification and empirical evidence, it is found that no flypaper effect exists for federal aid. Thus, federal aid and income have the same effect on per student state spending in public education when one more dollar of federal aid or income is increased. According to Table V-10, per student state spending in public education would instantaneously increase \$.005, \$.014, \$.012, and \$.009 for the Northeast, the Midwest, the West, and the South, respectively, with one more dollar increase of federal aid to public education. The impact shows that federal aid has the least stimulating effect on per student state spending in public education for the Northeast during the first year. In the long run, the impacts of one more dollar of federal aid on per student state spending in public education would be \$.12, \$.14, \$.10, and \$.01 for the Northeast, the Midwest, the West, and the South, respectively. Comparing the instantaneous and long-run effects, it is found that during the first year only 4 percent of the impact of a change in federal aid will be felt

TABLE V-10

SIMULATED IMPACT ON PER STUDENT STATE SPENDING IN PUBLIC EDUCATION
(DOLLARS)

		Northeast	Midwest	West	South	US
$\partial E / \partial r_f$	Long-Run Impact	0.121	0.135	0.103	0.011	0.041
	Instantaneous Impact	0.005	0.014	0.012	0.009	0.007
$\partial E / \partial NS$	Long-Run Impact	-1.067	-4.256	-1.577	-1.205	-1.242
	Instantaneous Impact	-0.044	-0.447	-0.185	-0.947	-0.222
$\partial E / \partial t_l$	Long-Run Impact	-0.747	-0.816	-0.954	-0.064	-0.713
	Instantaneous Impact	-0.030	-0.086	-0.112	-0.050	-0.083
$\partial E / \partial p_{rt}$	Long-Run Impact	-0.993	0.201	-0.117	0.110	-0.042
	Instantaneous Impact	-0.040	0.021	-0.014	0.086	-0.007

Notes: Unit for NS in this table is 1,000 students.
Long-run impact indicates impact at long-run equilibrium.

for the Northeast while over 90 percent of impact will be felt for the South within the same period.

Tuition tax credits are one of the major public policies proposed for aiding private schools, increasing competition pressures on public schools. It is also a kind of financial support for parents who pay for tuition in private schools. These parents would receive a credit against their income tax of a certain percentage or dollar amount, based on the specific structure of the credit. However, for the tuition tax credit to be effective, taxpayers must have a positive tax liability that can be offset by the credit. In the absence of refundable credits (for those with an insufficient tax liability), tuition tax credits would appear to only provide aid to the higher-income families who prefer private schools. Those families with a low-income level would not benefit from tuition tax credits.

An alternative public policy proposed for aiding private schools is the school voucher. The basic idea of a school voucher is that the government issues a voucher directly to the student or the family to pay for the student's education. The student or the family would choose a school (public or private) and uses the voucher as a payment for the education program. Unlike the tuition tax credit, the family would receive the full value of the voucher. Other things being equal, an additional dollar of school voucher would cause

more students to transfer to private schools than an additional dollar of tuition tax credit.

In general, tuition tax credits and school vouchers would lead to a decrease in private school tuition, assuming elastic supply of private schools. But, whether or not a tuition tax credit or a school voucher would affect per student state expenditure on public education, through a decrease in private school tuition, would be determined by the situation or decision faced by the median voter. If the median voter has insufficient income tax liability, then the tuition tax credit would yield no influence on per student state expenditure. In addition, if the median voter has no interest in private school, then both the tuition tax credit and the school voucher would not affect per student state expenditure. The school choices of the median voter appear to be an important determining factor affecting state spending in public education under the policies of tuition tax credits and school vouchers.

Table V-11 gives an example for the simulated instantaneous impacts of the \$250 tuition tax credits on per student state expenditure by region.³³ It is assumed one dollar of tuition tax credit faced by the median voter will

³³If the school voucher and tuition tax credit are of equal values, then the voucher would tend to have greater impact on per student state expenditure on public education.

