THE IMPACTS OF THE FEDERAL AID HIGHWAY PROGRAM ON STATE AND LOCAL HIGHWAY EXPENDITURES

by

LEONARD SHERMAN

S.B., Massachusetts Institute of Technology
(1971)

S.M., Massachusetts Institute of Technology
(1971)

Submitted in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

at the

Massachusetts Institute of Technology

February, 1975

Signature of Author . . . .
Department of Civil Engineering, January 22, 1975

Certified by . . . .
Thesis Supervisor

Accepted by . . . .
Chairman, Departmental Committee on Graduate Students
of the Department of Civil Engineering

ABSTRACT

THE IMPACTS OF THE FEDERAL AID HIGHWAY PROGRAM ON

STATE AND LOCAL HIGHWAY EXPENDITURES

by

LEONARD SHERMAN

Submitted to the Department of Civil Engineering on January 22, 1975 in partial fulfillment of the requirements for the degree of Doctor of Philosophy

This thesis investigates the impacts of the Federal Aid Highway Program on State and local highway expenditures. Our concern throughout the conduct of the research is to focus on this issue from a national policy perspective. Several recent events have led to an increasing interest in restructuring the Federal role in highway finance, most notably the controversy surrounding the passage of the 1973 Federal Aid Highway Act and the debate over post-Interstate System highway policy. Accordingly, the motivation of this research is a consideration of the design of and response to Federal Aid highway financing.

The starting point is a review of the mechanics of State and Federal highway finance. Special attention is given to the unique aspects of the Federal Aid Highway Program (FAHP) and the attendant implications for empirical modelling. The thesis then proceeds to develop a theory of State highway expenditure behavior. Our purpose here is to draw attention to the premise that State highway expenditure behavior depends not only on the level of available Federal grants-in-aid, but on the structural characteristics of the grant program as well. The theoretical models suggest that for the Interstate program, Federal grants have stimulated State expenditures that would most likely have not been made in the absence of the grant program. This behavior is contrasted with the experience on the non-Interstate Federal Aid programs where the theoretical models suggest that Federal grants have had a relatively insignificant impact on States' expenditure levels.

The theoretical hypotheses of State expenditure behavior are then validated with econometric models designed to explore the factors influencing States' total highway expenditure levels and the allocation of States' highway budgets amongst alternative expenditure categories. The models are estimated using a pooled data sample comprising the forty eight mainland States over a fourteen year analysis period.

Evaluation of the empirical results from the expenditure models suggest several basic policy recommendations for future Federal highway policy. Most notably, it is recommended that the U.S. Department of Transportation undertake a grant consolidation program, eliminate existing grant matching provisions, and restructure current apportionment factors and Interstate Highway Trust Fund revenue mechanisms.

Thesis Supervisor: Marvin Lee Manheim

Title: Professor of Civil Engineering

ACKNOWLEDGEMENTS

Throughout the course of this research, I have benfitted from the advice, encouragement and assistance from many individuals. The contributions of Professor Marvin L. Manheim, my thesis advisor to the development of this study extend far beyond his valuable suggestions on particular phases of the research. In a larger sense, he has been singlularly influential in stimulating my interest in the anlysis of transportation policy issues. Professors Paul Roberts, Wayne Pecknold, and Moshe Ben-Akiva, as members of my doctoral committee provided several valuable ideas and suggestions that aided in both the development of the theoretical analyses and in the writing of the final manuscript. I would also like to express particular appreciation to Professor Richard Tresch of Boston College. I have benfitted greatly from reading his own research in this field. And as a member of my doctoral committee, Professor Tresch's advice and encouragement have contributed greatly to the development and presentation of the ideas in this dissertation.

Several individuals in the U.S.Department of Transportation also deserve special mention for their role in assisting in the conduct of this research. Ira Dye of the Office of Transportation Planning Analysis is gratefully acknowledged for his constant encouragement and for arranging the financial support by DOT that allowed this study to be undertaken. Arrigo Mongini and George Wiggers, also in the Office of Transportation Planning Analysis have been extremely helpful in contributing numerous keen insights throughout the conduct of this research. In addition I would like to express my appreciation to Ed Gladstone and Bill McCallum of the Federal Highway Administration for freely giving of their time, advice and encouragement during the formative stages of this research.

To my friends and colleagues at M.I.T., in particular Frank Koppelman, Uzi Landau and Steve Lerman, I would like to express my thanks for their constant help alon the way. Bronwyn Hall of the Harvard Bureau of Economic Research must also be acknowledged for jer assistance in ironing out problems encountered in using the computer for the econometric analysis phases of this research.

And finally, my thanks go to the numerous people who contributed greatly to the preparation of the final document: Carol Walb, Charna Garber, Charlotte Goldberg, Rebecca Lord and Shulamit Kahn.

TABLE OF CONTENTS

Page

Page

Page

Page

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

CHAPTER I

INTRODUCTION AND SUMMARY

I.1 Motivation for Research

This study is concerned with the impact of Federal aid financing on the highway expenditures of State and local governments. The motivations for this research are numerous. First, it is aimed at providing useful input to the ongoing debate over structural changes in the Federal aid highway program. Although Federal responsibility for the financing of highway facilities has been increasing in recent years, both in terms of the extent of activity and the amounts of money involved, the basic principles upon which the Federal aid highway program operates was established over 50 years ago in the Federal-Aid Act of 1916. For the first time proposals have been advanced which, in one case will allow Federal monies to be used for non-highway urban mass transit systems,[1] and in another, would establish non-modally aligned block funding for a broad spectrum of transportation activities (including non-capital expenditures).[2] In order to evaluate the consequences of these, and other program variants, it is first necessary to assess the impacts of the existing Federal grant-in-aid program.

By any measure, the Federal aid highway program represents a large expenditure of funds. Its magnitude, combined with its singular status as a restricted trust fund, provide a second motivation for

[1] As embodied in the Federal-Aid Highway Act of 1973.

[2] As embodied in S.1693: the Special Transportation Revenue Sharing Act of 1969.

focusing this analysis on the Federal aid highway program. Federal expenditures for highways in 1970 amounted to $4.84 billion,[1] second only to Federal welfare payments ($6.47 billion[2]). Moreover, Federal highway outlays account for a large percentage of total (by all units of government) highway expenditures, averaging 27% nationwide, and over 60% in some States (1970).[3] Consequently, changes in the structure of the Federal aid highway program (e.g., amounts of Federal money available, changes in the matching provisions, etc.) may cause significant changes in State and local governmental highway investment behavior. Viewed in this perspective, the structure of the Federal aid highway program is a significant policy tool with which the U.S. Department of Transportation can influence the pattern of highway investments.[4] To exploit this potential, an understanding of the dynamics of State and local transportation investment behavior is essential.

A third motivation for focusing this investigation on the Federal aid <u>highway</u> program as opposed to the broader question of

---

[1]Federal Highway Administration, HIGHWAY STATISTICS, 1970.

[2]Advisory Commission on Intergovernmental Relations, STATE-LOCAL FINANCES: SIGNIFICANT FEATURES AND SUGGESTED LEGISLATION, 1972 ed.

[3]ibid.

[4]In this regard, the federal aid highway program has been used as a tool to counteract cyclical fluctuations in the Nation's economy. During the recession of the late 1950's, Congress appropriated $600 million (the so-called "D" funds) in addition to the appropriations for the Interstate and "ABC" programs, for the purpose of stimulating governmental expenditures. For a description of the State response to the D fund program, see Friedlaender, A.F., "The Highway Program as a Public Works Tool," pp. 93-101, in Ando, A.,

intergovernmental fiscal relations (in all functional areas[1]), is that it allows for a more detailed analysis of the complexities involved in State and local investment decision-making behavior. There exists ample evidence to suggest that States' expenditure responses to Federal functional grants (e.g. highways, welfare, education, etc.) exhibit more significant trade-offs amongst expenditures <u>within</u> a particular function than between different functions. Federal grants for public assistance provide one example. Since their inception in 1935, these grants have been restricted to specific categories of needy people,[2] leaving general welfare payments as the sole responsibility of States and metropolitan areas. The experience has been that the States were liberal in expanding the welfare programs in the Federally eligible categories, and parsimonious in spending for general (non-aided) relief.[3]

---

et al., STUDIES IN ECONOMIC STABILIZATION, The Brookings Institution, 1968.

In this thesis, we will be more concerned with the allocative impacts of the Federal aid highway program than with the use of Federal funds in conjunction with a stabilization policy. We will raise the issue of whether Federal aid stimulates State expenditures (i.e. over and above the amounts required to simply match Federal funds).

[1]For a general discussion on the characteristics of the various functional Federal aid programs, see: Break, G.F., INTERGOVERNMENTAL FISCAL RELATIONS IN THE UNITED STATES, The Brookings Institution, 1967; Maxwell, J.A., FINANCING STATE AND LOCAL GOVERNMENTS, The Brookings Institution, Revised Edition, 1969.

[2]There are currently five major Federal aid welfare programs: Old Age Assistance, Aid to the Blind, Aid to the Permanently and Temporarily Disabled, Aid for Dependent Children, and Medicaid.

[3]Maxwell, J.A.,"Federal Grant Elasticity and Distortion," National Tax Journal, Vol XXII, No. 4, pp. 550-552

Highways present perhaps an even more striking example where State/local responses to Federal grants are more manifest in expenditure adjustments between particular highway categories, than in overall adjustments to the State budget. Here too, Federal grants are directed at designated types of highways,[1] leaving expenditures on other highway-related activities to the discretion of the States. Moreover, State restrictions on the use of their own trust fund monies[2] indicate that there is minimal interaction between investment decisions in the highway "sector" and other sectors (e.g. welfare, health, education, etc.) of the State budget.

In short a basic premise of this research is that investigation of the impacts of the functional Federal grants in aid must explicitly consider State/local expenditure responses within the aided function. Thus, we will be more concerned with the magnitude of State highway expenditures and the allocation of these expenditures amongst various highway programs, than in attempting to trace the overall State/local budget responses to Federal grants in terms of broadly defined functions.

---

[1]For example, Federal aid highway programs include capital grants for Interstate, Primary ("A"), Secondary ("B"), Urban Extension Roads ("C").

[2]Twenty eight States have "anti-diversion" (State) constitutional amendments. In all but four of the 50 states, gas tax and motor vehicle revenues are earmarked exclusively for highway related expenditures.

I.2 Summary of Previous Studies

Whether we approach the subject from a normative or a postive stance, the central issue is an analysis of the consequences of alternative congressional actions. From a normative perspective, we must know how the market[1] reacts to various program structures so that we can choose a policy which in some sense optimizes public sector decision making. From a positive analysis stance, we must establish a framework for predicting how the market will react to specific policies (in particular, the existing program structure), so that we can determine directions for incremental changes in program structure. Thus, the central issue is a consideration of the design of, and the response to Federal aid highway financing.

These questions have not gone totally unanswered in the literature, (although few researchers have chosen to focus their efforts specifically on the highway sector). And yet, despite the formidable array of recent statistical articles which purport to measure the affects of federal grants on State/local spending, we do not as yet have conclusive answers to such questions as: Have increasing levels of Federal highway aid stimulated additional State/local spending, or have Federal grants served mainly as a substitute for State expenditures? How will the recently increased Federal share of "ABC"[2]

---

[1]In this context, we make use of the term "market" to signify the investment pattern of State and local transportation decision-making units.

[2]The Federal-Aid Highway Act of 1970 stipulated that as of fiscal year 1974, the Federal share of Primary, Secondary, and Urban Extension ("ABC") expenditures would increase from 50% of project cost to 70% of project cost.

road expenditures affect the allocation of highway investments in Wisconsin? Will this behavior differ significantly from that of West Virginia (or any other State for that matter)? If so, what factors -- social, economic, demographic, and political will temper their separate reactions?

Our task would be relatively simple if we can address these questions by simply adapting existing empirical studies to an investigation of highway investment behavior. This is not the case however, because neither of the two general approaches to estimating State/local expenditure models advanced to date are appropriate for our purposes.

The first, and most common approach found in the literature has been advanced by Sacks and Harris, Osman, and researchers.[1] The basic method here is to estimate a model of State and Local expenditures in a variety of functional categories, as a function of Federal grants and socio-economic indicators. The National Tax Journal, which has served as a forum for these articles since 1957, has published each new study on the basis of the:

1) introduction of a new variable which apparently increases the explanatory power of the models

---

[1] Sacks, Seymour, and Richard Harris, "The Determinants of State and Local Government Expenditures and Interfovernmental Flow of Funds," National Tax Journal, Vol. XVII, No. 1
Osman, J.W., "The Dual Impact of Federal Aid on State and Local Government Expenditure," National Tax Journal, Vol XIX, No. 4
Gabler, L.R., and J.I. Brest, "Interstate Variations in Per Capita Highway Expenditures," National Tax Journal, Vol. XX, No. 1
Fisher, Glenn W., "Interstate Variations in State and Local Government Expenditures," National Tax Journal, Vol. XIV, No. 2

2) incorporation of different structural model forms -- e.g. log-linear as opposed to linear

3) discussion of a new technique for including grants-in-aid as explanatory variables.

The basic problem with these studies is that they proceed without an underlying model of individual State preferences. No account is taken of the States' budget constraint, and as such, the essential interdependence between functional activities (i.e. that a decision to increase expenditures on one function must simultaneously by compensated by reduced expenditure on others, or an increase in taxes) is ignored. A second weakness with these approaches is their failure to distinguish between long and short run State responses. In all but O'Brien's study,[1] a single year cross section of State expenditures is regressed against explanatory variables (including Federal grants) of the same year. This raises two immediate questions, both related to inferring time series information from cross section data. First we must question the validity of assuming (as the previously cited studies implicity do) that States and localities react fully and

---

Kurnow, Ernst, "Determinants of State and Local Expenditures Reexamined", National Tax Journal, Vol. XVI, No. 3
Fisher, Glenn W., "Determinants of State and Local Government Expenditures: A Preliminary Analysis," National Tax Journal Vol.XIX , No.3
Bishop, George A., "Stimulative Versus Substitutive Effects of State School Aid in New England," National Tax Journal, Vol.XVII , No.2
Pogue, Thomas F., and L.G. Sgontz, "The Effect of Grants-in-Aid on State-Local Spending," National Tax Journal, Vol.XVIII, No. 1
O'Brien, T., "Grants-in-Aid: Some Further Answers," National Tax Journal, Vol. XXIV, No. 1
Sharkansky, Ira, "Some More Thoughts About the Determinants of Government Expenditures," National Tax Journal, Vol.XXII , No. 4

[1] op cit

immediately to changes in the explanatory variables. And second, we must question the value of "one-shot" cross section models in light of the likelihood of inter-temporal instability of the cross section estimates.

These questions will be considered in greater detail in Chapter V. We raise these issues here in order to stress the inadequate treatment of the impact of Federal grants-in-aid on State and local highway expenditures advanced to date. In summary, our basic objection to these studies (and at the same time, a starting point for the methodology to be advanced by this study) are:

1) they fail to distinguish intra-(highway) function allocation tradeoffs from the less significant inter-function State allocation decision-making process

2) they fail to account explicitly for the influence of a constrained budget on allocation choices

3) no distinction is made between short and long run expenditure responses

4) a limited data set - usually a single year cross section is employed in the estimation of models.

Some of these objections are overcome in the second general approach that has been taken in estimating the affects of Federal grants-in-aid on State and local expenditures. The common theme of the studies advanced by Henderson[1], Gramlich[2], and Tresch[3], is that

---

[1]Henderson, James M., LOCAL GOVERNMENT EXPENDITURES: A SOCIAL WELFARE ANALYSIS, Unpublished Ph.D. Thesis, University of Minnesota, 1967.

[2]Gramlich, Edward M., "Alternative Federal Policies for Stimulating State and Local Expenditures: A Comparison of Their Effects," National Tax Journal, Vol. XXI, No. 2.

[3]Tresch, Richard W., ESTIMATION OF STATE EXPENDITURE FUNCTION, 1954-1969, Unpublished Ph.D. Thesis, M.I.T., 1973.

States' expenditure decisions can be described in a manner analogous to the (individual) consumer utility maximization framework. Thus, the starting point of these analyses is the specification of the States' utility function (in terms of the variety of functional activities, i.e. expenditure categories) and a budget constraint. The actual demand relations for public good consumption which are empirically estimated are derived from first order utility maximization conditions.

Our criticism here is not so much with the theoretical underpinnings of these models[1], as with their treatment of the highway expenditure question. Neither the Henderson[2] or Gramlich[3] study disaggregate State and local expenditures by functional (in particular, highway) category. As such, their results are not germane to the questions which motivate the present study.

The Tresch thesis was the first study to employ both cross

---

[1]It is important, however, to recognize that adoption of the State-as-utility-maximizer framework implies rather heroic assumptions on the political and administrative realities of State expenditure behavior. In particular, the use of social indifference maps imply the existence of a well defined, consistent set of preferences for publically provided goods. If we choose to regard these preferences as belonging to a governmental body, then we must assume that the legislature accurately expresses societal preferences. Furthermore, we must assume that the often conflicting preference orderings of different governmental agencies can be subsumed into one -- in some sense "final" -- utility mapping. See chapter III.

[2]Henderson's model is directed towards explaining the factors influencing inter-county differences in per-capita total county government spending. His data set is a single year 3080 county cross section.

[3]Gramlich uses a time series formulation on quarterly national account (all State aggregate) data. As such, his results explain neither inter-function, nor inter-State expenditure behavior.

section and time series data in estimating State expenditures in a variety of functional areas (including highways) within a utility maximizing model framework. He correctly addresses the second and fourth weaknesses (cited on page 25) of the previous studies by explicitly accounting for the influence of the States' budget constraint on the provision of publically provided goods, and testing for the stability of his cross section estimates over time. But he fails to distinguish between intra and inter-function expenditure tradeoffs, and ignores possible time lagged expenditure responses. These omissions are particularly serious for the highway sector.[1]

The structure of Tresch's model "explicitly recognizes the simultaneous nature of State expenditure decisions,"[2] whereas we have argued that the States' highway budgeting and decision making institutions operate quite apart from other State functional expenditure decisions. Because the underlying structure of his model assumes an expenditure interaction which is not relevant, it is not surprising for Tresch to conclude that "the transportation equation is most notable for what is missing, rather than the single variable (percentage of State population living in urban areas) that entered significantly."[3]

---

[1]Tresch focuses his research on State welfare expenditure behavior. Since these expenditures are financed from States' general tax revenues (as are other non-highway expenditures), and Federal grants are provided on a year-to-year basis (i.e. there is no "grace period" for grant obligation analogous to the highway program), his assumed structure seems reasonable. The problem is that he applies this structure to the estimation of highway expenditure response.

[2]Tresch, op cit, page 21

[3]ibid, page 374. Variables that proved insignificant include: driving age population, Federal Highway grants, population growth rates, all income variables, and ratio of debt to total revenues.