TABLE V-11

THE INSTANTANEOUS IMPACTS OF A \$250 TUITION TAX CREDIT
(Dollars)

	Tuition Effect Only	Tuition and Student moving effects
Northeast	10.00	17.93
Midwest	-5.00	75.00
West	3.50	37.40
South	-21.50	-0.88
US	1.75	43.70

Notes: Students moving from public schools to private schools are based on surveys conducted by Kutner et al. (1986), which are 21.9 percent, 21.7 percent, 25.2 percent, 24.4 percent, and 23.5 percent of students for the Northeast, the Midwest, the South, and the U.S.

lead to a decrease in private school tuition by one dollar. With a tuition tax credit of \$250, per student state expenditure on public education would instantaneously increase by \$10.00, \$3.50, and \$1.75 for the Northeast, the West, and the U.S., and decrease by \$5.00 and \$21.5 for the Midwest and the South through the response of the median voter. The South appears to have the greatest instantaneous impact due to its relatively high short-run elasticity of tuition in private schools.

According to Kutner et al. (1986), with a tuition tax credit of \$250, 21.9 percent (Northeast), 21.7 percent (midwest), 23.2 percent (West), 24.4 percent (South), and 23.5 percent (U.S.) of public school parents would be "very likely" or "somewhat likely" to move their children to private schools.³⁴ As shown in Table V-11, if the effects due to students switching are considered, the Midwest would have the largest instantaneous impact on per student state spending and the South would have the least impact.

Finally, the implication of wealth neutrality is discussed. In this study, wealth neutrality requires that spending in public education not reflect differences in state wealth. According to Feldstein (1975), the wealth neutrality measure can be expressed as:

³⁴See Kutner et al. (1986), P. 73. It should be noted that data are only average values, not median values. The simulation impacts only yield proximate results.

$$(6.1) \quad \xi_{tew} = \xi_{ew} + \xi_{tp}\xi_{pw}$$

where ξ_{tew} = total elasticity of educational expenditure with respect to wealth;

ξ_{ew} = adjusted elasticity of educational expenditure with respect to wealth;

ξ_{tp} = tax-price elasticity; and

ξ_{pw} = elasticity of tax price with respect to wealth.

The wealth neutralizing scheme reduces the value of ξ_{tew} . Given ξ_{ew} and ξ_{tp} are behavioral parameters, policy-makers could adjust matching grants in line with ξ_{pw} needed to achieve the desired degree of wealth neutrality. When ξ_{tew} is equal to zero, complete wealth neutrality occurs and

$$(6.2) \quad \xi_{pw} = -(\xi_{ew}/\xi_{tp}).$$

Based on (6.2), the wealth neutralizing ξ_{pw} is determined by the tax-price elasticity (ξ_{tp}) and adjusted wealth elasticity (ξ_{ew}). But, generally, the tax price elasticity is critical for determining ξ_{pw} . The more elastic the demand for public education, the more effective the federal matching grant will be in reducing the state wealth differential effects on educational expenditure.

In this study, no adjusted wealth elasticities are estimated and only the tax-price elasticities are used to address the implications of wealth neutrality. According to the estimates for the tax price elasticities listed on Table V-6, it is found that the tax price elasticity for the

Northeast is very low. In order to attain complete wealth neutrality, it seems to require the federal government to provide negative aid (i.e., $\xi_{pw} > 1$) to some states for the Northeast, unless the adjusted wealth elasticity is also extremely low.³⁵ As for the Midwest, the relatively high tax-price elasticity makes it possible to neutralize the influence of wealth in state educational expenditure by adjusting federal matching aid. For the West and the South, a complete wealth neutrality is still possible if the adjusted wealth elasticities are low and less than their respective tax-price elasticities.

³⁵According to Feldstein (1975), the adjusted wealth elasticity estimate is 0.37 for local educational expenditure in Massachusetts.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Empirical studies of spending on public education have been in the literature for several decades. Most of these empirical studies primarily focus on local public educational expenditure by using cross-sectional data. The demand for public education from higher levels of government has received little attention in the empirical studies. Accordingly, this study attempts to fill this gap by using time-series and cross-sectional data to estimate the state expenditure on public education. On the whole, the empirical evidence in this study appears to be consistent with theoretical expectations.

This study starts with reviewing the previous empirical studies, identifying strengths and weaknesses. According to the review, it is found that the median-voter approach has been widely used to estimate public educational expenditure since this approach lends itself to the derivation of demand elasticities with respect to price and income.

Following the literature review, an alternative demand for public education from state government is formulated based on the median-voter approach. According to this theoretical model, a static equation for estimating the

demand for public education from state government is derived under the assumption of a multiplicative demand function. Moreover, two dynamic specifications of the demand equation for public education are also derived, based on the partial adjustment model to allow for the possibility of differences between short-run and long-run responses of the demand for public education. The first is an adjustment pertaining to the amount of public education demanded. This specification leads to a case of overidentification for the estimation equation. The other is an adjustment pertaining to spending in public education.

There are three estimation methods for estimating the relevant equations. The MLE method is used to estimate the overidentified equation. The OLS and GLS methods are used to estimate the just-identified static and dynamic equations. The GLS method is based on a cross-sectionally correlated and time-wise autoregressive model, taking the autocorrelation problem over time and mutual dependence among states into consideration.

According to the hypothesis testing, it has verified that the estimation of the demand for public education from state government by region is justifiable. Regions do show differences in the estimated parameters. The empirical results have been presented and analyzed to explain the long-run elasticities of the demand for public education from

state government and the differences of the estimated parameters among regions.

The empirical results reveal several major findings. In the existing literature of estimating spending on public education, it is common to assume that there is no lag in the adjustment between actual spending and desired level based on a static model from cross-sectional data. According to this study, the t-test of the lagged dependent variable demonstrates that the dynamic model based on a partial adjustment mechanism is more desirable than the static one. The estimated values for the adjustment coefficients show that, for any given period, the actual level of spending on public education does not adjust completely to obtain the desired level. A static demand framework for public education may be a misspecification, leading to erroneous inferences and misleading public policy.

In addition, the empirical results also demonstrate that the GLS method for the dynamic specification has provided better results for analyzing the demand for public education from state government. When pooled time-series and cross-sectional data are considered for estimating state spending on public education, the cross-sectional units (states) are not mutually independent and the disturbances are autocorrelated over time. Due to autocorrelation over time and mutual dependence among states, the OLS method will yield

a poor estimate with a low t-value. The GLS method is used to deal with these two problems and provide a consistent, asymptotically unbiased, and efficient estimator.

According to the GLS results from the dynamic equation, it is found that the tax-price elasticities are negative, that the income elasticities are positive, that the local revenue elasticities are negative, that economies of scale exist, and that state public education is not a pure public good for all regions. At the same time, there exist different behavioral responses among regions.

Based on the estimated values for the adjustment coefficients and elasticity coefficients, the lagged response of per student state spending on public education to a change in one of the explanatory variables is calculated. The evidence shows that the South has the shortest response lag, and the Northeast has the longest. For the Northeast, about 5 percent of the impact of per student state spending on public education is felt during the first year. For the South, the impact is more than 80 percent in the first year. The response lag for the Northeast is so long that the goal of a long-run equilibrium may never be obtained before another school financing reform begins.

An additional result, based on the model specification in this study, is that the flypaper effect of federal aid does not exist for all regions. As for the role of private

school tuition, it is found that it yields a negative effect for the Northeast and the West and a positive effect for the Midwest and the South. The empirical findings also show that in the Midwest and the South, the rate of productivity growth in public education seems to be in line with that of the private sector. The rate of productivity growth in public education for the Northeast and the West is relatively slow compared to the private sector.

Finally, the impact of public policies on state spending in public education is examined. Increases in federal aid yield positive effects on state spending in public education for all regions. The South appears to have the greatest instantaneous effect for an additional dollar of federal aid, compared to the long-run impact.

Both tuition tax credits and school vouchers will reduce the tuition in private schools. Other things being equal, the introduction of tuition tax credits and school vouchers would lead to an increase in per student state expenditure on public education for the Northeast and the West based on the simulated responses of the median voter. For the Midwest and the South, they would yield negative effects on state spending in public education.

Concerning the implication of wealth neutrality, it seems very difficult to completely remove the wealth differential effects on educational expenditure across states

by adjusting federal matching aid, except for the Midwest. In particular, the federal government may need to have another policy scheme to produce a desired degree of wealth neutrality for the Northeast.

Admittedly, there are some limitations in this study. The cost of capital service is not included in the estimation; the tax-price term is a proxy and does not consider the role of exporting;³⁶ and there is no output measure for public education and no role for bureaucrats on the supply side of public education. Nevertheless, this study has addressed the particularly important question of lagged spending response, yielding numerous interesting results that provide some implications for educational policies at the federal and state levels. This study may provide a remedy for the deficiencies in the studies of the demand for public education and lay the groundwork for future work in the general area of the demand for government-provided goods and services.

³⁶This omission may not be a problem. Downes and Pogue (1994) suggest that tax exporting has nothing to do directly with the tax share and tax prices, and the fraction of taxes exported is not a determinant of the median voter's demand.