1.3 Modelling Strategy

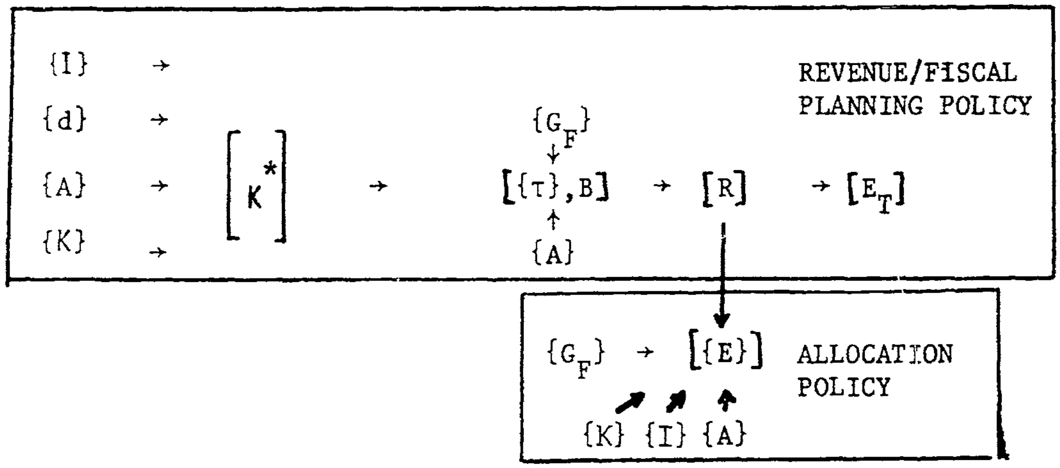
The basic premise of this research is that States' highway investment behavior can be separated from the overall State budgetary process. In this context, it is useful to distinguish between State highway revenue (or total expenditure) policy -- i.e. long range fiscal planning, and allocation policy -- i.e. short range project programming. In the simplest sense, we can say that policy decisions in the first category determine the level of State highway expenditures over several years, while the second policy determines the allocation of a (predetermined) budget amongst alternative geographical areas and highway projects within the State on a year-to-year basis.

Figure I.1 summarizes the hypothesized structure of highway investment behavior that will be adopted in this study. The depicted structure is recursive in nature, wherein the determination of highway revenue is non-project specific, and allocation policy reflects project selection given a fixed budget.

The fiscal planning policy model is based on the States' widespread use of Needs Studies.[1] Perceived needs (expenditures), K^* are determined by design standards (d), traffic and socio-economic indicators (A), institutional characteristics and financing conventions (I), and the age and mix of the existing highway stock (K). Given the gap

[1] Needs Studies develop a State's perceived highway expenditure level necessary to provide road service at a level consistent with current standards. All States have conducted Needs Studies, both for fiscal planning purposes, and in conjunction with the FHWA's National Highway Needs Study.

STATE HIGHWAY INVESTMENT BEHAVIOR



NOTATION

{ } → vector of values of bracketed term

[ ] → decision stage

* → desired value of variable

{d} ≡ design criteria (standards)

{A} ≡ socio-economic descriptors
{I} ≡ institutional characteristics
{K} ≡ mix and age of existing highway stock

$[K^*]$ ≡ desired highway plant ("needs")

G_F ≡ total amount of Federal highway grants

$\{\tau\}$ ≡ highway-related State tax rates

B ≡ amount of bond obligation assumed

[R] ≡ highway-related revenue

$[E_T]$ ≡ total highway expenditures

$\{G_F\}$ ≡ program components of Federal aid

{E} ≡ highway expenditures on each of several categories

Figure I.3.1

between perceived (desired) highway stock K^*, and available revenues -- determined by existing tax rates (Υ), tax base, (A), approved bond issues B, and Federal grants, G_F -- the State exercises its adopted revenue policy by adjusting tax rates, seeking new bond issues, and possibly effecting transfers to or from State general tax revenues. These policy decisions ultamiately determine available highway revenues R, and total State highway expenditures E_T.

While the administrative and political realities of altering tax rates and debt obligation inhibit quick adjustments to changes in costs and demand[1], the project selection (programming) process operates on a relatively short cycle time.[2] In figure I.1, allocation policy is reflected by the choices of expenditure levels (E), i.e. the component categories (Interstate, Primary, Secondary, and maintenance, etc.) of highway expenditure. These choices are influenced by the categorical provisions of Federal aid (G_F), the fixed State highway budget R (as determined by revenue policy), and the traffic and socio-economic, and institutional characteristics of the State.

The specification of the empirical models of total expenditure and allocation policy that are empirically estimated in this thesis follow the block recursive structure shown in figure I.1. In its simplest form, the total expenditure model asserts that:

---

[1]Bond approval is usually issued over a two to five year period. The average duration between tax rate adjustments is even longer -- somewhat over ten year during the 15 year period 1951-1965.

[2]We refer here to the time required to obligate funds for particular projects (in response to changes in Federal aid, travel demand, etc.), not the construction time to complete individual projects.

$$(1)\quad \begin{array}{l}\text{TOTAL STATE HIGHWAY}\\ \text{EXPENDITURES FROM}\\ \text{OWN RESOURCES}\end{array} = f\left(\begin{array}{l}\text{GAP BETWEEN EXISTING}\\ \text{AND DESIRED HIGHWAY}\\ \text{STOCK}\end{array},\ \begin{array}{l}\text{AMOUNTS OF}\\ \text{FEDERAL H/W}\\ \text{GRANTS REC'D.}\end{array}\right)$$

The allocation model builds on the study of Tresch[1] where the States' highway investment demands for each expenditure category are derived as first order conditions[2] from a utility function and budget constraint (where the budget constraint is determined in the revenue policy model) specification. We argue in chapter III that adoption of the utility maximization framework does not necessarily impose an unrealistic assumption on the motivations of State highway investment behavior. In fact, the fundamental premise of our model specification is simply that States allocate their fixed highway budget so as to maximize their derived benefits (utility)[3].

To state the allocational process formally, let E_i represent State expenditure on category i; E_T represent total expenditures from the State's own resources; G_F represent total Federal aid received by the State. The model asserts that States allocate their budget so as to maximize their utility, U:

---

[1]op cit

[2]We refer to the optimization conditions that requires marginal utility to equal marginal cost for each investment alternative.

[3]It should be noted here that this study is largely limited to allocational problems, and questions of economic efficiency. We will not dwell on the distributional implications of specific highway tax systems or investment decisions. Nor will we raise the issue of whether the States' investment behavior truly represent the preferences of a voting polity, or simply represent a set of decisions made by an isolated bureaucratic agency.

$$(2) \qquad \max \quad U = U(E_1, E_2, \ldots, E_n)$$

subject to

$$\sum_i E_i = E_T + G_F$$

We are not directly concerned with the utility function itself but with first order maximization conditions which provide the investment relations:[1]

(3) EXPENDITURES DEVOTED TO CATEGORY i = g [STATE SOCIO-ECONOMIC AND INSTITUTIONAL CHARACTERISTICS, TRANSPORTATION CHARACTERISTICS, FEDERAL AID FOR CATEGORY i, TOTAL HIGHWAY REVENUE]

The essential structure of the revenue policy model and the allocation policy model have been presented in this chapter in their simplest form. We have ignored for the moment, specification of appropriate dynamic structures, the distinction between the price and income effects of Federal grants, and the specification of a capital stock adjustment process. These details are left for later chapters. Our purpose in briefly outlining the model structure here is to indicate the differences in the approach that will be followed in this thesis from the previous studies in this area.

---

[1]The derivation of these first order condition relations requires an assumption on the form of the utility function. The derivation is discussed fully in chapter V.

1.4 Theoretical Models of State Expenditure Behavior

One of the major findings of this research is that both the level and structure of Federal grant programs influence State expenditure behavior. It is useful to characterize a grant structure according to the following provisions:

--categorical vs. non-categorical
--matching vs. block funding
--open-ended vs. close-ended

The first distinction relates to whether the grant is restricted to expenditure on specific activities. The second classification distinguishes grants requiring specified matching funds from grants with no matching provision. Finally, the open vs. close-ended classification distinguishes grant programs with predetermined authorization ceilings from those programs placing no limit on available Federal Aid. The current Federal Aid Highway Program (FAHP) is an example of categorical, matching close-ended grants. A transportation revenue sharing program would exemplify non-categorical, close-ended block funding.

While the empirical models employed in this research are perfectly general (in the sense that they may be used to assess the expenditure impacts of any grant structure) , the fact is that the structure of the FAHP did not change over our analysis period (1957-1970). For this reason, it is important to develop theoretical models that enable the formulation of hypotheses describing the expected State expenditure responses to various structural variants of the FAHP.

Two theoretical models of State expenditure behavior are advanced in this thesis -- one based on an application of consumer allocation theory and the other based on a simple benefit/cost investment criterion. Although these theoretical analyses apparently differ with respect to their underlying assumptions, in fact the conclusions drawn from both approaches are quite similar. Both the models draw attention to the price and income effects introduced by Federal grants, and proceed to demonstrate how State responses will differ according to the presence of one or both of these grant characteristics.

In simplest terms, a price effect refers to the allocational responses to grants which effectively reduce the perceived price (or benefit/cost ratio) of a particular aided function. An income effect describes changes in expenditure patterns resulting from grants which increase States' available resources, but do not alter the prices of alternative highway facilities. The importance of the theoretical models is to demonstrate the relationship between the structural characteristics of a grant (e.g. matching vs. non-matching) and the corresponding price and income effects of the grant in State expenditure behavior. The major findings here are twofold. First, grants providing price subsidies on specific highway categories will induce a more significant reallocation of State highway expenditures (both in terms of concentrating expenditures on the aided function and increasing total expenditure levels) than grants (of like amount) that serve solely as income subsidies. Second, it was shown that grants which are ostensibly characterized by matching provisions may in fact be (allocationally) equivalent to income subsidies. That is, the notion of marginality was introduced to distinguish between non-binding matching grants and grants which effectively serve as price subsidies.

The latter finding is particularly germane to the evaluation of the Federal Aid Highway Program. It is shown that although both the ABC and Interstate programs are characterized by matching provisions, ABC grants are not of sufficient magnitude to serve as price subsidies at the States' investment margin. Accordingly, the theoretical models indicate (and the emperical models validate) that changes in the level of Interstate grants will have a greater allocational impact on the States' highway investments than changes in the level of ABC grant funding.

A complete typology of alternative Federal highway grant structures and the theoretical modelling framework to assess their relative impacts is presented in chapter III.

1.5 The Empirical Study

The empirical models developed in this research attempt to explain the factors influencing States' total highway expenditures (the total expenditure model - TEM) and allocation decisions (the short run allocation model - SRAM), amongst alternative highway expenditure categories. The data set employed in the estimation of the empirical models consists of a fourteen year time series (1957-1970) of a 48 State cross section. Thus the pooled time series/cross-section data set yields 672 (14 years x 48 States) observations of State highway expenditures, Federal grant availability, and socio-economic, institutional and highway inventory descriptors.

While it would have been desirable to estimate separate expenditure models for each State (i.e. as forty eight separate time series), lack of sufficient time series data precluded this approach. Accordingly, both the total expenditure model and the allocation model were estimated using the pooled (time series plus cross-section) data set. In addition to the use of the full pooled data set, several estimations were performed on selected subsets of the data -- for example singling out those States with conspicuously low Interstate expenditures over and above minimal matching requirements.

Several alternative specifications of the total expenditure model were estimated using both price deflated and undeflated data. The basic form of the TEM is presented in figure I.2. The first eight explanatory variables in the model correspond to the set of socio-economic and institutional characteristics which influence a States' perception of "desired" highway capacity (c.f. equation 1). The

THE TOTAL EXPENDITURE MODEL

$$R^{o} = a_{o} + a_{1}*SPOP + a_{2}*UFAC + a_{3}*PCY + a_{4}*GINI + a_{5}*RLTOT$$
$$+ a_{6}*TOLPCT + a_{7}*BIPTCX + a_{8}*KSTK + a_{9}*AVNIGP$$
$$+ a_{10}*AVIGP + u$$

where: R^{o} = State expenditures on highways exclusive of Federal per capita grants

a_{o} = constant terms

a_{i} = estimated coefficients

SPOP = State population

UFAC = percent of population residing in urban areas

PCY = per capita State income

GINI = index of income inequality

KSTK = present discounted value of highway capital stock per capita

RLTOT = percent of total expenditures (all units of government) contributed by local (i.e. county and municipal) governments

BIPTCX = percent of total capital expenditures provided for by debt financing

AVNIGP = apportioned "ABC" grants (three year moving average) per capita

AVIGP = apportioned Interstate grants (three year moving average) per capita

u = error term

Figure I.5.1

variable KSTK serves as a proxy for existing highway inventories. Finally, the availability of Federal highway aid is represented by AVNIGP and AVIGP -- a three year moving average of non-Interstate and Interstate grants respectively.[1]

The short run allocation model actually consists of six distinct structural equations -- one for each expenditure category -- although the estimation technique employed explicitly accounts for the joint interaction between shares.[2] The estimated form of the SRAM is reproduced in Figure I.3. As indicated, the six shares considered in this analysis consist of expenditures on the Interstate System, Primary System, Secondary System, non-Federal Aid System construction, maintenance and a miscellaneous expenditure category.

The dependent variable in each of the equations of the SRAM represents the share of total expenditures devoted to a particular highway expenditure type. Similar to the total expenditure model, the explanatory variables fall into three categories; socio-economic and highway system characteristics (SPOP, UFAC, GINI, PCY, KSTK, PCCRMT, PCMF, KSTK), institutional characteristics (TOLPCT, RLTOT) and the highway grant terms (AVIG, AVNIG, AVPG, AVSG and AVTG).

---

[1]The use of three year moving averages was employed to account for two factors. First, since Federal aid highway grants are actually available for obligation over a three to three and one-half year period, inclusion of just a single years' grant would not accurately reflect the multi-year grant availability. Second, the use of moving averages partly accounts for the fact that States may not fully and immediately adjust to changes in Federal grant availability.

[2]In effect, the six equations are not independent. Since the sum of the shares must equal 1.0, an increase in expenditures on one category must be accompanied by a decrease in expenditures in one or more of the remaining share categories (in conformance with the budget constraint).

THE SHORT RUN ALLOCATION MODEL

SHARE 1: $$\frac{E_1}{E_T} = a_{10} SPOP^{a_{11}} UFAC^{a_{12}} KSTK^{a_{13}} TOLPCT^{a_{14}} AVIG^{a_{15}} AVNIG^{a_{16}}$$

SHARE 2: $$\frac{E_P}{E_T} = a_{20} SPOP^{a_{21}} UFAC^{a_{22}} KSTK^{a_{23}} AVPG^{a_{24}} AVIG^{a_{26}}$$

SHARE 3: $$\frac{E_S}{E_T} = a_{30} SPOP^{a_{31}} UFAC^{a_{32}} GINI^{a_{33}} TSPMR^{a_{34}} PCCRMT^{a_{35}} AVSG^{a_{36}} AVIG^{a_{37}}$$

SHARE 4: $$\frac{E_N}{E_T} = a_{40} UFAC^{a_{41}} PCCRMT^{a_{42}} RLTOT^{a_{43}} AVIG^{a_{44}}$$

SHARE 5: $$\frac{E_M}{E_T} = a_{50} SPOP^{a_{51}} KSTK^{a_{52}} PCMF^{a_{53}} RLTOT^{a_{54}} AVTG^{a_{55}}$$

SHARE 6: $$\frac{E_O}{E_T} = a_{60} SPOP^{a_{61}} PCY^{a_{62}} KSTK^{a_{62}} RLTOT^{a_{63}} AVTG^{a_{64}}$$

Figure I.5.1

E_I = total State Interstate expenditures (State and Federal)

E_P = total Primary System expenditures

E_S = total Secondary System expenditures

E_N = non-Federal-Aid System construction expenditures

E_M = maintenance expenditures

E_O = "other" expenditures (administration, grants to local govts., miscellaneous expenditures)

E_T = total expenditures: sum of the above expenditures

SPOP = State population

UFAC = percent of population residing in urban areas

KSTK = present discounted value of highway capital stock

TOLPCT = percent of total State revenues raised on State-administered toll roads

AVIG = apportioned Interstate grants (three year moving average)

AVNIG = apportioned "ABC" grants (three year moving average)

AVPG = apportioned Primary System grants (three year moving average)

AVSG = apportioned Secondary System grants (three year moving average

AVTG = apportioned total grants (three year moving average)

GINI = index of income inequality

TSPMR = State rural primary system mileage

PCCRMT = percent of rural primary system mileage carrying more than 10,000 ADT

PCMF = percent of total primary system mileage carrying more than 5,000 ADT

RLTOT = percent of total expenditures (all units of govt.) contributed by local governments

PCY = State per capita income

aij = estimated coefficients

Figure I.5.1 (contd.)

It should be clear that the total expenditure model and the short run allocation model may be evaluated in a complementary fashion. The TEM serves to predict the effect of Federal grants (among other factors) on total State highway expenditures while the SRAM predicts how the total budget will be allocated amongst alternative expenditure categories. It is not our purpose here to provide a detailed description of the estimation results. However, a convenient means to summarize the most important emperical findings is contained in figure I.4. The entries in this figure represent the elasticities of the expenditures in each of the six highway categories with respect to each of the variables in our analysis.[1] Perhaps the most striking finding in light of our research objective to assess the expenditure impacts of the Federal Aid Highway Program (FAHP) is that States have viewed the Federal "ABC" grant program as a substitute for their own expenditures as contrasted with Interstate grants which has served to stimulate States' own highway expenditures. This is evident from

---

[1]Chapter VI derives the simple result that

$$\eta E_j/X_k = \eta E_T/X_k + \eta S_j/X_k$$

where $\eta E_j/X_k$ = elasticity of category j expenditures w.r.t. variable X_k

$\eta E_T/X_k$ = elasticity of total expenditures w.r.t. variable X_k (derived as a function of the estimated parameters of the TEM)

$\eta S_j/X_k$ = elasticity of the share of expenditures devoted to category j w.r.t. variable X_k (derived as a function of the estimated parameters of the SRAM)

ELASTICITIES OF THE CATEGORICAL EXPENDITURES

Forty Eight State Sample

LONG RUN MODEL ELASTICITIES

VARIABLE	INTERSTATE	SHARE PRIMARY	SECONDARY
SPOP	0.330	0.943	1.117
UFAC	0.396	-0.198	-0.287
PCY	0.623	0.623	0.623
GINI	-0.029	-0.029	0.302
KSTK	-0.067	0.214	0.127
TSPMR	-0.031	-0.031	0.277
PCCRMT	-0.011	-0.011	0.026
PCMF	-0.001	-0.001	-0.001
TOLPCT	-0.059	0.023	0.023
RLTOT	0.028	0.028	0.028
AVIG	1.232	-0.057	-0.074
AVPG	-0.070	0.534	-0.176
AVSG	-0.002	-0.045	0.261

Figure I.5.3

LONG RUN MODEL ELASTICITIES

VARIABLE	NONFASYST	SHARE MAINT	OTHER
SPOP	1.662	0.497	1.987
UFAC	-0.890	-0.042	-0.042
PCY	0.623	0.623	1.440
GINI	-0.029	-0.029	-0.029
KSTK	0.127	0.387	0.034
TSPMR	-0.031	0.031	-0.031
PCCRMT	0.183	-0.011	-0.011
PCMF	-0.001	0.007	-0.001
TOLPCT	0.023	0.923	0.023
RLTOT	-0.489	-0.043	0.026
AVIG	0.198	0.440	-0.146
AVPG	-0.130	-0.062	-0.226
AVSG	-0.026	0.001	-0.066

Figure I.5.3 (contd.)

the elasticities in figure I.4 which indicate that a 1% increase in Primary or Secondary grants leads to less than a 1% increase (.53% and .26% respectively) in total expenditures on these systems while each dollar increase in Interstate grants have tended to increase total Interstate expenditures by more than the amount of the grant (elasticity = 1.23). A more complete discussion of the impacts of the FAHP (as well as other explanatory factors) in both total highway expenditure and expenditure allocation is developed in Chapters IV through VI. Suffice it to say here that the true value of the econometric models is to allow us to isolate the effects of Federal grants on State highway expenditures. Clearly there are factors other then Federal grants -- socio-economic, demographic and institutional characteristics -- that influence State highway expenditure behavior. The total expenditure model and the short run allocation model developed in this thesis evaluate the influence of each of these factors in States' highway expenditures.

1.6 Summary and Conclusions

This study develops a methodology for assessing the impacts of the Federal Aid Highway Program on State expenditure behavior. Unlike several previous studies in this area, the empirical work conducted in this thesis builds upon a behavioral representation of State highway investment decision making. As such, it has been possible to develop several hypotheses, based on theoretical models, of the expected State responses to numerous structural variants to the Federal Aid Highway Program. Most importantly, it was shown that not only the level, but the structure of a grant program influence State expenditure behavior.

In general, the findings from the empirical research corroborate the theoretical hypotheses. Interstate grants have been shown to have a more significant impact on both the total expenditures and allocation of States' highway budgets than the non-Interstate grant programs. These results were reported in terms of the stimulatory impact of the grants on States' own expenditure levels. The empirical models clearly demonstrate that ABC grants have been viewed as a substitute for expenditures the States would have undertaken in the absence of grants. Contrastingly, the Interstate program has been characterized by expenditure stimulation.

These results have important policy implications for the US Department of Transportation. This research has shown that (for the ABC program), whereas the Federal government provides categorical grants, presumably in those types of activities for which it perceives a national interest in stimulating expenditures (i.e. inducing construction that may not have been undertaken in the absence of grants), the net result may be the expansion of expenditures (or contraction through tax relief) in other (non-aided) areas in which the Federal government has no officially stated interest. The major policy implications of this finding are twofold. First, if essentially the same expenditure pattern as currently exists can be achieved with grants devoid of categorical restrictions and specific matching provisions, the administrative requirements of the FAHP are ineffective and wasteful. Secondly, to the extent that the Federal Aid Highway Program (and specifically the ABC component of that program) has not achieved a significant reallocation of States' resources, it raises the fundamental question of the objectives accomplished by the Federal role in highway finance. While it may be argued that the chief rationale for the FAHP is to accelerate the construction of highway systems that serve the national interest, the evidence developed in this research indicates that at least some components of the FAHP singularly fail to meet this objective.

1.7 Organization of the Thesis

This thesis has attempted to develop a series of econometric models derived from an explicit representation of highway investment decision making behavior. Accordingly, the elements of State highway planning and programming procedures are presented in chapter II. The intent here is to provide a factual setting for development of empirical models. In this vein, the mechanics of Federal highway financing, and a comparison of the highway program to the Federal role in other modal areas are also discussed.

Chapter III sets forth a series of theoretical models which address the question of the impacts of Federal grants-in-aid on State and local transportation investments. We begin with models drawn from consumer theory and applied to State highway investment behavior. We choose to present these models for several reasons. First, as mentioned above, our State highway allocation models are based on consumer theory. Second, this theory provides the basis for normative statements on the design of Federal highway grant programs. And third, consumer theory provides a convenient framework with which to evaluate a wide variety of questions concerning State responses to Federal grant availability. Thus, accepting the assumptions which the consumer theory imposes[1], we can investigate the differences in the "idealized State" response to matching as opposed to block grants.

---

[1]These assumptions will be itemized in full, and discussed in view of the description of actual State highway planning and programming procedures presented in chapter II.

Similarly the analysis can be applied to the questions of "distortion" (i.e. whether Federal matching grants cause unsubsidized highway services to be neglected relative to subsidized activities), and the effects of the grant program specificity (i.e. the allocational consequences of restricting Federal grants to narrowly defined highway categories). Next, a modelling framework based on a simple benefit/cost investment criterion is presented to further clarify the distinction between the price and income effects characterizing Federal highway grants. Chapter III concludes with an application of the benefit/cost investment model to the Interstate and ABC grant programs.

Needless to say, we would like to assess the expenditure impacts of the Federal Aid Highway Program with empirical analyses as well. This is the purpose of chapters IV - VI. Chapter IV develops an econometric model designed to explain the States' total expenditure responses to the Federal Aid Highway Program. Because we are using a pooled data set of time series and cross sectional observations, careful attention must be given to the correct specification of error variance - covariance matrix. A recent technique developed by Theil and Goldberger is applied to our estimation problem to develop generalized least squares estimates of the total expenditure model.

Chapter V develops an econometric model of the second dimension of States' highway expenditure behavior, namely budget allocation. A six category share model is estimated using data covering the forty eight Mainland States over a fourteen year analysis period. Here too special attention must be given to the proper econometric treatment of the model structure. A generalized least squares technique is advanced to account for the joint interaction between expenditure shares.

Chapter V also attempts to unite the empirical findings of the SRAM with TEM developed in the previous chapter. In particular, the analysis shows how to derive the elasticities and derivatives of highway expenditures as a function of the estimated parameters of the total expenditure and short run allocation models. These emprirical measures of the impacts of the Federal Aid Highway Program are compared to the theoretical hypotheses of State highway expenditure behavior advanced in chapter III.

Finally, chapter VI presents a summary of the major findings developed in this thesis. The policy implications of the theoretical and empirical models are discussed and related to directions for future fruitful research.

CHAPTER II

THE MECHANICS OF HIGHWAY FINANCE: A FACTUAL SETTING

II.1 Introduction

Any attempt to model the highway investment behavior of State governments must take careful account of the institutional, political, and administrative realities of the Federal-Aid Highway Program (FAHP). The purpose of this chapter is to summaraize the major features of the FAHP, and draw attention to the issues that will be addressed in the theoretical and empirical analyses that follow.

Although not all of the material described in Chapter II is directly required for the development of the empirical models of State highway investment behavior, the presentation of a detailed description of the FAHP provides a useful perspective for the evaluation of the Federal highway programs in following chapters.

The Federal-Aid Highway Program has evolved in an incremental fashion. Although the recently enacted Federal-Aid Highway Act of 1973 established several new Federal policies, the fundemental principles upon which the FAHP operates were established in the germinal highway legislation of 1916. Section 2 of this chapter traces the historical development of the Federal-Aid Highway Program with particular emphasis on landmark legislation in the years 1916, 1921, 1944, 1956, and 1973. In each of these years, new Federal-Aid Systems were incorporated into the FAHP starting with the Primary System in the earliest acts, through the Interstate System of the 1956 act, to the mass transit-inclusive Urban System of the 1973 act. Each Federal Aid System is described in detail with respect to categorical restrictions, Federal matching provisions and authorization levels.

Section 3 focuses on the mechanics of the Interstate Highway Trust Fund (IHTF). Particular attention is paid to tracing out the flow of Federal funds from the point of initial Congressional authorization to the actual receipt of funds by State Highway Departments. In addition, this section includes a discussion of highway taxation to show the various aspects of regressiveness and inequities inherent in the IHTF revenue measures.

Section 4 presents a comparison of the FAHP to the Federal mass transit assistance program in order to highlight the singular aspects of the Interstate Highway Trust Fund. The IHTF is unique not only by virtue of its magnitude of expenditures, but becuase of the mechanics of its operation as well. The comparison between the Federal aid programs in these two modal areas is presented in terms of the sources of Federal funds, total expenditure levels, authorization cycles, apportionment methods, matching provisions, expenditure restrictions, local recipients of Federal funds, and the sources of local matching funds.

Chapter II concludes with a summary of findings, with particular emphasis on the major considerations for empirical models of State expenditure response to the Federal-Aid Highway Program.

II.2 Historical Development of the Federal-Aid Highway Program

The Federal interest in transportation has its origin in the Constitution, which enpowers the United States Government to regulate interstate commerce, to provide for the general welfare and the common defense, and to establish post roads. Obviously, the evolution of the national transportation policy has undergone innumerable changes since the original mandate of 1787, most notably in the area of Federal highway policy.

Road development in the United States began slowly, with the first major Federal highway capital investment program coming in 1916. At that time, Congress established the fundamental principles upon which the Federal-Aid Highway Program (FAHP) still operates today. These principles - namely that the States would act as financial intermediaries in the planning, construction and maintenance of roads, receiving Federal aid in the form of matching grants - have been refined in land-mark legislation in the years 1921, 1944, 1956, 1970, and 1973.

i. The Early Federal-Aid Highway Acts

The provision of roads in the United States was almost entirely under local jurisdictional control before the turn of the century. Although several States began organizing State Highway Departments (SHD) in the early 1900's in response to a growing awareness of the inadequacy of existing road networks in light of the rising popularity of the automobile, a major stimulus for creation of SHD's came with the passage of the Federal-Aid Road Act of 1916.

This act - the first Federal-aid highway legislation, stipulated that each State seeking a grant was required to establish a State Highway Department as well as meet Federal standards of road construction and management. Although Federal aid under this Act was minimal,[1] the States responded immediately in establishing SHD's. As shown in table II.2.1 all States had legislated the creation of State Highway Departments by 1917.

Four fundamental principles were established by the Federal-Aid Road Act of 1916 which still dictate the operation of the FAHP:

1) The conditional, matching [2] grant in aid would be the sole instrument of Federal financial assistance for the provision of highways.

2) Federal funds would be restricted to expenditure on construction.

---

1. The total 1917 appropriation under this Act was only $5 million. By the time this appropriation was apportioned to the States, Delaware received scarcely more than $8000. Moreover, this aid was restricted to the improvement of rural post roads. A State could receive no Federal funds for bridges greater than 20 feet in length, and were limited to a maximum of 10,000 Federal dollars per road mile.

2. Conditional grants-in-aid refer to the requirement that funds are restricted to particular categories of expenditure (e.g. rural post roads). Matching grants require States to furnish funds from their own sources (in some fixed matching ratio) in order to qualify for Federal funds. A complete taxonomy of grant characteristics will be presented in chapter III.

YEAR IN WHICH FIRST STATE-AID LAW PASSED AND HIGHWAY DEPARTMENT CREATED

STATE	YEAR FIRST STATE-AID LAW PASSED	DATE OF ESTABLISHMENT OF FIRST STATE HIGHWAY DEPARTMENT	
		YEAR	REMARKS
Alabama	1911	1911	
Arizona	1909	1909	
Arkansas	1913	1913	
California	1895	1907	State Department of Engineering, Highway Commission created in 1911.
Colorado	1909	1909	Originally to administer aid to counties only.
Connecticut	1895	1895	Commission of 3 members; single commissioner provided for in 1897.
Delaware	1903	1903	Organization to administer State-aid; present organization created in 1917.
Florida	1915	1915	
Georgia	1908	1916	
Idaho	1905	1913	
Illinois	1905	1905	First commission provided for road study; State Highway Department created in 1913.
Indiana	1917	1917	Held unconstitutional same year; present organization created in 1919.
Iowa	1904	1904	Iowa State College designated as commission; in 1913 a 3-man commission provided.
Kansas	1911	1917	State department with limited powers for administration of Federal-aid.
Kentucky	1912	1912	Commissioner with advisory powers only; State Highway Department created in 1920.
Louisiana	1910	1910	Present highway board created in 1921.
Maine	1901	1907	Commissioner to supervise State-aid roads; law of 1913 established commission.
Maryland	1893	1898	Highway Division of geological survey; commission established 1908.
Massachusetts	1892	1892	Preliminary commission for studies; in 1893 new commission established.
Michigan	1905	1901	Highway committee appointed; State Reward Law in 1905.
Minnesota	1905	1905	Commission authorized in 1898; enacted into law in 1905.
Mississippi	1915	1916	
Missouri	1907	1907	Engineer advisory to county officials; Highway Commission created in 1913.

Table II.2.1

YEAR IN WHICH FIRST STATE-AID LAW PASSED AND HIGHWAY DEPARTMENT CREATED

STATE	YEAR FIRST STATE-AID LAW PASSED	DATE OF ESTABLISHMENT OF FIRST STATE HIGHWAY DEPARTMENT	
		YEAR	REMARKS
Montana	1913	1913	
Nebraska	1911	1911	
Nevada	1911	1917	
New Hampshire	1903	1903	Commissioner appointed in 1905 after study by engineer commission.
New Jersey	1891	1894	Aid to counties in 1891 under administration of board of agri-culture.
New Mexico	1909	1909	Territorial road commission; State Highway Commission created in 1912.
New York	1893	1898	Appropriation for State-aid approved by state engineer and surveyor.
North Carolina	1901	1915	
North Dakota	1909	1909	"Good roads experiment station"; State Highway Commission created in 1913.
Ohio	1904	1904	Advisory until 1910.
Oklahoma	1911	1911	
Oregon	1913	1913	
Pennsylvania	1903	1903	
Rhode Island	1902	1895	Report of Board of Public Roads approved by legislature, and a commissioner appointed.
South Carolina	1917	1917	
South Dakota	1911	1913	Present department created in 1917.
Tennessee	1915	1915	
Texas	1917	1917	
Utah	1909	1909	
Vermont	1892	1898	
Virginia	1898	1906	
Washington	1905	1905	Board provided for.
West Virginia	1909	1909	Commissioner; a bureau provided in 1913.
Wisconsin	1911	1907	Work by geological survey; commission created in 1911
Wyoming	1911	1917	

Source: U.S. Bureau of Public Roads
HIGHWAY STATISTICS, Summary to 1945

Table II.2.1 (contd.)

3) The States would act as financial intermediaries in the expenditure of Federal highway funds.

4) The States would be legal owners of Federal aid roads, in that the responsibility for planning, constructing and maintaining these roads would be "the duty of the States, or their civil subdivisions, according to the laws of the several States."[1]

The second major piece of Federal-aid Highway legislation was passed in 1921, with the purposes of increasing the minimal existing Federal authorizations, designating a primary system on which all Federal aid would be spent, and establishing a floor on minimal State appropriations. With passage of the Federal Road Act of 1921, Congress established two more fundamental principles (in addition to the four principles of the 1916 Act) which still guide the FAHP:

5) Federal-aid would be accorded to specific road categories on designated Federal-Aid Systems. Each Federal-Aid System would be defined according to operating and design criteria established by the Bureau of Public Roads.

6) Apportionment of national highway authorizations to the States would be made according to a formula which weights the

---

1. Section 7, 39 Stat. 355

States' population, land area, and existing road mileage. No State would receive less than .5% of the total yearly authorization.

States were quick in responding to the Federal requirement of designating a primary road system. As shown in Table II.2.2 all States had designated their primary systems by 1924.

Although the expenditure of Federal funds on secondary and urban roads was permitted on a limited scale during the depression, the official creation of the Federal-Aid Secondary and Federal-Aid Urban systems was first stipulated in the Federal-Aid Road Act of 1944. The Federal-Aid Secondary (FAS) program provided matching grants for "principal secondary and feeder roads, including farm-to-market roads, rural free delivery mail, and public school bus routes."[1] Federal-aid urban extension funds were provided for portions of primary roads which passed through urban areas.

The 1944 Act served to establish what has since become known as the "ABC"program.[2] The total Federal aid ABC authorization was (and still is) divided in the ratio of 45 percent FAP, 30 percent FAS, and 25 percent urban extension. Only minor modifications have been made to the provisions of the ABC program as stipulated in 1944.

1. Federal-Aid Road Act of 1944.

2. "A" refers to the Federal Aid Primary (FAP) system, "B" the FAS system, and "C", urban extensions of FAP and FAS.

DATE OF AUTHORIZATION OR CREATION

OF STATE HIGHWAY SYSTEMS

STATE	YEAR	REMARKS
Alabama	1915	
Arizona	1910	Tentative State system laid out in 1910 by State Highway Department.
Arkansas	1923	Legislative enactment.
California	1902	Constitutional amendment empowered legislature to establish State system; system laid out in 1910.
Colorado	1917	System of State routes for present and future improvement approved by legislature.
Connecticut	1913	Map of trunk lines prepared in 1901 but not approved by legislature until 1913.
Delaware	1917	System designated as a result of planning to expend Federal-aid funds.
Florida	1915	State Highway Department authorized to designate system; revised system adopted by legislative enactment, 1923.
Georgia	1919	Legislative enactment.
Idaho	1915	Legislature directed commission to designate trunk highway system.
Illinois	1913	Law provided for the systematic laying out of 16,000 miles of State-aid roads.
Indiana	1917	System of main market highways provided by legislative enactment.
Iowa	1913	Inter-county road system designated.
Kansas	1918	System designated as a result of planning to expend Federal-aid funds.
Kentucky	1912	Primary system established by legislature as "Inter-county seat system."
Louisiana	1921	
Maine	1913	Complete system, including trunk lines, State-aid, and "3rd Class", roads designated.
Maryland	1908	State system established to be improved with state bond issue. Roads classified about 1899.
Massachusetts	1893	
Michigan	1913	Trunk-line system established limiting state road mileage in each county.
Minnesota	1921	Trunk-line plan presented to legislature in 1919; in effect May 1, 1921.
Mississippi	1924	
Missouri	1917	
Montana	1913	
Nebraska	1921	System designated as a result of planning to expend Federal-aid funds.

Table II.2.2

DATE OF AUTHORIZATION OR CREATION
OF STATE HIGHWAY SYSTEMS

STATE	YEAR	REMARKS
Nevada	1917	
New Hampshire	1905	
New Jersey	1917	
New Mexico	1912	Certain roads designated "inter-county", later called "State highway."
New York	1907	State engineer's map adopted by legislature.
North Carolina	1915	
North Dakota	1917	
Ohio	1911	
Oklahoma	1913	Map of State system included in annual report of commissioner.
Oregon	1917	Authority granted commission to designate State routes
Pennsylvania	1911	
Rhode Island	1903	
South Carolina	1917	System designated as a result of planning to expend Federal-aid funds.
South Dakota	1919	Trunk road system provided for.
Tennessee	1915	Commission provided to plan system.
Texas	1917	System designated as a result of planning to expend Federal-aid funds.
Utah	1912	Selected by commission.
Vermont	1917	System designated as a result of planning to expend Federal-aid funds.
Virginia	1918	System designated as a result of planning to expend Federal-aid funds.
Washington	1905	System in isolated units. Primary highway designated by legislature in 1913.
West Virginia	1917	
Wisconsin	1917	Trunk highway system selected.
Wyoming	1919	

Source: U.S. Bureau of Public Roads
HIGHWAY STATISTICS, Summary to 1945

Table II.2.2 (contd.)