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APPENDIX

Estimation Results on the Demand for Public Education Equations

TABLE A-1

ESTIMATED COEFFICIENTS OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (U.S.)
(THE DEPENDENT VARIABLE = LnE_{nt})

Independent Variables	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
Constant	2.204 (1.48)	2.919*** (16.23)	0.451 (0.89)	1.024** (1.97)	0.222** (2.15)
$\text{Ln}\tau_{nt}$	-0.401*** (-4.38)	-0.069*** (-2.71)	0.003 (0.14)	-0.057* (-1.75)	-0.121*** (-11.26)
$\text{Ln}y_{ma_{nt}}$	0.278* (1.75)	0.239*** (19.58)	-0.001 (-0.10)	-0.013 (-0.23)	0.143*** (9.66)
$\text{Ln}w_{nt}$	0.683*** (5.31)	-0.042*** (-3.11)	0.846*** (6.13)	0.097** (2.09)	0.092*** (11.02)
LnNS_{nt}	-0.345*** (-3.49)	0.061** (2.57)	-1.068*** (-4.68)	-0.054 (-1.54)	-0.120*** (-11.22)
Lnprt_{nt}	0.125** (2.17)	0.099*** (26.67)	0.195*** (2.79)	-0.023 (-1.14)	-0.015*** (-7.31)
Lntl_{nt}	-0.191*** (-9.75)	-0.108*** (-13.67)	-0.014 (-1.88)	-0.018** (-2.42)	0.078*** (-17.22)
$\text{Ln}w_{n,t-1}$	-	-	-0.831*** (-3.99)	-	-
$\text{LnNS}_{n,t-1}$	-	-	0.973*** (4.72)	-	-
$\text{LnE}_{n,t-1}$	-	-	0.911*** (60.76)	0.884*** (57.88)	0.821*** (141.27)
R^2	0.212	-	0.907	0.903	-
Observations	480	480	480	480	480

Notes: Figures in parentheses are t-values. ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% level, respectively.

TABLE A-2

PARAMETER ESTIMATES OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (U.S.)

	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
ξ_{tp}	-0.401 ^{***} (-4.38)	-0.069 ^{***} (-2.71)	0.031 (0.14)	-0.494 (-1.10)	-0.675 ^{***} (-18.77)
ξ_{yma}	0.278 [*] (1.75)	0.239 ^{***} (19.57)	-0.007 (-0.01)	-0.112 (-0.23)	0.802 ^{***} (5.20)
β	1.140 ^{***} (4.82)	-0.045 ^{***} (-2.96)	0.844 ^{***} (6.02)	1.655 (1.23)	1.587 ^{***} (3.75)
ξ_{pb}	1.096 ^{**} (1.97)	1.140 ^{***} (21.92)	-0.068 (-0.30)	0.078 (0.13)	1.015 ^{***} (61.47)
ξ_{tl}	-0.191 ^{***} (-9.75)	-0.108 ^{***} (13.67)	-0.162 ^{**} (-2.22)	-0.157 ^{***} (-2.64)	-0.436 ^{***} (-18.89)
ξ_{prt}	0.125 ^{**} (2.17)	0.099 ^{***} (26.67)	0.22 (0.94)	-0.200 (-1.10)	-0.086 ^{***} (-7.09)
π or θ	-	-	0.089 ^{***} (5.95)	0.116 ^{***} (7.60)	0.179 ^{***} (115.70)

Notes: See Table A-1.

TABLE A-3

ESTIMATED COEFFICIENTS OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (NORTHEAST)
(THE DEPENDENT VARIABLE = $\ln E_{nt}$)