"C" funds are now accorded to extensions of the secondary as well as the primary system (1954 Federal-Aid Road Act). Furthermore, States now are allowed to transfer up to 20[1] percent of their appropriation in any one Federal-Aid System to any other System (1956 Federal-Aid Highway Act).

In historical perspective the 1944 Federal-Aid Road Act was perhaps even more significant for its germinal role in establishing the Interstate Highway System. Culminating six years of cooperative study by the Bureau of Public Roads (BPR) and individual SHD's, the 1944 Act directed the BPR to designate a "National System of Interstate Highways." Although no special funds were appropriated at this time, the Interstate network did become an established component of the Federal-Aid System.

The Federal-Aid Highway Act of 1956 carried with it the most sweeping reforms in the history of the Federal-Aid Highway Program. Building on the six fundamental principles of FAHP operation established in previous legislation, two final principles were added by this landmark Act:

7) The National System of Interstate and Defense Highways would be established as a distinct Federal Aid system with separate authorizations, apportionment formulas, and matching ratios.

---

1. Changed to 40% by the Federal-Aid Highway Act of 1973.

8) The Interstate system as well as other Federal Aid systems would be financed from the Interstate Highway Trust Fund (IHTF). This Fund would be composed of excise taxes on motor fuel, auto-related parts and oil, and truck use. Furthermore, the IHTF would be restricted solely for the disbursements of grants to States for the construction of roads on the Federal-Aid System.

Since its inception in 1956, the Interstate program has dominated the Federal-Aid Highway Program, with over $43 billion of Federal funds obligated as of the end of calendar year 1972 (approximately 73% of the total Federal highway aid over this period). Although the States' share of the Interstate program is at most 10 percent, State funds devoted to Interstate construction represent a sizeable fraction of total yearly SHD budgets as shown in figure II.2.1. In fact, in the mid-1960's, State expenditures on the Interstate system exceeded expenditures on the ABC system.

More recently, Federal-aid legislation has given increased emphasis (i.e. funding) to urban road systems. Without changing the structure of the FAHP, new functional classes have been added to the already existing ABC and Interstate programs. In particular, the Federal Aid Highway Act of 1968 initiated the Traffic Operation Program to Increase Capacity and Safety (TOPICS) funded at $100 million per year. In the next highway bill (1970) Congress authorized funding for the Urban (arterial) system which provided $100 million in addition

STATE EXPENDITURES ON THE FEDERAL AID SYSTEMS

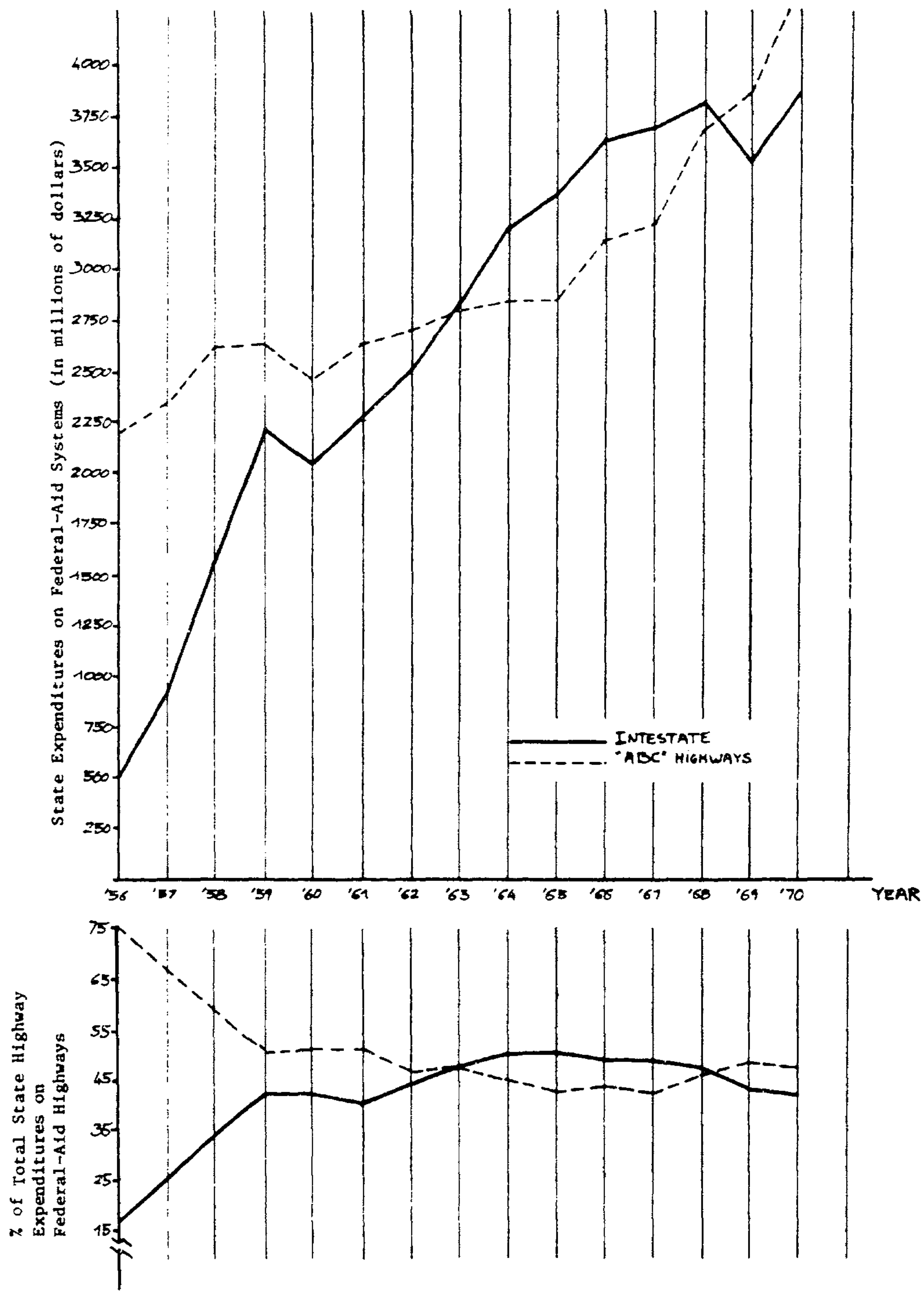


Figure II.2.1

to the extant urban extensions (of FAP and FAS) program. With passage of the 1968 and 1970 Federal Aid Highway Acts, the overall level of funding for urban road systems increased from 25 percent to 33 percent of non-Interstate authorizations.[1]

The current Federal Aid Highway Program is administratively structured in terms of several distinct Federal Aid Systems. Each System is characterized by a separate biyearly authorization, and a distinct set of factors employed in apportionment formulas. The design and operating characteristics of each Federal Aid System are broadly defined in various pieces of enabling legislation described previously in this section.[2] However, the legislative definitions of the Federal Aid Systems are intended to provide only general guidance as to the Congressional intent in stimulating the construction of particular class of roads. Ultimately the States, in cooperation with the Federal Highway Administration are responsible for

---

1. Prior to the 1968 Act, urban road funding (exclusive of Interstate) was limited to the "C" program, where ABC authorizations were divided on a 45/30/25% basis. For FY 1972 urban road system authorizations included $275 million for urban extensions, and $100 million for each TOPICS and urban arterial comprising 33% of the total $950 million non-interstate authorization.

2. Sections II.2.i through II.2.vii immediately following will trace out the characteristics of the FAHP as of the end of calendar year 1972, and thus are relevant for the empirical analyses found in chapters III, IV and V (the empirical analyses cover the period 1954-1970). Section II.2.viii outlines the changes in the FAHP introduced by the Federal-Aid Highway Act of 1973.

the specific assignment of roads to a particular Federal Aid System.

ii. The Federal Aid Primary System (the "A" System)

The Federal Aid Primary (FAP), first established in 1921, is the oldest of the Federal Aid Systems. The FAP is defined as "an adequate system of connected main highways" not to "exceed 7 per centum of the total highway mileage of each ... State."[1] Although the ultimate size of each State's FAP appears to have been limited by law, this is not the case. Provision has been made to increase the relative size of the FAP whenever the 7 percent ceiling is approached. As a matter of practice, no State has had to forfeit FAP grants because of the mileage restriction.

FAP authorizations are normally made from the Interstate Highway Trust Fund every two years by two means: as a fixed percentage of total ABC authorizations, and (possibly) as a supplemental authorization. Forty five percent of the total ABC funds are dedicated to the Primary System. In addition, Congress may authorize funds over and above the ABC percentage Primary share.[2]

Apportionment of FAP authorizations to the States is derived from the following formula:

1. 103(b), Subpart A, Title 23, U.S.C.

2. For example, in the Federal Aid Highway Act of 1970, Congress authorized $1.1 billion for the ABC System (yielding $495 million for the FAP), as well as a supplemental $75 million FAP (rural) grant for each of fiscal years 1971 and 1972.

1) one third of the total apportioned on the basis of a State's land area relative to the total U.S. land area

2) one third of the total apportioned on the basis of a State's population relative to total U.S. population

3) one third of the total apportioned on the basis of a State's rural postal route mileage relative to the U.S. total of such mileage

4) no State to receive less than 0.5% of the total apportionment

iii. The Federal Aid Secondary System (the "B" System)

The Federal Aid Secondary System includes farm-to-market roads, rural mail routes, public school bus routes, local rural roads, county roads, and township roads. As the legislative guidelines indicate, the FAS consists of projects on a smaller scale than the FAP. There is no mention of connectivity (as in the legislative guidelines for FAP). The secondary system is intended to provide a series of routes of secondary Statewide significance linking markets to urban centers or to other FAS or FAP highways.

The method of authorization and apportionment for FAS is very similar to the FAP System. Thirty percent of the total ABC authorization from the IHTF is dedicated to the Secondary System.

Additional funds for rural sections of the FAS may be authorized.[1]

The apportionment formula is identical to the provisions of the FAP formula, except that rural rather than total population is used as an apportionment factor (see summary Tables II.2.3, and II.2.4).

iv. Urban Extensions of the Primary and Secondary Systems (the "C" System"

This system consists of projects on approved extensions of the Federal Aid Secondary and Federal Aid Primary Systems in urban areas. In practice, this System is merely an administrative classification, since urban roads can be Federally financed from "A," "B," or "C" funds. Federal funds for FAP/FAS urban extensions are set at 25 percent of the total ABC authorization. Apportionment to States is based on each State's relative population living in urban places with population over 5000.

v. The Federal Aid Urban System (FAU)

The FAU program was established by the Federal Aid Highway Act of 1970 as a distinct system of urban roads. That is the FAU and "C" systems conform to different project selection criteria, authorizations, and apportionment factors. The FAU system is intended to be "so located as to serve the major centers of activity, and designed taking into consideration the highest traffic volume corridors, and

---

1. For example, the Federal Aid Highway Act of 1970 authorized $50 million for this purpose.

FACTORS EMPLOYED IN APPORTIONING FEDERAL AID SYSTEM FUNDS (as of December 31, 1972)

1. FEDERAL AID PRIMARY ("A" FUNDS)*

   One third on land area
   One third on total State population
   One third on rural postal route mileage

2. FEDERAL AID SECONDARY ("B" FUNDS)*

   One third on land area
   One third on rural State population
   One third on rural postal route mileage

3. PRIMARY AND SECONDARY URBAN EXTENSIONS ("C" FUNDS)*

   Population in urban places over 5000

4. FEDERAL AID URBAN SYSTEM

   Population in urbanized areas over 50,000

5. TOPICS

   Population in urban places over 5000

6. FEDERAL AID INTERSTATE

   Federal share of the estimated cost of completing the

   the Interstate System in each State

* No State to receive less than one half of one percent of the total ABC apportionment

Table II.2.3

CURRENT FACTORS EMPLOYED IN APPORTIONING FEDERAL-AID SYSTEM FUNDS[1]

Pursuant to the Federal-Aid Highway Act of 1973

1. FEDERAL AID PRIMARY ("A" FUNDS)*

   One third on land

   One third on population of rural areas**

   One third on the mileage of intercity mail routes where service is performed by motor vehicles**

2. FEDERAL AID SECONDARY ("B" FUNDS)*

   Same as primary apportionment formula**

3. PRIMARY AND SECONDARY URBAN EXTENSIONS ("C" FUNDS)*

   Population in urban places over 5000

4. FEDERAL AID URBAN SYSTEM

   Population in urban places over 5000**

5. FEDERAL AID INTERSTATE

   Federal share of the estimated cost of completing the Interstate System in each State

* No State to receive less than one half of one percent of the total ABC apportionment

** Apportionment formula has changed from previous legislation

Table II.2.4

the longest trips within such (urban) area."[1]

Authorizations from the IHTF are made every two years.[2] Apportionment to States is on the basis of each State's relative population living in urbanized areas (population over 50,000)

vi. Traffic Operations Projects to Increase Capacity and Safety (TOPICS)[3]

The TOPICS program is intended to stimulate the construction of projects "designed to reduce traffic congestion and to facilitate the flow of traffic in the urban areas.[4] Of all the Federal Aid Systems, TOPICS projects are generally of the smallest scale. Examples of TOPICS improvements include grade separation of intersections, widening of lanes, channelization of traffic, traffic control systems, and loading and unloading ramps.

Authorization from the IHTF for TOPICS are made every two years. Apportionments are made in the same basis as for the FAU system (see Table II.2.3).

vii. The Federal Aid Interstate System

The Interstate System (FAI) is different in several important

---

1. 103 (d), Subpart A, Title 23, United States Code.

2. For example, the 1970 Highway Act authorized $100 million for each fiscal years 1972 and 1973

3. The TOPICS program was discontinued as of the beginning of fiscal year 1974

4. 135 (a) Subpart A, Title 23, U.S.C. TOPICS was established by the Federal Aid Highway Act of 1970

respects from the other components of the Federal Aid System. First, the FAI is the only System that is close-ended in terms of both total System mileage and required completion date. Current legislation limits the mileage of the Interstate System to 41,200 miles,[1] and stipulates completion of the FAI by the end of fiscal year 1979.[2]

Secondly, unlike the other Federal Aid Systems, the Bureau of Public Roads played a major role in the selection of corridors for future Interstate development. As early as 1944, a 41,000 mile Interstate network (excluding urban sections) was established. Thus, the major policy option exercised by the States was simply the programming[3] of Interstate investments on the approved network.

A third innovation of the Interstate System is in its method of financing. The Federal/State matching ratio on the Interstate is 90/10, compared with the 50/50[4] matching ratio on other Federal Aid Systems. Interstate authorizations are established for the entire

1. As of December 31, 1972, total expenditures on completed Interstate projects amounted to $49.3 billion, 65% of the 1972 estimated cost of $76.3 billion for the entire Interstate system.

2. Future Federal Aid Highway Acts may extend this completion deadline.

3. In this context, programming refers to the scale of the projects (i.e. number of lanes), and the timing of Interstate investments.

4. The Federal Aid Highway Act of 1970 increased the Federal share payable on non-Interstate projects to 70% beginning with fiscal year 1974. The new matching ratio also applies to funds unobligated from previous apportionments.

duraction of the FAI program. Thus unlike the biannual cycle for other Federal Aid Systems, new Interstate Authorization levels are set only when the duration of the Interstate program is extended.[1] Finally, the method of Interstate apportionment differs from other Federal Aid System apportionment in that it is based on the estimated Federal share of the total cost to complete the FAI in each State, rather than on State socio-economic characteristics (see table II.2.3).

viii. <u>Structural Revisions to the FAHP Incorporated in the 1973 Federal Aid Highway Act</u>[2]

The Federal-Aid Highway Act of 1973, signed into law on August 13 of that year introduced perhaps the most sweeping policy revisions since the inception of the Federal-Aid Highway Program in 1916. The revisions reflected the increasing awareness on the part of Congress and various interest groups of the shortcomings of the FAHP (see Section III.2.iii). In fact, Congressional debate on the proposed measures carried past the end of the 1972 legislative session representing the first time in more than two decades that a highway bill was not signed on a biennial basis.

The majority policy revisions incorporated into the Act are:

- diversion of grants from the Interstate Highway Trust Fund to urban mass transit facilities are allowed for the first

---

1. For example, the 1973 Highway Act established FAI authorizations for 6 years covering 1974 through 1979.

2. Public Law 93-87. An excellent description of the specifics of the 1973 Act is contained in the pamphlet HIGHWAYS, SAFETY AND TRANSIT: AN ANALYSIS OF THE FEDERAL AID HIGHWAY ACT OF 1973, published by the Highway Users Federation for Safety and Mobility, Washington, D.C.

time beginning in fiscal year 1975

- greater emphasis is placed on the upgrading of non-Interstate systems

- significant expansion of the Federal-Aid Urban System is called for

- for the first time States are directed to channel Federal urban planning monies directly to authorized metropolitan area planning agencies

- grants designated for construction on the Interstate System may, under certain conditions be used instead as mass transit aid

- a major realignment of the Federal-Aid highway systems is called for. In addition, three new systems are established: Priority Primary Routes, the Special Urban High Density Traffic Program, and Economic Growth Center Development Highways[1]

The most significant message imparted by the Federal-Aid Highway Act of 1973 is the increased flexibility incorporated into the Federal-Aid Highway Program. Although the Act did not go to the extreme of dropping all categorical restrictions on the use of Federal aid (as embodied in S. 1693 - the Special Transportation Revenue Sharing Act of 1969), several features of the 1973 legislation allow

---

1. The major thrust of the Federal-Aid highway system realignment is to redesignate routes eligible for Federal assistance on the basis of anticipated future functional usage. The greatest change effected by the Act will be on the Federal Aid Secondary System where the 636,000 miles of the 1972 System is expected to be reduced to 275,000 miles (as reported in the Federal Highway Administration's Report on Functional Classification, 1972). The intent here is to concentrate Federal aid on those segments of the nation's road network with the greatest regional significance. For a concise description of the characteristics of the three new Federal-Aid systems, see the Highway Users Federation pamphlet (op. cit.)

the States greater latitude in tailoring the use of Federal highway aid to meet the particular needs of their highway and transit investment program. The diversion provisions on the use of FAHP grants for mass transit, the increase in the allowed fund transfer between non-Interstate systems from 20% to 40% (see Section II.2.i), and the recent increase (stipulated by the 1970 Act) in the Federal share payable in all non-Interstate systems from 50% to 70% of total project cost, all signal a relaxation in the specificity of the categorical restrictions which characterized previous FAHP legislation.

Despite the numerous innovations introduced in the 1973 Federal-Aid Highway Act, the Interstate Highway Trust Fund (IHTF) continues to serve as the primary vehicle of Federal highway finance. The IHTF is a unique Federal finance program, not only by virtue of its magnitude of expenditures, but because of the mechanics of its operation as well. The next section will detail the operation of the Trust Fund.

II.3. The Mechanics of the Interstate Highway Trust Fund

i. Program Structure

It is convenient to summarize the program structure of the Interstate Highway Trust Fund in terms of the following major characteristics: source of Federal funds, total expenditure levels, authorization cycle, apportionment method, matching provisions, expenditure restrictions, local recipients of Federal funds, and sources of local matching funds.

Source of Federal Funds

Since the 1956 Highway Act, all Federal disbursements for expenditures on the Federal-Aid Systems have been made from the Interstate Highway Trust Fund (IHTF). The IHTF is an institutional mechanism designed to serve as the respository for all earmarked Federal user charges associated with road use.

The major sources of IHTF revenue are shown in table II.3.1. By far the greatest contribution to the Trust Fund comes from the excise tax on gasoline. In calendar year 1970, for example, highway-related consumption yielded over $3.67 billion, or 70% of the total IHTF revenues (see table II.3.2).

IHTF revenues have been growing at an average rate of 9.2% through the late 1960's (fiscal years 1966-1971), currently yielding over $5.5 billion dollars.

Total Expenditure Levels

The Federal-Aid Highway Program represents by far the largest

TRUST FUND REVENUE SOURCES

SOURCES	TAX RATE
Motor Fuel	4 per gallon
Trucks, buses, and trailers	10% of manufacturers wholesale price
Inner tubes	10 per pound
Tread rubber	5 per pound
Truck and bus parts	8% of the manufacturers wholesale price
Lubricating oil	6 per gallon
Vehicle use	$3.00 per 1,000 lbs. (gross vehicle weight) for trucks weighing more than 26,000 lbs.

Source: page 56, HIGHWAY STATISTICS **1970**, Federal Highway Administration

Table II.3.1

INTERSTATE HIGHWAY TRUST FUND

REVENUE BY SOURCE

CALENDAR YEAR 1970

Source	Amount (billions of dollars)	Percent of Total
Motor Fuel	$3.673	70.1
Trucks, buses and trailers	.655	12.4
Inner Tubes	.585	11.2
Motor Vehicle Use	.141	2.89.
Parts and Accessories	.085	1.69.
Lubricating Oil	.065	1.39.
Tread Rubber	.028	0.69.
	5.232	1.00%

Source: Tables FE-205, FE-206
HIGHWAY STATISTICS 1970,
Federal Highway Administration

Table II.3.2

Federal public works grant program. In fact, of the more than 500 categorical grant programs administered by the Federal government, the FAHP ranks second (to the welfare program) in expenditure of funds. The latest FAHP authorization allows for a total expenditure of $16.7 billion dollars (over the three year period 1974-1976) divided among the Federal Aid Systems as follows: $8.75 million FAI, $3.42 billion FAU, Urban High Density Routes and urban extensions of FAP/FAS, $1.19 billion FAS, and $2.127 billion FAP. Authorization levels over the 10 year period 1961-1971 are shown in Table II.3.3.

Expenditure Restrictions

Federal-Aid Highway Program funds are restricted to expenditure on preliminary engineering,[1] right-of-way acquisition, and construction of Federal-Aid System roads. Federal disbursements on each Federal-Aid System are limited to the amounts specifically apportioned with the exception that States may reapportion up to 40% of their funds for any one System to any other System.[2]

---

1. Preliminary engineering includes surveys and other elements of a location study, and detailed designs and other plans, specifications and estimates covering the construction on a selected location.

2. It's interesting to note that as of 1972, only 11 isolated cases of reapportionment have been exercised by the States. The reluctance to transfer funds among systems is partly explained by the flexibility in employing FAHP grants. For example, "C" projects may be funded from "A", "B", or "C" funds, without the need for formal reapportionment.

INTERSTATE HIGHWAY TRUST FUND
RECEIPTS AND AUTHORIZATIONS

1961-1971

YEAR	REVENUES (in billions of dollars)	AUTHORIZATIONS[1] (in billions of dollars)	FISCAL CONTROL TOTALS (in billions of dollars)
1961	2.799	2.725	
1962	2.956	3.125	
1963	3.293	3.325	
1964	3.539	3.550	
1965	3.670	3.675	
1966	3.924	3.800	
1967	4.455	4.000	
1968	4.428	4.400	
1969	4.690	4.800	4.769
1970	5.469	5.425	5.000
1971	5.725	5.425	4.600

Sources: (1) pp. II-153, FEDERAL LAWS, REGULATIONS MATERIAL RELATING TO THE FEDERAL HIGHWAY ADMINISTRATION, FHWA, 1971.
(2) TABLE 1, PROGRAM PROGRESS, FHWA memo dated 1/19/73

Table II.3.3

[1] Funds administered by the Bureau of Public Roads

Local Recipients of Federal Funds

The States are the sole recipients of Federal Highway capital grants. No money is directly channeled to lower units of government, although States are free to enter into agreement with their subdivisions to financially cooperate on particular Federal-Aid projects. In any event, the States maintain sole responsibility relative to plans, specifications and estimates (PS & E), surveys, contract awards, design, inspection, and construction of all projects on the Federal-Aid Systems.

Authorization Cycle

FAHP funds for all Federal-Aid Systems except the FAI are normally authorized every two years.[1] These authorizations are included in a biennial Highway Act enacted at least one-half year before the States are allowed to use Federal funds. For example, the Federal-Aid Highway Act of 1970, passed December 31, 1970, authorized HTF expenditures for fiscal years 1972 (beginning July 1, 1971) and 1973.

Interstate authorizations are determined for the duration of the FAI program. The Federal-Aid Highway Act of 1973 authorized FAI funding through FY 1979.

Apportionment Method

Apportionment refers to the amount of Federal Aid made available to each State for each of the Federal-Aid Systems. As shown in

---

1. The Federal-Aid Highway Act of 1973 departed from the biennial pattern of highway legislation. This Act authorized funds for three fiscal years.

Tables II.2.3 and II.2.4, each Federal-Aid System is associated with a specific apportionment formula, expressed in terms of State demographic and geographic characteristics. Ordinarily, the apportionment of IHTF funds among States would be derived directly from the approved authorization levels. However, between 1969 and 1973, the Office of Management and Budget (OMB) imposed restrictions on Federal highway expenditure levels, in an effort to curb government expenditures. Consequently, the amounts apportioned to the States in these years were actually derived from the OMB-imposed Federal highway fiscal control totals. (see Table II.3.3)

Matching Provisions

The Federal-Aid Interstate Systems is characterized by a 90/10 Federal/State matching ratio. All other Federal-Aid Systems are subject to a 50/50 matching ratio. States with a large public land holding are entitled to a larger Federal share of highway funds, as determined by a "sliding scale" formula which increases the Federal share in proportion to the amount of State land in the national public domain. Thirteen States qualify for an increased Federal highway share as shown in Table II.3.4.

Sources of Local Matching Funds

Although all levels of government assume some responsibility for collecting and disbursing funds for highway-related activities, the States are by far the largest contributor in the FAHP. For example, in calendar year 1970, the States' highway expenditures

VARIABLE MATCHING PERCENTAGE

FOR STATES WITH MORE THAN

FIVE PERCENT OF PUBLIC LAND[1]

State	Federal Share on Interstate	Federal Share on other Federal-Aid Systems
Alaska	--------	95.00 (max)
Arizona	94.39	71.96
California	91.62	58.09
Colorado	91.31	56.57
Idaho	92.30	61.50
Montana	91.31	56.54
Nevada	95.00 (ceiling level)	83.74
New Mexico	92.58	62.91
Oregon	92.38	61.90
South Dakota	91.71	55.83
Utah	94.88	74.42
Washington	90.71	53.54
Wyoming	92.87	64.36

Source: Burch, P.H., HIGHWAY REVENUE AND EXPENDITURE POLICY IN THE UNITED STATES

Table II.3.4

1. Other States subject to 90/10 Interstate share, and 50/50 share on other Federal-Aid Systems.

(10.55 billion), were greater than the combined highway expenditures of the Federal government (4.96 billion), county governments (1.43 billion), and municipal governments (2.39 billion).

Besides the sheer magnitude of their financial commitment to the FAHP, the States play a central role in highway finance for two more reasons. First, Federal grants-in-aid for highways are received, programmed, and expended by States. In this context, Federal highway "expenditures" can be considered as State highway revenue. Second, all States have established some form of shared tax or grant-in-aid mechanism with their civil subdivisions. As such, the State influences the expenditure pattern of the counties and municipalities.

State highway revenue derive from four major sources: Federal highway grants, State taxes on motor fuel and motor vehicles, proceeds from bond sales, and appropriations from State general tax re revenues.[1] Motor fuel/vehicle tax revenue is the largest component of State highway revenue, yielding about 60% (nationwide average) of total SHD revenue in 1970. Highway bond sales represent varying degrees of importance in different States. At one extreme are the 11 States that have not resorted to bond financing of either toll or free roads (see Table II.3.5) over the ten year period 1961-1970. At the other extreme are 5 States which have established debt financing

1. In addition, several States derive revenue from the collection of tolls. For the purposes of this thesis, activities concerning toll facility construction and operation will not be discussed.

STATE HIGHWAY FINANCE:

HIGHWAY BOND SALES, 1961-1971

Category I: States which have not issued bonds for toll or free roads

Arkansas	Missouri
Colorado	Montana
Idaho	Nevada
Iowa	South Dakota
Kansas	Utah
	Wyoming

Category II: States which have issued bonds solely for toll road construction

California	Indiana	Texas
Illinois	Louisiana	Virginia

Category III: States which have issued (free and toll) highway bonds at irregular intervals

Alaska	Kentucky	Mississippi	New York
Arizona	Maine	Nebraska	North Carolina
Florida	Maryland	New Hampshire	North Dakota
Georgia	Michigan	New Jersey	Ohio
Hawaii	Minnesota	New Mexico	Oklahoma
	Oregon	Washington	Tennessee
	Pennsylvania	West Virgina	Vermont
	South Carolina	Wisconsin	

Table II.3.5

STATE HIGHWAY FINANCE:

HIGHWAY BOND SALES, 1961-1971 (contd.)

Category IV: States which have issued free road bonds every year

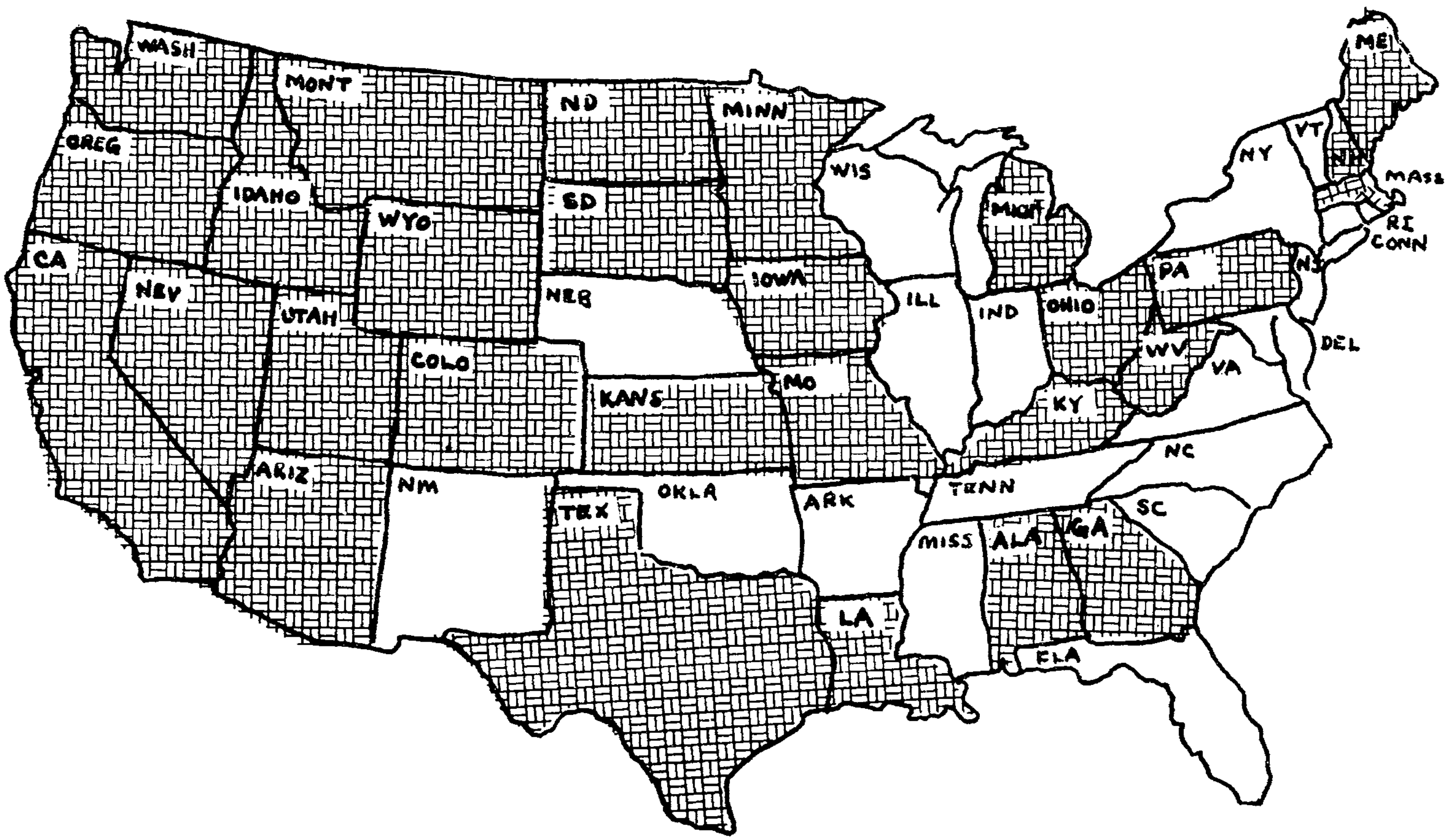
Alabama	Delaware	Rhode Island
Connecticut	Massachusetts	

Table II.3.5 (contd.)

as a regular component of their highway finance program. These States (see Table II.3.5) have issued free road bonds in each of the ten years 1961-1970. The remainder of the States have resorted to bond financing on an irregular basis, presumably to meet perceived short-term highway "needs" that could not be financed out of current revenue sources.

Appropriations to State Highway Department programs from State general tax revenues do not represent significant amounts of money, nor are these transfers performed on a regular basis for the great majority of the States. The notable exceptions to this rule are the so-called general fund States: Delaware, New Jersey, New York and Rhode Island. In these four States, all highway user tax revenues are deposited in the State General Treasury, and thus technically all appropriations for highway activities come from a non-earmarked general fund. In practice, even in these States, yearly highway appropriations tend to nearly equal highway user tax revenues. For the remaining States, all highway user revenues are set aside in State Trust Funds, earmarked exclusively for highway-related expenditures. Of the 46 "Trust Fund States" 28 States are subject to anti-diversion Constitutional Amendments (see Figure II.3.1). The remaining States have either established expenditure restrictions by State Statute or simply through historical practice.

STATES HAVING ANTI-DIVERSION CONSTITUTIONAL AMENDMENTS



-States having anti-diversion constitutional amendments - 28

Figure II.3.1

ii. Time Lag Structure

From the time that highway-related revenue is deposited in the Federal Treasury account for the IHTF, to the time States receive Federal reimbursements for completed work on Federal-Aid Systems, Trust Fund monies pass through a series of stages at the Federal and State level.

These stages can be defined as:

- authorization - the Congressional allotment of Federal funds to each of the Federal-Aid Systems
- apportionment - the division of Federal funds on each of the Federal-Aid Systems among each of the 50 states
- obligation - a contracted agreement between a State and the Federal government to commit funds to a particular Federal-Aid System project
- reimbursement - the actual transfer of Federal funds to a State based upon a State's current billing of contracted highway construction

In practice, there is a contracted stream of funds passing between the IHTF and the States. However, the actual reimbursement from a given annual authorization may take as long as 15 years.[1] In order to trace the dynamics of the intergovernmental transfer of highway funds, we represent the lag structure in five distinct steps.

---

1. That is, a State may receive a reimbursement from funds authorized 15 years prior to the fund transfer.

Lag 1: Authorization-to-Apportionment

As previously noted, Congressional authorization of highway funds precedes apportionment by at least six months.

Lag 2: Apportionment-to-Programming

This lag relates to the time required by States to develop highway programs for submittal to BPR review. The duration of this lag is somewhat uncertain, varying for different project types, and from State-to-State (for a given project type). Since the level of Federal highway aid has been growing at a fairly steady rate since the inception of the IHTF, States are well aware of the amounts of grants they can expect to receive. Accordingly, the States have tried to "keep one step ahead" of the apportionment process by developing programs containing enough projects to fully obligate their apportionment levels.

In practice however, States have encountered varying degrees of community opposition to proposed projects. The result has been a lag between the initial availability of Federal-Aid apportionments, and submittal of an approved program of Federal-Aid System projects.

Friedlaender[1] has estimated that the apportionment-to-programming lag was usually on the order of four to six weeks in the late 1950's. In recent years, the increasing difficulty in negotiating community

1. Friedlaender, Ann, F., "The Federal Highway Program as a Public Works Tool," in Ando, A. et al, STUDIES IN ECONOMIC STABILIZATION, The Brookings Institute, 1968.

acceptance of highway projects has led to a significant increase in the duration of the apportionment-to-programming lag. In fact, there has been one case where a State,[1] was unable to program its highway apportionment before the deadline for obligating Federal funds was reached.

Each State is given two years beyond the year for which funds are authorized to obligate its highway apportionment. Figures II.3.2 and II.3.3 show that most States are, in recent years programming projects from previous years' apportionments. Figure II.3.2 presents the frequency distribution of State obligations for Interstate apportionments. Midway through fiscal year 1973, four States were still obligating 1971 funds, nine States were obligating 1972 funds, and the remaining thirty eight States had obligated some portion of their current apportionment.[2] Taking the nation as a whole, only 17% of the then current Interstate apportionment had been obligated by December 31, 1972.

Figure II.3.3 shows the frequency distribution of ABC apportionments obligated as of December 31, 1972. Relative to the Interstate program, a higher percentage of current ABC apportionments have been obligated. Only one State was still obligating 1971 funds, twelve

1. Actually, the "State" was Washington, D.C., which for the purposes of highway apportionments receives Federal funds in the same manner as States.

2. States always obligate their "oldest" apportionments first. Thus, any State obligating current apportionments has already completely obligated its previous apportionments.