Independent Variables	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
Constant	0.147 (0.02)	-9.640 ^{***} (-12.97)	-1.147 (-0.96)	-2.320 (-1.57)	-1.380 ^{***} (-3.01)
$\ln r_{nt}$	-0.472 [*] (-1.89)	0.021 ^{***} (2.79)	-0.010 (-0.48)	0.029 (0.60)	-0.003 (-0.26)
$\ln yma_{nt}$	0.634 (0.84)	0.765 ^{***} (11.87)	0.197 (0.33)	0.246 [*] (1.77)	0.105 ^{***} (4.89)
$\ln w_{nt}$	1.325 [*] (1.72)	-0.171 ^{***} (-2.91)	0.657 ^{***} (2.75)	0.265 ^{**} (1.97)	0.287 ^{***} (5.68)
$\ln NS_{nt}$	-0.254 (-0.86)	0.471 ^{***} (14.65)	1.444 [*] (1.67)	0.019 (0.35)	-0.025 (-1.50)
$\ln prt_{nt}$	0.341 (0.64)	0.450 ^{***} (10.95)	-0.074 (-0.85)	-0.136 (-1.41)	-0.107 ^{***} (-4.04)
$\ln tl_{nt}$	-1.097 ^{**} (-2.54)	-0.080 (-1.62)	0.010 (0.13)	-0.128 (-1.48)	-0.044 (-1.37)
$\ln w_{n,t-1}$	-	-	0.649 (0.74)	-	-
$\ln NS_{n,t-1}$	-	-	1.147 (1.12)	-	-
$\ln E_{n,t-1}$	-	-	0.979 ^{***} (49.80)	0.923 ^{***} (31.80)	0.959 ^{***} (69.50)
R^2	0.306	-	0.978	0.976	-
Observations	90	90	90	90	90

Notes: See Table A-1.

TABLE A-4

PARAMETER ESTIMATES OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (NORTHEAST)

Independent Variables	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
ξ_{tp}	-0.472 [*] (-1.89)	0.021 ^{***} (2.79)	-0.444 (-0.49)	-0.246 (-0.22)	-0.086 (-0.26)
ξ_{yma}	0.634 (0.84)	0.765 ^{***} (11.87)	9.257 (0.92)	0.919 (1.22)	2.585 ^{***} (2.73)
β	2.510 (1.29)	-0.168 ^{***} (-2.91)	0.663 ^{***} (2.77)	9.654 (0.32)	3.753 [*] (1.75)
ξ_{pb}	1.412 ^{***} (6.87)	1.442 ^{***} (48.35)	-0.448 (-0.51)	0.110 (0.06)	0.416 ^{**} (1.98)
ξ_{tl}	-1.097 ^{**} (-2.54)	-0.080 (-1.62)	0.448 (0.12)	0.180 (0.09)	-1.081 (-1.86)
ξ_{prt}	0.340 (0.62)	0.450 ^{***} (10.95)	-3.470 (-0.60)	-4.015 (-1.24)	-2.641 ^{***} (-3.48)
π or θ	-	-	0.021 (1.09)	0.041 ^{**} (2.07)	0.041 ^{***} (2.94)

Notes: See Table A-1.

TABLE A-5

ESTIMATED COEFFICIENTS OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (MIDWEST)
(THE DEPENDENT VARIABLE = $\ln E_{nt}$)

Independent Variables	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
Constant	-1.548 (-0.47)	3.805*** (9.02)	-2.498 (-1.59)	-2.586* (-1.67)	-1.992*** (-3.57)
$\ln r_{nt}$	0.533 (1.62)	0.134*** (2.80)	-0.095 (-0.16)	-0.106 (-0.67)	-0.209*** (-4.73)
$\ln y_{ma_{nt}}$	0.938** (2.70)	0.319*** (9.17)	0.365 (0.615)	0.364** (2.20)	0.316*** (6.17)
$\ln w_{nt}$	-0.090 (-0.25)	-0.308*** (-6.69)	1.646*** (7.93)	0.231 (1.38)	0.232*** (4.50)
$\ln NS_{nt}$	0.433 (1.23)	0.085* (1.76)	1.646 (1.15)	-0.164 (-0.98)	-0.266*** (-5.73)
$\ln t_{l_{nt}}$	-0.374*** (-4.92)	-0.153*** (-21.15)	-0.073* (-1.87)	-0.071* (-1.85)	-0.109*** (-8.72)
$\ln pr_{nt}$	0.485*** (6.10)	0.331*** (25.16)	0.057 (1.32)	0.056 (1.29)	0.046*** (4.43)
$\ln w_{n,t-1}$	-	-	0.659 (0.55)	-	-
$\ln NS_{n,t-1}$	-	-	1.498 (1.21)	-	-
$\ln E_{n,t-1}$	-	-	0.874*** (21.85)	0.874*** (20.08)	0.895*** (29.03)
R^2	0.425	-	0.873	0.874	-
Observations	120	120	120	120	120

Notes: See Table A-1.