Frequency Distribution of Interstate Obligations

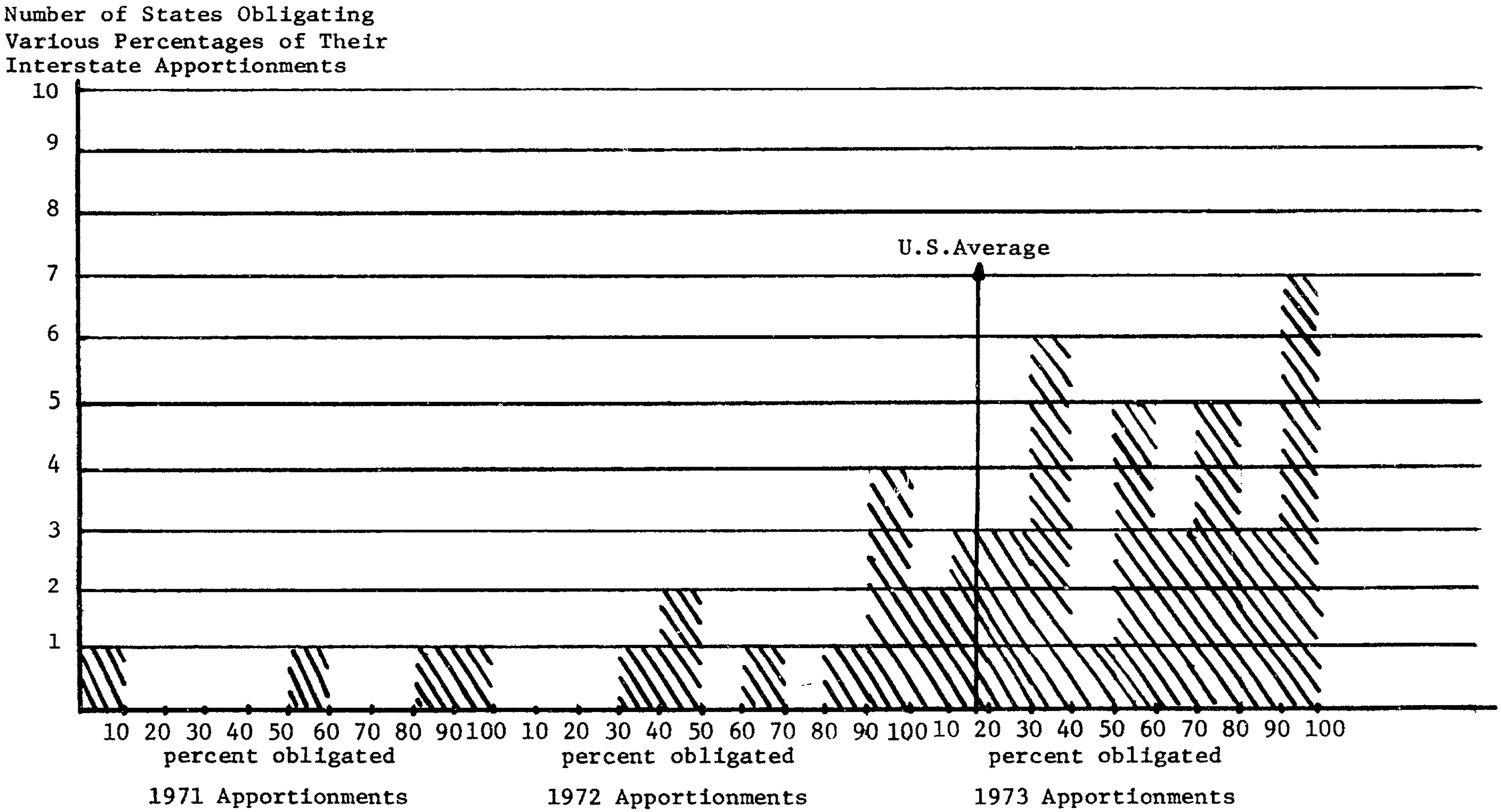


Figure II.3.2

<u>Frequency Distribution of ABC Obligations</u>

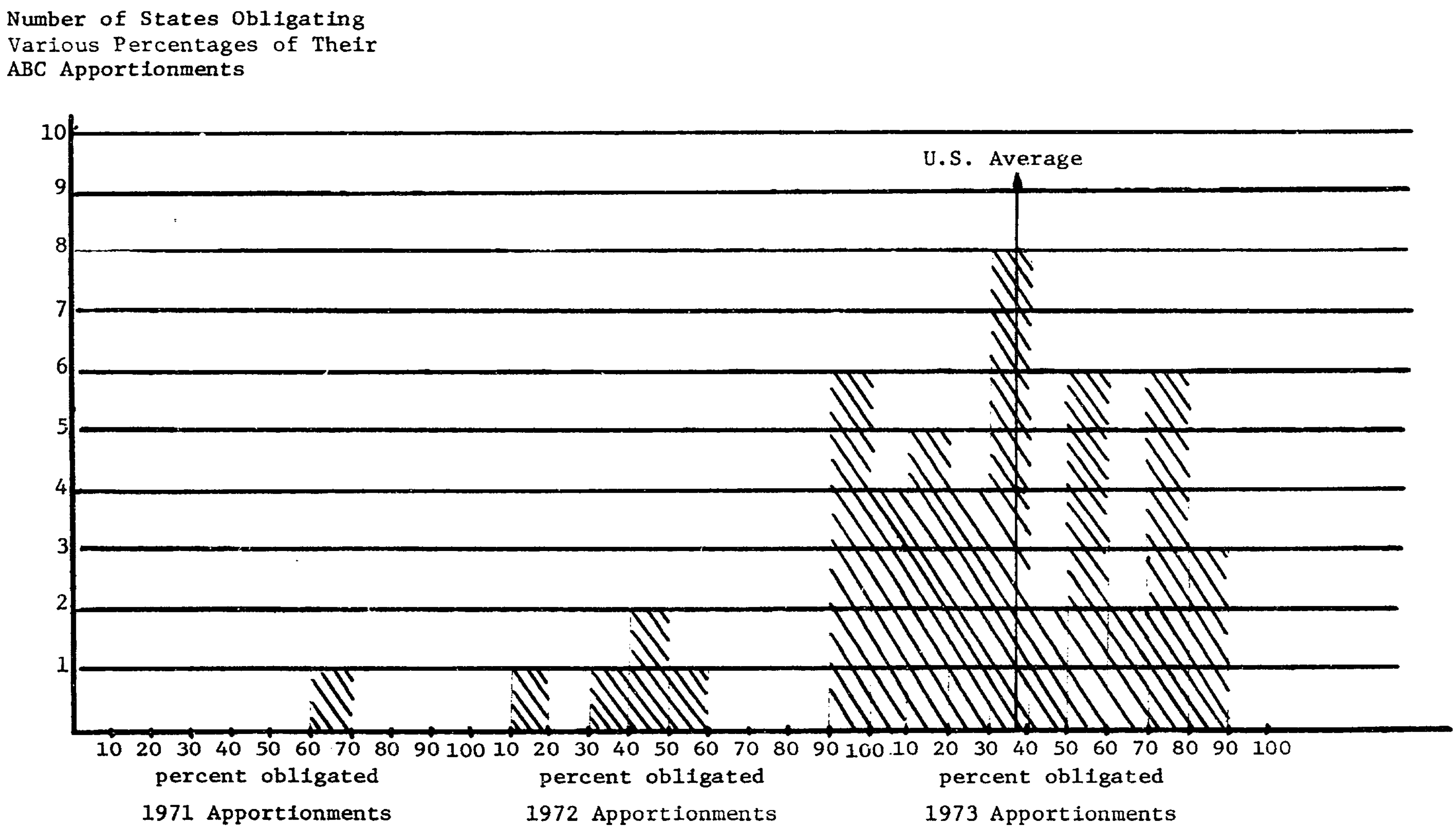


Figure II.3.3

States were obligating 1972 funds, and the remaining thirty nine States were obligating current ABC apportionments. The U.S. average of ABC apportionments obligated by mid-fiscal year 1973 was 32%. It may be concluded from these two figures that the apportionment-to-programming lag is greater for the FAI program than for the ABC program. Moreover, it is apparent that this lag has lengthened significantly since Friedlaender's estimate in the late 1950's. Several States have been unable to program potentially funded Federal-Aid System projects for 2 1/2 years or longer. The nationwide average lag between apportionment and programming appears to be on the order of ten months.

Lag 3: Programming-to-Approval

Following a State's submission of a highway project to the BPR, the District Engineer reviews the plans, specifications and estimates detailed in the State application. The review process can take anywhere from one month to more than a year, depending on the complexity and scale of the project. For example, a simple rural resurfacing project may be approved within one or two months, while a large Interstate section with several complex drainage and bridge structure requirements would take several months to review.

The culmination of the BPR review is an approved project agreement, allowing States to obligate the use of Federal funds.

Lag 4: Obligation-to-Contract Lag

An obligation does not involve an actual flow of funds. At this point, a State has merely obtained the approval of the BPR to seek bids on an approved project. The State now proceeds to enter the project into its ongoing construction program. The State's decision as to when to advertise a contract for construction is influenced by its capital budgeting status. Assuming a State advertises a contract immediately upon signing a project agreement with the BPR, there is usually a minimum of a three to four week period before sealed bids are opened. After the low bidder is determined, the State must obtain the BPR's final approval on the contractor's qualifications. Thus, the minimum lag between initial BPR approval, and the final signing of a construction is typically on the order of one month.

Lag 5: Contracts-to-Federal Reimbursement

IHTF monies are disbursed to States on a reimbursement basis. Thus, the final lag in this process involves the time required for the contractors to mobilize their work force and submit the first month's expense voucher, and for the State to verify that the work has been done, and submit a record of expenses to the BPR office in Washington. The lag here could be anywhere from one to two months.

Summary: Lag Structure on the Federal-Aid Highway Program

Figure II.3.4 traces the FAHP lags from initial Congressional authorization to the time that Federal funds actually enter the income stream as construction expenditures. Two alternatives sequences are shown, one with a total lag of one year, and the other with a two year total lag. The major source of variation between these two lag

FEDERAL AID HIGHWAY PROGRAM LAG STRUCTURE

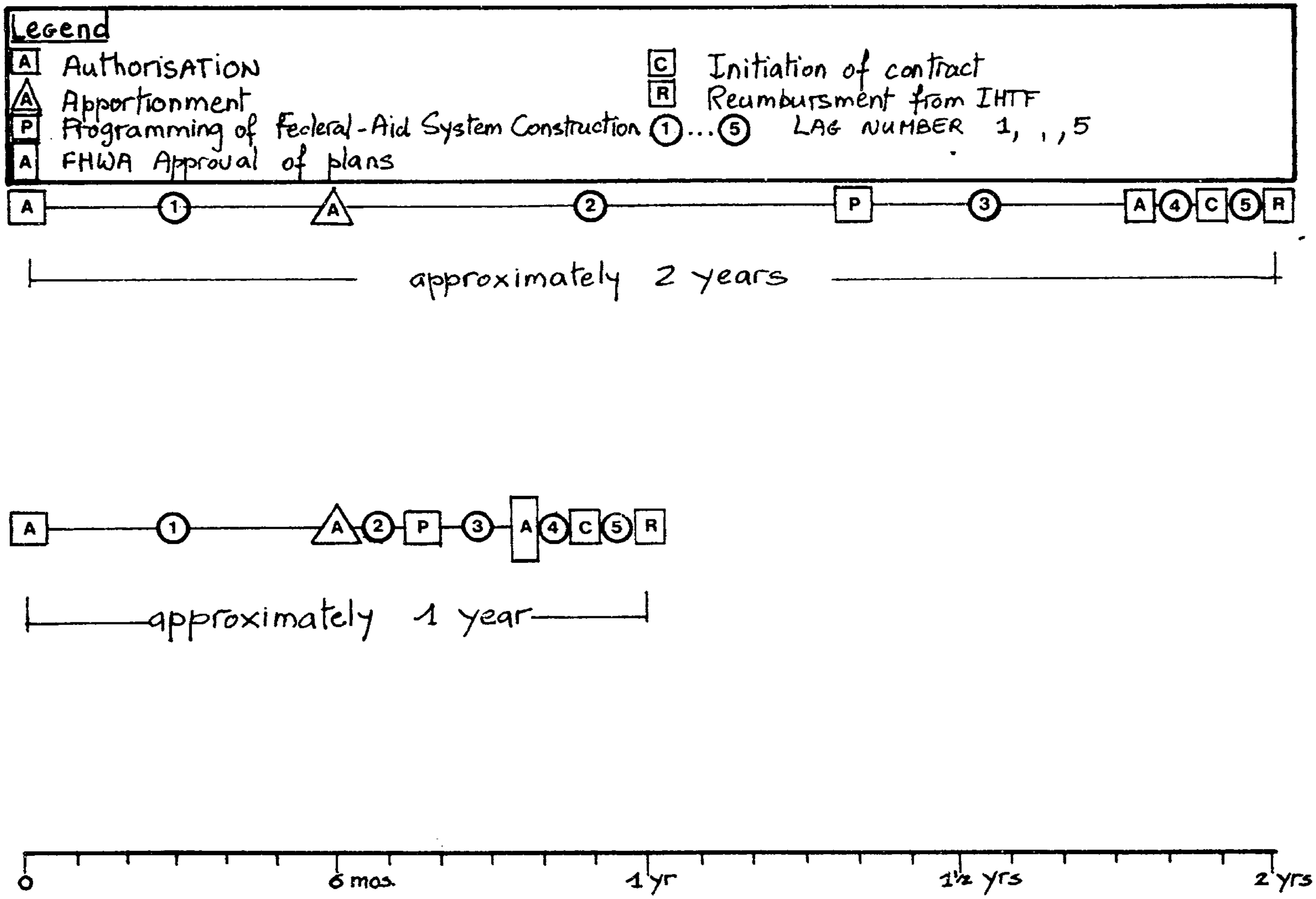


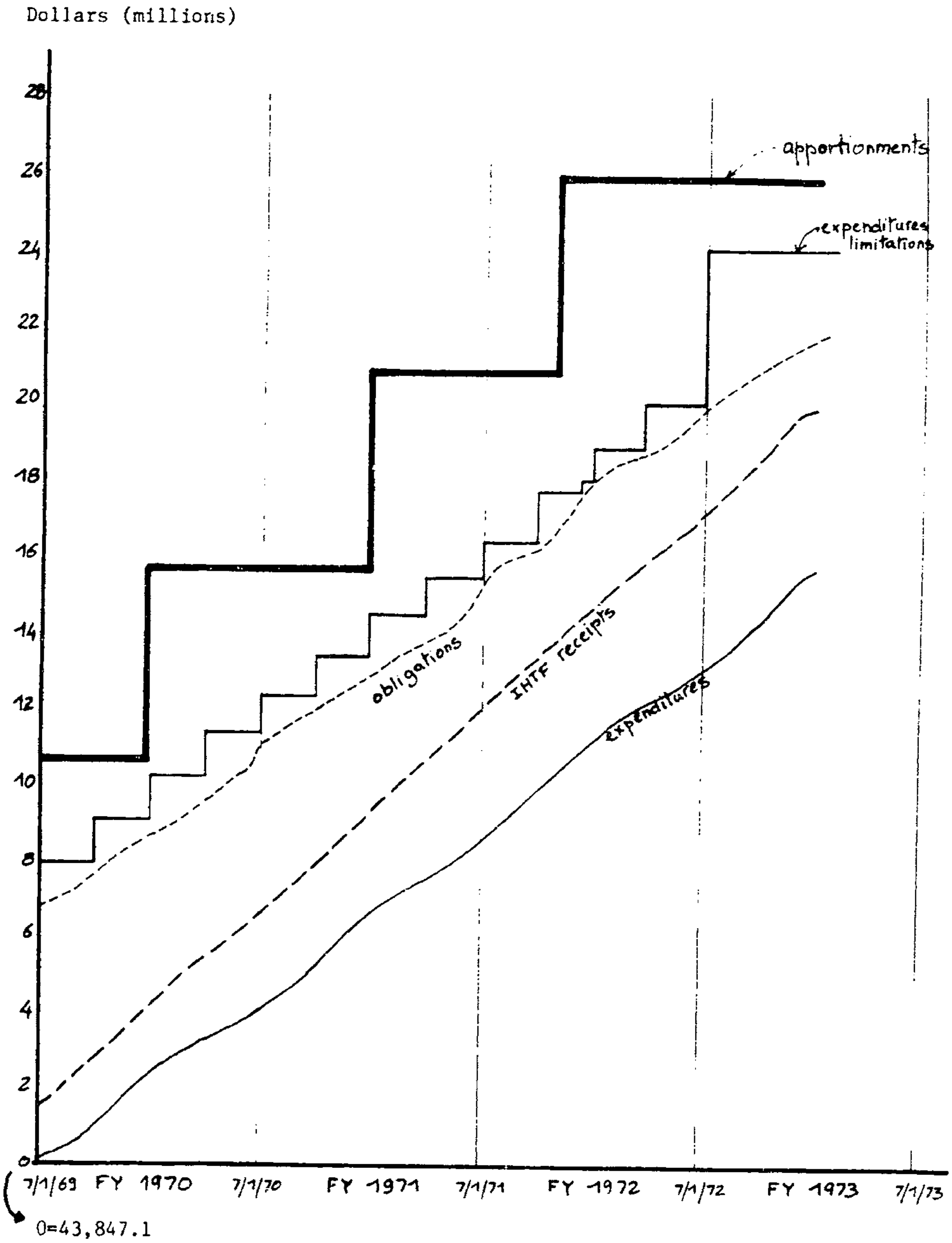
Figure II.3.4

sequences is in the apportionment-to-programming lag, which may take anywhere from one month to several years.

It should be noted that the total authorization-to-reimbursement lag for those States who are still programming prior years' FAHP funds, will generally be longer than the lag for States who are programming current apportionments. In other words, States with a relatively large unobligated portion of FAHP funds will not react fully and immediately to changes in present FAHP apportionment levels.

Taking the nation as a whole, total highway obligations have been running fairly close to the OMB-imposed fiscal control limitation on IHF expenditure levels, as shown in figure II.3.5. The total lag between project approval (obligation), and Federal reimbursement is represented by a horizontal line connecting the obligation and expenditure lines on figure II.3.5. For example, at the point marked A, this lag appears to be approximately 18 months.

FEDERAL-AID HIGHWAY PROGRAM
INTERSTATE HIGHWAY TRUST FUND
EXPENDITURES AND RECEIPTS



Source: FHWA Memo Dated 1/19/73, "Progress of the Federal Aid Highway Program"

Figure II.3.5

iii. Aspects of Trust Fund Taxation

The previous sections have detailed the mechanics of the Federal-Aid Highway Program as it has evolved since the early 1900's. While the focus of this chapter - in fact of the entire thesis - is an investigation of how States react to the availability of Federal highway grants, an underlying issue that deserves some attention is the taxation conventions associated with the Interstate Highway Trust Fund.

It is somewhat paradoxical that while the IHTF has come under serious scholarly and Congressional scrutiny in recent years,[1] the use of Trusts Funds as a mechanism to finance transport facilities has been introduced to other modal areas. In particular, the Airport and Airway Development Act of 1970[2] established ticket tax-based trust funds to finance the development of aviation facilities, and similar proposals have been raised in regard to the inland waterway system.

Perhaps the strongest argument in favor of a trust fund financing approach is in facilitating the orderly long-range planning and implementation of public facilities by guaranteeing a stable level of Federal financial assistance. Nonetheless, the practice of establishing a set of earmarked user charges in the use of transport facilities

1. As manifest by the prolonged debate over passage of the 1973 Federal-Aid Highway Act.

2. Public Law 91-258, Titles I and II, enacted May 21, 1970.

represents an intervention into the private market sector, and carries with it impacts on equity, efficiency and redistribution of income. This section will attempt to evaluate the economic consequences of the IHIF with particular attention paid to the aspects of trust fund taxation.

Depending on one's viewpoint, the revenues raised for the Interstate Highway Trust Fund are variously referred to as indirect excise taxes, user charges, or prices for the use of the publically provided road system. Some unambiguous definitions of these and related key terms are essential if this analysis is to proceed on a common ground.[1]

Definitions of the Revenue Terms

Prices - a cost-based charge for the consumption of a scarce resource

User Charges - a revenue-raising levy, not necessarily based on the real economic cost incurred in producing a (public) good

Taxes - a pure revenue measure which bears no explicit relation to the cost of providing public goods.[2]

In general, a tax is associated with a pure revenue objective, and evaluated in terms of its regressiveness/progressiveness (the relative burden of the levy on various income classes). User charges

1. The definitions presented here are drawn from "The Public Finance Aspects of the Transportation Sector," A Staff Paper prepared by the Office of Policy and Plans Development, U.S. Department of Transportation.

2. In fact, the inherent nature of a pure public good (e.g. national defense) renders an explicit pricing system infeasible.

are commonly associated with an equity goal - the concept that users should pay a fair share for their consumption of a service and prices are normally related to the concept of economic efficiency. The importance of these distinctions between taxes, prices and user charges is more than a mere semantic issue. The fundamental question relates to goals of the Interstate Highway Trust Fund revenue measures. For if the IHTF is to be viewed as a price system, then those prices must be justified on the basis of the real costs incurred by an individual user (driver) of the Federal-Aid Sytems. Conversely, if the IHTF revenue measures are to serve as user charges, then a valid concern is whether those charges meet an equity criterion. Finally, to view the IHTF as a pure revenue mechanism raises the question of the relative regressiveness of the revenue measures.

It would be difficult to argue the case for the IHTF as a mechanism to foster efficient use of scarce highway resources. No claim was originally made that the Trust Fund was to be financed through a price (as previously defined) system.[1] The revenue sources (see Table II.3.1) simply represented a pragmatic means to provide an assured stream of revenues for highway construction.

Because the IHTF revenue sources have the properties of (excise)

---

1. Referring to Table II.3.1, it is clear that the revenue sources of the IHTF do not fit our definition of prices. The levies on tires, tread rubber, oil, new trucks, buses and trailers, parts and accessories, gasoline, diesel and special fuels may be considered as either user charges or (excise) taxes.

taxes and user charges, it is important to assess the impacts of the program in terms of income redistribution and equity.

Income Redistributive Properties of the IHTF

The income redistributive properties of the IHTF can be viewed in terms of either an individual driver, or in terms of the fifty States. In the former case, we are concerned with the burden of the IHTF revenue measures on an individual driver relative to his income. In the latter case, the focus is on the amounts of FAHP aid received by each State relative to their per capita income. In either case the IHTF revenue measures may be defined as:

progressive - a wealthier individual (State) pays more (receives less) in both absolute and proportional terms than a poorer individual (State)

proportional - a wealthier individual (State) pays more (receives less) in only absolute terms than a poorer individual (State)

regressive - a wealthier individual (State) pays less than or an equal amount (receives more than or an equal amount) as a poorer individual (State).

In general, excise taxes tend to be proportional, or in some cases[1] even regressive. This is true as long as consumption of an item by individuals tends to grow less than proportionately with

---

1. Excise taxes will be regressive if the taxed item is an inferior good - i.e. an individual's consumption of the item decreases with increasing income. For a general note on the regressivity of excise taxes see Due, J.F. and A.F. Friedlaender, GOVERNMENT FINANCE, Richard D. Irwin, Inc., Fifth Edition, 1973, page 384.

increases in personal income. Thus, for an evaluation of the regressivity of the IHTF revenue measures, in terms of the burden on the individual driver, the issue is to determine the relative case of the automobile (and thus the relative amount of the IHTF levy) by individuals with differing income levels.

Table III.3.6 displays the distribution of person miles by income class and type of transport based on a 1967 nationwide survey. The survey was restricted to trips involving overnight stops away from home and/or journeys in excess of 100 miles each way. Thus, we may infer that the data is indicative of travel patterns for vacation and business travel rather than journey-to-work travel. The most striking finding indicated by the table is that the percent of households in each income class using auto for vacation or business travel tends to decrease with increasing household income. Thus for example, while auto accounted for 86% of the total person miles of travel by households with income $6000 - 7499, the corresponding figure for the highest income group ($15,000 and over) is only 51.7%. The difference in the intensity of auto usage between income groups for trips in excess of 100 miles derives primarily from the marked increase in the patronage of commercial air service by higher income households. The choice of the air mode varies from a low of 8.5% of total person miles of travel by the lowest household income category to a high of over 41% commercial air patronage[1] by the highest income households.

1. The percentages reported here do not indicate the frequency with which one mode or another is chosen, but only the percent of total miles traveled on each mode. Thus one transcontinental car trip may account for more mileage than dozens of auto trips of a shorter distance.

Distribution of Person-Miles by Income

and Type of Transport

(For Overnight Journeys and/or Trips in Excess of 100 Miles One Way)

Annual Household Income	Primary Mode of Travel				
	Auto	Bus	Train	Commercial Air	Combinations and Other
Under $4000	79.0	6.1	4.4	8.5	2.0
$4000-5999	84.8	2.8	2.6	9.0	0.8
$6000-7499	86.0	1.0	1.9	9.4	1.7
$7500-9999	82.9	1.2	1.4	13.3	1.2
$10,000-14,999	74.8	0.7	1.1	21.1	2.3
$15,000 and over	51.7	0.6	1.6	41.1	5.0
Income not reported	74.0	1.7	2.5	18.6	3.2
All income groups	77.0	1.9	2.0	16.8	2.3

Percent of Households in Each Income Class Choosing Each Mode

Source: Bureau of the Census, 1967 CENSUS OF TRANSPORTATION, Volume 1, July, 1970, pp. 35-36 (Table 12)

Table II.3.6

The data is indicative, if not conclusive of the phenomenon that consumption of auto travel for relatively long trips may be considered an inferior good. Further insight into this question is provided by Table II.3.7 which combines the modal split information of Table II.3.6 with data describing total person miles of travel across all modes by income class. The last column of this table lists the auto person-miles per household as a function of household income. The pattern that emerges is that auto travel per household increases with income, but less than proportionately, except for the highest income level where auto travel decreases sharply. Note that travel by all modes increases uniformly with (column 4, Table II.3.7) income, indicative that vacation/business trips per se are superior economic goods. Nonetheless, auto travel exhibits the characteristics of decreasing patronage with increasing income.

Since the IHTF is (partly) financed through an excise tax on the sale of gasoline, the tax burden on an individual household is directly related to the intensity of auto usage. Given the above findings on the pattern of auto usage for relatively long trips, it is clear that IHTF taxation is regressive.

A similar pattern emerges for home-to-work auto trips. Data supporting the contention that IHTF taxation is regressive with respect to commuting is found in Tables II.3.8 and II.3.9. The first table displays the modal split of home-to-work trips as a

Distribution of Auto Travel Patterns by Household Income Level

(For Overnight Journeys and/or Trips in Excess of 100 Miles One Way)

Annual Household Income	Number of Households (Millions)	Number of Person-Miles (Billions)	Person-Miles Per Household Per Year	Percentage of Person-Miles by Auto	Auto Person Miles Per Household
Under $4000	7.3	35.0	4790	79.0	3790
$4000-5999	6.8	46.0	6770	84.8	5740
$6000-7499	5.2	42.9	8270	86.0	7110
$7500-8999	6.5	58.6	9020	82.9	7490
$10,000-14,999	5.7	65.9	11570	74.8	8660
$15,000 and over	2.6	34.8	13400	51.7	6920
Income not reported	4.0	28.6	7170	74.0	5300
All income groups	38.1	311.8	8180	77.0	6300

Source: Bureau of the Census, 1967
CENSUS OF TRANSPORTATION,
Volume 1, July, 1970, pp. 17, 35-46

Table II.3.7

Relationship of Mode Choice and Household Income

for Home-to-Work Trips

Annual Household Income	Mode of Transportation					
	Automobile					
	Driver	Passenger	Total	Public Transportation	Walking	Other
Under $3000	25.6	20.1	45.7	12.8	11.9	29.6
$3000-3999	29.7	18.8	48.5	12.5	12.7	26.3
$4000-4999	34.7	21.4	56.1	11.6	7.0	25.3
$5000-5999	45.2	18.5	63.7	9.4	5.5	21.4
$6000-7499	46.4	20.8	67.2	6.9	5.3	20.6
$7500-9999	49.8	20.5	70.3	5.9	4.5	19.3
$10,000-14,999	54.9	19.2	74.1	5.1	2.9	17.9
$15,000 and over	58.8	16.4	75.2	6.5	3.3	15.0
All	48.4	19.1	67.5	7.2	5.0	20.3

Percent of employed persons in each household income group by mode of home-to-work transportation (1969)

Source: U.S. Department of Transportation, Federal Highway Administration, NATIONWIDE PERSONAL TRANSPORTATION STUDY, HOME-TO-WORK TRIPS AND TRAVEL, Report No. 8, August, 1973.

Table II.3.8

Relationship of Average Commute Time for

Home-to-Work Auto Trips and Household Income

Annual Household Income	Average Commute Time (in minutes)
Under $3000	18
$3000-3999	18
$4000-4999	20
$5000-5999	22
$6000-7499	19
$7500-9999	20
$10,000-14,999	20
$15,000 and over	21
All income groups	20

Figures represent 1970 data

Source: U.S. Department of Transportation, Federal Highway Administration, NATIONWIDE PERSONAL TRANSPORTATION SURVEY, HOME-TO-WORK TRIPS AND TRAVEL, Report No. 8, August, 1972

Table II.3.9

function of income, based on a 1969-1970 nationwide survey.[1] As might be expected, the choice of auto for the journey-to-work tends to increase as household income increases. However, it should be noted that this increase is less than proportional: the range in household income varies by a factor of more than five to one, while auto patronage increase by only slightly more than two to one.

Some indication of the average trip distance for journeys-to-work by income groups is given by Table II.3.9. The Nationwide Personal Transportation Survey did not directly report on the variation in trip distance by income group. However, it is apparent from the striking uniformity of commuting travel time across different income groups, that travel distance for journeys-to-work cannot vary appreciably across income classes.

The conclusion from these data is that the total auto mileage devoted to journey-to-work trips (and thus the corresponding burden imposed by the IHTF tax levies) increases less than proportionately to increases in household income. Accordingly, with respect to this trip purpose, the IHTF represents proportional tax system.

In addition to the income redistributive consequences of the IHTF revenue measures on individual drivers, the FHAP effects on explicit redistribution of income among States. We refer to the fact

---

1. The Nationwide Personal Transportation Survey conducted by the Bureau of the Census.

Comparison of Estimated State Payments to the Highway Trust Fund with State Receipts from the Highway Trust Fund and Federal-Aid Apportionments, Fiscal Years 1957-1970

State	Estimated Payments to the Highway Trust Fund (Millions of Dollars)	Federal Aid Apportionments	For Each Dollar the State Paid into the Highway Trust Trust Fund 7/56 to 7/70, State was Apportioned	State Per Capita Income 1963
Alabama	833	1,006	$1.21	1669
Arizona	451	682	1.51	2220
Arkansas	539	539	1.00	1625**
California	4,766	4,102	.86	2993
Colorado	561	647	1.15	2479*
Connecticut	624	692	1.11	3113
Delaware	143	180	1.26	2994*
Florida	1,500	1,032	.69	2141**
Georgia	1,152	1,008	.88	1878**
Idaho	224	361	1.61	2045
Illinois	2,358	2,508	1.06	2911*
Indiana	1,372	1,188	.87	2467
Iowa	780	747	.96	2299
Kansas	674	613	.91	2398
Kentucky	744	930	1.25	1840
Louisiana	800	1,124	1.40	1839
Maine	258	291	1.13	1957
Maryland	768	799	1.04	2678*
Massachusetts	1,083	1,073	.99	2774**
Michigan	2,089	1,778	.85	2581
Minnesota	938	1,157	1.23	2365*
Mississippi	555	638	1.15	1434
Missouri	1,258	1,279	1.02	2360*
Montana	235	627	2.67	2263
Nebraska	448	463	1.03	2273

Source: Federal Highway Administration, 1972 National Highway Needs Study Project C-1.

Table II.3.10

Comparison of Estimated State Payments to the Highway Trust Fund with State Receipts from the Highway Trust Fund and Federal-Aid Apportionments, Fiscal Years 1957-1970 (Continued)

State	Estimated Payments to the Highway Trust Fund (Millions of Dollars)	Federal Aid Apportionments	For Each Dollar the State Paid into the Highway Trust Fund 7/56 to 7/70, State was Apportioned	State Per Capita Income 1963
Nevada	155	352	$2.27	3235*
New Hampshire	169	246	1.46	2343*
New Jersey	1,514	1,238	.82	2960
New Mexico	340	583	1.71	2048
New York	2,897	2,718	.94	3009
North Carolina	1,234	719	.58	1801**
North Dakota	176	349	1.98	1999
Ohio	2,442	2,689	1.10	2508*
Oklahoma	776	668	.86	1990**
Oregon	593	820	1.38	2471*
Pennsylvania	2,424	2,311	.95	2437
Rhode Island	185	251	1.36	2510*
South Carolina	606	494	.82	1576**
South Dakota	207	428	2.07	1908
Tennessee	939	1,156	1.23	1772
Texas	3,192	2,579	.81	2102**
Utah	276	601	2.18	2210
Vermont	110	320	2.91	2013
Virginia	1,056	1,369	1.30	2093
Washington	804	995	1.24	2618*
West Virginia	394	804	2.04	1778
Wisconsin	963	706	.73	2375
Wyoming	147	469	3.19	2412*

* States with higher than average per capita income who are apportioned more than they contribute to the Trust Fund

** States with lower than average per capita income who are apportioned less than they contribute to the Trust Fund

Table II.3.10 (contd.)

that the various apportionment formulas described in section II.2, determining the relative amounts of Federal-Aid System grants to be given to the States result in several States contributing more to the IHTF than they receive in the form of grants (and vice versa).

Table II.3.10 indicates the extent of income redistribution resulting from the Federal-Aid Highway Program apportionment formulas. Of the thirty-one States which were apportioned more than they contributed to the Trust Fund (over the period 1957-1970), fourteen had higher than average per capita income.[1] Conversely, the same amount as they contributed to the IHTF, eight had a lower than average per capita income. Both of these instances are examples of perverse income distribution. It is not surprising to find that the formulas used to apportion FAHP grants result in several cases (22 out of the 48 mainland States) of States with higher than average per capita incomes receiving proportionately higher income transfers in the form of highway grants (and vice versa), since the enabling legislation did no consider income distribution as an espoused goal of the Federal-Aid Highway Program.[2] None of the apportionment formulas described in Tables II.2.3 and II.2.4 take account of per capita income, fiscal capacity tax effort, or similar measures of State Wealth. Nonetheless, as has been shown, the fact that a Federal grant program does not

1.The average per capita income in 1963 was $2287. Income data is shown for 1963 because this represents the meddle of the 1957-1970 sample period for which apportionment data is presented.

2. For a good discussion of the debate over the selection of factors to be incorporated into apportionment formulas, see Burch, P. op.cit.

address an explicit income redistribution goal, does not imply that the program will be distributionally neutral.[1]

In summary, two aspects of the income redistributive impacts of the Interstate Highway Trust Fund have been explored. First, <u>the excise taxes used to finance the IHTF</u> tend to be regressive or proportional, depending on individual drivers' trip purposes. Secondly, <u>the formulas employed in apportioning IHTF revenues</u> among States result in a mildly progressive redistribution of income. One more point should be stressed with regard to the latter conclusion. The low value of the correlation coefficient between per capita income and apportionments (see footnote 1 below) reflects the fact that there are nearly as many States exhibiting perverse income distribution with respect to the FAHP grants, as there are States emblematic of the "commonly accepted" goals of income distribution.[2]

1

Taken as a whole, the FAHP appears to be mildly <u>progressive</u>. The correlation coefficient between apportionments and per capita income in 1970 was -0.1965. However, it is still the case that for more than 20 States, the FAHP results in perverse income distribution.

2

It should be noted that the Federal government does administer several grant programs -- most notably the general revenue sharing program, and the welfare grant program -- which are structured to accomplish explicit income distribution goals. Pursuant to the State and Local Fiscal Assistance Act of 1972 (general revenue sharing), States with lower per capita income and/or higher tax effort receive proportionately higher Federal aid. And in the welfare grant programs, States with relatively large numbers of welfare recipients (and thus presumably those States with relatively low per capita income), receive proportionately higher amounts of Federal welfare assistance.

Equity Considerations in Administering the IHTF

The issue of equity deserves some attention if for no other reason than that it has been the primary argument espoused by proponents of continuing the trust fund approach to financing roads. This justification follows the general principle that those who use roads often should pay more than those who use them little. The obvious extension of this principle -- often referred to as the benefit principle -- is that those who do not use the road system (e.g. transit patrons) should neither pay for, nor receive aid from a highway trust fund. Although the concept of equity inevitably involves the vagaries inherent in deciding on what constitutes a "fair" distribution of the tax burden, some general conclusions on the equity characteristics of the Interstate Highway Trust Fund can nonetheless be established.

On an elementary level, it is indisputably true that the excise tax on gasoline sales guarantees a rough measure of equity in that those who drive more pay more. But the more sophisticated treatment of equity examines both aspects of IHTF taxation: the distribution of the tax burden and the distribution of benefits derived from the IHTF. It is not sufficient to conclude that the IHTF assures equity based only on examination of the revenue side of the IHTF. Since Federal highway grants are restricted to expenditure on roads comprising the Federal Aid System, a more rigorous test of equity would require that the tax burden assessed on individual users be distributed according to the intensity of their use of the Federal-Aid System. If all people drove in exactly the same proportion on the different Federal-Aid highways as well as on roads off the Federal-Aid System, (FAS), then the policy of spreading the costs of the FAS over all drivers would be justified. But as long as all drivers do not use the various highway systems equally, inequities are bound to result. More succintly, the driver who never uses the Federal-Aid System will effectively subsidize a person who predominately does.