TABLE A-6
PARAMETER ESTIMATES OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (MIDWEST)

	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
ξ_{tp}	0.533 (1.61)	0.134 ^{***} (2.97)	-0.754 (-1.59)	-0.846 (-0.53)	-1.993 ^{***} (-3.03)
ξ_{yma}	0.938 ^{***} (2.70)	0.319 ^{***} (9.17)	2.852 ^{**} (1.92)	2.889 ^{**} (1.92)	3.005 ^{***} (3.31)
β	-0.058 (-0.24)	-0.272 ^{***} (-6.77)	0.240 (1.14)	11.837 (0.12)	-2.229 (-1.55)
ξ_{pb}	0.934 ^{***} (5.09)	0.957 ^{***} (38.87)	-0.714 (-0.49)	-1.940 (-0.08)	1.550 ^{***} (17.94)
ξ_{tl}	-0.374 ^{***} (-4.92)	-0.153 ^{***} (-21.15)	-0.576 ^{**} (-1.96)	-0.568 ^{**} (-1.95)	-1.034 ^{***} (-3.55)
ξ_{prt}	0.485 ^{***} (6.10)	0.331 ^{***} (25.16)	0.453 (1.53)	0.441 (0.63)	0.442 ^{***} (3.28)
π or θ	-	-	0.127 ^{***} (2.89)	0.126 ^{***} (2.89)	0.105 ^{***} (3.41)

Note: See Table A-1.

TABLE A-7

ESTIMATED COEFFICIENTS OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (WEST)
(THE DEPENDENT VARIABLE = $\ln E_{nt}$)

Independent Variables	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
Constant	3.991 [*] (1.69)	3.593 ^{***} (16.55)	0.171 (0.19)	-0.139 (-0.15)	-0.805 ^{***} (-3.70)
$\ln r_{nt}$	-0.533 ^{***} (-4.62)	-0.395 ^{***} (-48.80)	0.760 (0.17)	-0.051 (-0.99)	-0.080 ^{***} (-5.99)
$\ln y_{ma_{nt}}$	0.548 [*] (1.84)	0.462 ^{***} (27.86)	0.007 (0.07)	0.128 (1.06)	0.220 ^{***} (6.21)
$\ln w_{nt}$	0.547 ^{**} (2.58)	-0.265 ^{***} (-14.38)	0.333 (1.30)	0.076 (0.87)	0.043 (1.39)
$\ln NS_{nt}$	-0.512 ^{***} (-3.91)	-0.375 ^{***} (-32.96)	-0.206 (-1.48)	-0.053 (-0.94)	-0.082 ^{***} (-5.07)
$\ln t1_{nt}$	-0.433 ^{***} (-9.60)	-0.274 ^{***} (-34.36)	-0.004 (-0.36)	-0.059 ^{**} (-2.39)	-0.073 ^{***} (-6.40)
$\ln prt_{nt}$	-0.141 (-1.37)	0.110 ^{***} (8.85)	-0.012 (-0.31)	-0.033 (-0.81)	-0.026 (-1.38)
$\ln w_{n,t-1}$	-	-	-0.776 [*] (-1.74)	-	-
$\ln NS_{n,t-1}$	-	-	0.215 (0.47)	-	-
$\ln E_{n,t-1}$	-	-	0.978 ^{***} (37.60)	0.910 ^{***} (22.20)	0.883 ^{***} (44.77)
R^2	0.556	-	0.931	0.929	-
Observations	110	110	110	110	110

Notes: See Table A-1.

TABLE A-8
PARAMETER ESTIMATES OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (WEST)

	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
ξ_{tp}	-0.533 ^{***} (-4.62)	0.395 ^{***} (-48.80)	0.793 [*] (1.74)	-0.562 (-1.07)	-0.680 ^{***} (-6.98)
ξ_{yma}	0.548 [*] (1.84)	0.462 ^{***} (27.86)	0.307 (0.07)	1.411 (1.01)	1.884 ^{***} (5.07)
β	1.171 ^{**} (2.10)	0.763 ^{***} (22.74)	0.327 (1.30)	1.980 (0.58)	1.148 ^{**} (1.96)
ξ_{pb}	1.044 ^{***} (18.17)	1.032 ^{***} (48.95)	0.780 [*] (1.66)	0.972 ^{***} (3.05)	0.928 ^{***} (5.74)
ξ_{tl}	-0.433 ^{***} (-9.60)	0.274 ^{***} (-34.36)	-0.203 (-0.80)	-0.654 ^{***} (-4.62)	-0.623 ^{***} (-7.20)
ξ_{prt}	-0.141 (-1.37)	0.110 ^{***} (8.85)	-0.568 (-0.31)	-0.370 (-0.79)	-0.410 ^{**} (-2.23)
π or θ	-	-	0.022 (0.84)	0.090 ^{**} (2.20)	0.117 ^{***} (5.95)

Note: See Table A-1.

TABLE A-9

ESTIMATED COEFFICIENTS OF THE DEMAND EQUATIONS FOR PUBLIC
EDUCATION (SOUTH)
(THE DEPENDENT VARIABLE = $\ln E_{nt}$)

Independent Variable	Equation (4.8)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
Constant	5.972 ^{***} (3.55)	1.109 ^{**} (2.20)	1.383 (1.43)	3.700 ^{***} (3.13)	4.427 ^{***} (7.88)
$\ln \tau_{nt}$	-0.496 ^{***} (-3.51)	-0.599 ^{***} (-15.79)	0.407 ^{***} (-7.71)	-0.269 ^{***} (-2.69)	-0.423 ^{***} (-9.55)
$\ln y_{ma_{nt}}$	0.129 (0.77)	0.571 ^{***} (15.04)	0.063 (0.60)	0.007 (0.07)	0.177 ^{***} (3.34)
$\ln w_{nt}$	-0.150 (-0.90)	-0.154 ^{***} (-4.27)	1.230 ^{***} (4.15)	-0.012 (-0.01)	-0.069 (-1.33)
$\ln NS_{nt}$	-0.622 ^{***} (-4.60)	-0.705 ^{***} (-22.03)	1.567 ^{***} (14.90)	-0.332 ^{***} (-3.44)	-0.532 ^{***} (-12.31)
$\ln t_{l_{nt}}$	-0.103 ^{**} (-2.00)	-0.053 ^{***} (-6.93)	-0.081 ^{**} (-2.29)	-0.023 (-0.63)	-0.034 [*] (-1.86)
$\ln pr_{nt}$	0.299 ^{***} (5.17)	0.170 ^{***} (5.41)	0.214 ^{***} (3.74)	0.060 (1.36)	0.147 ^{***} (6.16)
$\ln w_{n,t-1}$	-	-	0.519 ^{***} (8.28)	-	-
$\ln NS_{n,t-1}$	-	-	1.095 ^{***} (14.26)	-	-
$\ln E_{n,t-1}$	-	-	0.560 ^{***} (14.00)	0.533 ^{***} (12.82)	0.214 ^{***} (8.89)
R^2	0.407	-	0.731	0.713	-
Observations	160	160	160	160	160

Notes: See Table A-1.

TABLE A-10

PARAMETER ESTIMATES OF THE DEMAND EQUATION FOR PUBLIC
EDUCATION (SOUTH)

	Equation (4.9)		Equation (4.12)	Equation (4.15)	
	OLS	GLS	MLE	OLS	GLS
ξ_{tp}	-0.496 ^{***} (-3.51)	-0.599 ^{***} (-15.79)	-0.926 ^{***} (-10.38)	-0.576 ^{***} (-2.67)	-0.538 ^{***} (-9.32)
ξ_{yma}	0.129 (0.77)	0.571 ^{***} (15.04)	0.143 (0.60)	0.016 (0.06)	0.212 ^{***} (3.33)
β	-0.296 (-0.95)	-0.385 ^{***} (-3.99)	2.075 ^{***} (4.12)	-0.059 (-0.10)	-0.189 (-1.24)
ξ_{pb}	0.749 ^{***} (9.89)	0.736 ^{***} (22.63)	-0.960 ^{***} (-51.18)	0.680 ^{***} (4.36)	0.650 ^{***} (14.15)
ξ_{tl}	-0.103 ^{**} (-2.00)	-0.053 ^{***} (-6.94)	-0.184 ^{**} (-2.33)	-0.049 (-0.65)	-0.043 ^{**} (1.96)
ξ_{prt}	0.299 ^{***} (5.17)	0.170 ^{***} (5.41)	0.486 ^{***} (3.72)	0.129 (1.38)	0.187 ^{***} (6.58)
π or θ	-	-	0.440 ^{***} (11.18)	0.467 ^{***} (11.22)	0.786 ^{***} (32.61)

Notes: See Table A-1.

VITA

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