Table II.3.11 provides evidence that drivers in different size cities tend to make disproportionate use of roads on and off the Federal-Aid Systems. The pattern that emerges is that the percent of travel on all Federal-Aid Systems classified as principal and minor arterials tends to decrease monotonically with increasing city size. For example, while drivers in cities in the smallest population group devote 95.6% and 86.1% of their vehicle miles to principal arterials and minor arterials respectively on the Federal Aid System, the corresponding figures for cities in the highest population group are only 80.7% and 66.7%. Thus for each mile driven (and thus for each Federal excise tax dollar collected per vehicle mile), the population in smaller cities get greater use from Federally financed roads than their counterparts in larger cities.

In addition, there exists an equity issue with respect to the relative use of roads within the Federal-Aid System. In particular, the Interstate System carries only 27.2%[1] of the total vehicle miles on all Federal-Aid Systems in 1968, while accounting for 72% of the total Federal apportionments in the same year. Accordingly, users

---

[1] As reported in the 1972 National Highway Needs Report (op cit)

Distribution of 1968 Mileage on Travel on and Off Federal-Aid Systems by Functional System in Urban Areas by Population Groups

Population Group	Percent of Travel on Federal Aid Systems	
	Principal Arterial Systems	Minor Arterial Systems
5,000 - 9,999	95.6	86.1
10,000 - 24,999	94.2	82.2
25,000 - 49,999	93.3	78.1
50,000 - 99,999	91.0	76.5
100,000 - 249,999	86.4	72.8
250,000 - 499,999	87.9	74.2
500,000 - 999,999	83.8	70.2
1,000,000 and over	80.7	66.8

Source: Part II of the 1972 National Highway Needs Report, House Document No. 92-266 (Table III-2, page III-8)

Table II.3.11

of the Interstate System are heavily subsidized by drivers on the other Federal-Aid Systems.

Two other examples of inequitable financing within the Federal Aid Highway Program may be cited. Again, the rigorous test of equitableness employed here relates the use of specific classes of highways relative to the tax burden faced by specific types of highway users. Along these lines, it has often been cited that peak-hour highway users in urban areas are heavily subsidized by off-peak drivers. The point was made as early as 1959 by Professor William Vickrey in testifying before the Jiont Committee on Washington Metropolitan Problems. Table III.3.12 is condensed from Exhibit 51 of these hearings.

The data attempt to separate out the capital cost required in implementing alternative transportation plans solely due to peak hour traffic. The major finding here is that single occupant peak-hour drivers require an incremental investment of $63 per round trip per year (i.e., over and above the investment required to provide adequate capacity for off-peak auto use). While the exact figures reported by Professor Vickrey might be subject to question, it is nonetheless true that the IHTF revenue measures average costs over peak and off-peak users alike, while peak users are responsible for the greater share of the costs.[1] This is clearly an inequitable distribution of the costs for the provision of urban highway facilities.

---

[1] This issue also involves efficiency considerations, since the gasoline taxes do not serve as cost-based prices. In fact it may be argued that the result has been as an overexpansion of urban highways, since it is not at all clear that peak-hour drivers would be willing to pay the true social costs of their auto use.

Incremental Costs of Rush Hour Travel by Various Modes

Mode	Investment Costs Per Round Trip Per Person				
	Investment Per Round Trip per Year ($)	Rate of Capital Charge (percent)	Cost Per Round Trip	Operating Costs Per Round Trip Per Person ($)	Total Costs Per Round Trip Per Person ($)
Express Bus	2.70	15	0.40	0.35	0.75
Rail	4.20	10	0.42	0.19	0.61
Private Automobile: 1 Person Roads and Vehicles	63.00	5	3.15		3.15
Out of Pocket Operating Cost	--	--	--	0.30	0.30
Parking	10.00	8	0.80	0.20	1.00
Total Auto 1 Person	73.00	--	3.95	0.50	4.45
Total Auto 2 Persons	36.50	--	1.98	0.25	2.23

Source: Transportation Plan for the National Capitol Region, Hearing Before the Joint Committee on Washington Metropolitan Problems, Congress of the United States, Eighty-Sixth Congress, 1959, p. 478.

Table II.3.12

One final example of inequities inherent in the IHTF is provided by the Federal Highway Administration's 1969 study on the Allocation of Highway Cost Responsibility and Tax Payments. The major findings from this tudy are summarized in Table II.3.13. These data estimate the total IHTF tax payments assessed on various highway users (automobiles, buses, and trucks) as compared to the costs of providing the Federal Aid Highway Systems attributable to each of these users.[1] The apparent conclusion from these data is that buses andmedium-sized trucks are subsidizing automobile and heavy truck users of Federal-Aid roads.

Whether the subsidies (inequities) cited in this section are desirable or not ultimately depends on value judgments as to the relative merits of different types of travel. Inevitably, the choice of a financing mechanism for the provision of highways calls for compromises and political judgment. Thus for example, the explicit subsidy of the Interstate System by drivers on the other FAS might be justified on the basis of the particular importance of the Interstate System for the national defense, and interstate commerce. While the other instances of inequities inherent in the IHTF -- rural vis-a-vis urban, peak user vis-a-vis off peak user and auto vis-a-vis turck users -- might be harder to justify, the complexity involved in administering a "perfectly equitable" user charge mechanism must be weighed in deciding upon any changes that would reduce these inequities.

---

[1] The allocation of cost responsibility was based on the traffic volume, vehicular weight and vehicle size of each of the highway user classes. Heavier and/or larger vehicles require special structural considerations in the design of highway facilities (thicker pavements, taller overhead structures, etc.).

Total Federal Trust Fund Expenditure
Allocation vs. Tax Payments 1969

Type of Vehicle	Total Costs Allocated (Millions $)	Total Tax Payments (Millions $)	Ratio of Payments to Costs
Automobiles	2914	2742	.94
Buses	39	59	1.51
2 Axle-4 Tire Trucks	329	546	1.66
Other Single Unit Trucks	267	480	1.80
Heavy Truck Combinations	922	702	0.76
Other	7	11	1.57
Total	4540	4540	

Source: Allocation of Highway Cost Responsibility and Tax Payments 1969, U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, p. 74, Table 25.

Table II.3.13

II.4 Comparison of the Federal Aid Highway Program with the Federal Public Transportation Assistance Program

In order to provide further insight into some of the unique aspects of the Federal-Aid Highway Program (FAHP) it is interesting to compare its operation with the Federal Public Transportation Assistance Program (FPTAP). The FPTAP differs in several important respects from the FAHP. A convenient framework for comparing the Federal roles in these two modal areas is to summarize the FPTAP in terms of the same program descriptions used to characterize the FAHP (see Section II.3.i).

Sources of Federal Funds

There is no FPTAP trust fund analogous to the previously described Interstate Highway Trust Fund. Federal funds for transit assistance derive from United States Treasury general tax revenues. An important consequence of this characteristic is that Federal authorization levels are subject to Congress general budgetary review. Authorizations in years of "tight money" may be limited. This is in contrast to the IHTF whose financing is relatively automatic and "painless", determined primarily by the total revenues accruing to the Trust Fund.

Total Expenditure Levels

The magnitude of Federal financial effort in highway transportation dwarfs the FPTAP. Since the first Urban Mass Transportation Assistance Act (1964), Federal Transit grants have totaled $1.215 billion (FY 1965-1971), only 3.85% of the total FAHP funds over the same period. The most recent FPTAP bill, the Urban Mass Transportation Assistance Act of 1970 (as amended by Title III of the Federal-Aid Highway Act of 1973) authorizes $6.1 billion through fiscal year 1976.

Authorization Cycle

There is apparently no fixed authorization cycle in the FPTAP analogous to the 2-year Federal highway authorization process. The first significant Federal financial commitment to public transportation began with the Urban Mass Transportation Act of 1964 which authorized funds for the three fiscal years 1965-1967. Public Law 89-562 provided additional grants for the two fiscal years 1968-1969. Funds for the single FY 1970 were authorized by 701 of Public Law 90-448. Current authorizations derive from Public Law 91-152 which provides funding for at least five years (FY 1972-1976).

Apportionment Method

Unlike the FAHP, Federal transit funds are not apportioned among States or local areas on a formula or other prespecified basis. Federal grants are awarded on a project by project basis. A metropolitan area or public transportation agency may apply for as many Federal grants as it chooses. The only apportioning limitation is that no State (i.e., the aggregate of all grant-receiving agencies or municipalities in a State) may receive more than 12 1/2% of the cumulative national level of grants obligated since the beginning of

FY 1971.[1] An interesting consequence of this apportionment restriction is that a State which embarks on an ambitious transit capital improvement program may have to wait until other cities "catch up" before qualifying for additional funding.

Matching Provisions

Grants for any type of qualifying public transportation project are provided at a single matching rate -- a Federal share payable of 80% of the net project cost.[2] Net project cost is defined as the estimated portion of the cost of a project which cannot be reasonably financed from farebox revenues. It is clear that the stated matching provisions give transit agencies the incentive to build relatively high capital cost projects.

Expenditure Restrictions

Similar to the FAHP, the FPTAP is based upon Federal conditional, matching grants. In both programs, the conditional grants are

---

1. An exception is that any State which has received more than two-thirds of its grant limit may qualify for additional funding from a discretionary account which amounts to 15% of the total cumulative EPTAP authorization.

2. The initial determination of net project cost is made on the basis of estimates of total project cost and anticipated revenues derived from engineering studies, studies of economic feasibility, and data showing the nature and extent of the expected utilization of the project facilities and equipment. The actual amount of the Federal grant is determined at the completion of the project on the basis of the actual net project cost. Further information on the mechanics of Federal transit aid may be found in CAPITAL GRANTS FOR URBAN MASS TRANSPORTATION: INFORMATION FOR APPLICANTS, distributed by the Urban Mass Transportation Administration (June, 1972).

restricted to financing capital expenditures. Grant-eligible public transit projects include land acquisition, (re)-construction of transit-related facilities, and the purchase of buses, rail rolling stock, and related equipment.

Local Recipients of Federal Funds

A fundamental difference between the FAHP and the FPTAP is that the latter deals with municipalities and transit line agencies. The only State involvement with the administration of transit grants is in a general advisory capacity. Applications by local governments or transit agencies for Federal transit grants must be preceeded by a State and local review process as stipulated by OMB circular A-95 and other Federal proceedural requirements. In comparison, the FAHP is administered exclusively through the States, with metropolitan areas acting solely in an advisory/review capacity.

Sources of Local Matching Funds

The definition of transit net project cost implies that local agencies must provide some external (i.e. beyond operating revenues) means of financing their share of Federally-aided public transportation systems. Just as there is no established Trust Fund at the Federal level, very few cities have chosen to enact Trust Funds at the local level.[1] The traditional means of local financing is through a two

1. An exception is found in Minnesota where the Twin Cities Metropolitan Transit Commission is empowered to set aside a levy of $1.00 on all automobiles registered in Minneapolis-St. Paul for development and operation of mass transit systems.

layer bond issue: local property tax-supported bond issues for fixed plant, and revenue bonds for the purchase of rolling stock. However, there are several structural varients in the method of transit financing in different metropolitan areas.

It is interesting to note that the necessity to obtain bond issues to finance transit construction gives the local electorate (where referenda are required to ratify bond issues) or State legislatures virtual financial veto power. Several cases have arisen where transit bonding referenda have been defeated (e.g. Seattle (1969), Atlanta (1970), and New York (1972)), resulting in at least a temporary delay in project construction. In contrast, the FAHP is not characterized by an analogous veto process at the State level. Although several States have provided for local veto power over proposed highway projects, this control is not exercised through restrictions on the use of public funds.

II.5 Summary and Conclusions

This chapter has provided a factual setting necessary for the development of empirical models designed to assess the impacts of the FAHP on State highway expenditure behavior. Of particular importance is the finding that highway finance employs a trust fund approach at both the Federal and State levels. The modelling implication here is that the evaluation of alternative Federal highway grant policies can proceed without a complete analysis of State budgetary processes across functional areas outside the transportation environment. In other words, since nearly all States finance highway construction and maintenance from earmarked excise taxes, we can restrict our modelling attention to how the FAHP affects long range highway revenue policy, and short run highway programming (allocation).

The highway financing environment stands in contrast to financing conventions employed in the provision of other types of State services (e.g. welfare assistance, health facilities, education facilities) wherein all expenditures are made from a common budget. In these areas, changes in Federal grants (e.g. for education) would be expected to influence expenditure decisions on all functions other than highways due to the effect of a State's budget constraint.[1]

---

1. For an empirical analysis of the interaction between expenditure behavior on various State functional areas, see Tresch, R., op cit.

The interaction between highway expenditure behavior and the performance of other State functions is minimal, and thus this research will restrict the analysis to the highway sector.[1]

A second major finding with regard to the development of empirical models of expenditure behavior relates to the dynamics of the Federal-Aid Highway Program. As discussed in Section II.3, Federal highway grants are available for abligation by States over a period of up to three and one half years. This raises the issue of a time lagged response to the FAHP -- i.e., States may not react fully and immediately to the availability of any one year's highway authorization. In fact, the amount of Federal highway grants available to a State in one year is not simply that years' apportionment. The empirical models presented later will employ a three year moving average on Federal grants to account for this characteristic of the FAHP.

A third major characteristic of highway finance which must be accounted for in empirical models concerns the organization of the FAHP into several distinct Federal-Aid Systems. The implication here is that an important aspect of the highway expenditure behavior is the decisions on the allocation of a State's highway budget between alternative Federal Aid Systems (as well as expenditures on

---

1. Some interaction between highway and other functional area expenditure behavior may exist in those States with legislation limiting debt ceilings. In these cases, the decision to sell binds for construction of a State University (for example) might limit the debt service available for highway construction. Since debt financing does not constitute a major source of highway revenue for most States this type of interaction will be ignored.

other highway categories). Several previous studies[1] have simply attempted to model the effect of total Federal highway grant availability on total State highway expenditures. The problem with this approach is that it fails to distinguish between the separate expenditure effects of Federal grants for each of the Federal-Aid Systems (each characterized by distinct authorization levels, matching provisions, etc.). The research strategy adopted in this thesis explicitly accounts for the possibility of distinctly different State expenditure responses to each of the major Federal-Aid System grants.

Finally, the discussion of highway finance presented in this chapter serves to illustrate the two fundamental dimensions of State highway investment behavior: revenue policy and allocation policy. The former issue deals with the question of which factors influence a State to raise a greater or lesser amount of (earmarked) highway revenue. The second issue concerns the analysis of the factors that determine how a State allocates its highway budget amongst candidate expenditure categories. In this research the major focus is on the effects of Federal grants on these two dimensions of State highway expenditure behavior. Accordingly the empirical models presented

1. For example, O'Brien, T., op.cit., Gabler, L.R. and J.I.Brest, op cit.

in this research will explicitly deal with the behavioral bases for long run revenue policy formulation and short run allocation policy determination.[1]

---

1. The distinction between revenue policy as a "long run" phenomenon and allocation policy as a "short run" phenomenon derives from the fact that changes in the determinants of State highway revenue (e.g. tax rates, bond sales, etc.) tend to be infrequent relative to the expression of a State's allocation policy (e.g., year-to-year capital budgeting decisions.)

Chapter III

THE FEDERAL AID HIGHWAY PROGRAM: THE ANALYTICS OF DESIGN AND RESPONSE

III.1 Introduction

Economists have developed an extensive set of theoretical and analytical tools that have been applied with some measure of success in analyzing the operation and performance of the private sector. Attempts to extend these economic tools to the analysis of the public sector cannot boast of similar success. This is particularly true of recent research into the nature of the impacts of Federal grants - in-aid on State and local governments.

This chapter will set forth a series of theoretical models that serve to illustrate the expected consequences of a variety of Federal aid program structures. It should be stressed at the outset that there are several obstacles to a fruitful theoretical analysis of the impacts of the Federal aid highway program.

An immediate issue is whether to approach the analysis from a normative (prescriptive) or positive (descriptive) perspective. Indeed, in studies of the private sector, the normative analysis of, for example an optimal pricing policy, is often facilitated by rather simple assumptions on the objectives of the economic agents in the system (for example, profit maximization by a firm). Section 2 of this chapter discusses the difficulty of inferring a set of goals guiding the Federal government's role in highway finance. Despite the fact that the Federal objectives in administering the highway grant program are neither easily identifiable, non-conflicting or static, Section two does attempt to develop a series of possible rationales for Federal participation in the provision of the national highway system. For each rationale, the appropriate design of the Federal aid highway program is presented.

Section three adopts a descriptive analytic framework. A basic allocation model is presented based on the economic theory of the consumer (i.e. the State is viewed as a consumer of highway facilities), to develop the expected expenditure responses of States to a variety of Federal-aid program structures. Needless to say, the results reported here are relevant only to the extent that the assumptions underlying the allocation model accurately describe the decision-making calculus employed by the States. Here too, an obstacle to fruitful theoretical analysis is the lack of an easily identifiable set of objectives defining the criteria by which States determine the level and allocation of their transportation budget. Nonetheless, section three proceeds on the basis of a somewhat simplistic decsion rule: a State will allocate its transportation budget so as to maximize its perceived benefits (utility).

Qualifications to the analyses of State responses to a variety of grant types (open and close ended, categorical and non-categorical, and matching and block type grants) are discussed in subsection vi of section three.

Section four presents a different approach to analyzing State responses to Federal grants. The concept of the benefit/cost ratio of candidate highway projects is introduced as the basic investment criterion used by States. Although the theoretical analyses of sections three and four apparently differ with respect to their underlying assumptions, in fact the conclusions drawn from both approaches are quite similar. Both sections draw attention to the price and income effects introduced by Federal grants, and proceed to demonstrate how State responses will differ according to the presence of one or both of these grant characteristics.

Section five extends the analysis of the preceding section with an investigation of historical grant and expenditure levels of the Interstate and ABC highway programs. It is shown that for the Interstate program, Federal grants have stimulated State expenditures that would most likely have not been made in the absence of the grant program. This result is contrasted with the experience in the ABC program, where it is shown that Federal grants have had a relatively insignificant impact in determining total expenditure levels on an allocation within the ABC system.

Section six summarizes the theoretical findings of chapter three. The relationship between the response to Federal grants, and the structural characteristics of the grants is discussed. The similarity of findings between the consumer allocation model (Section 3) and the benefit/cost investment model (Section 4) are drawn, and related to the empirical evidence presented in Section 5. Finally, the importance of validating the theoretical findings in this chapter with econometric models of succeeding chapters is stressed.

III.2 Fiscal Federalism -- The Normative Aspects of Federal Highway Grant Program Design

A logical starting point for an evaluation of the consequences of the Federal Aid Highway Program (FAHP) is to consider the Federal role in highway financing in the broader context of Fiscal Federalism.[1] Viewed in this perspective, the immediate questions to be addressed relate not so much to a detailed examination of the merits of one or another apportionment formula or matching ratio, as to an *ex ante* discussion of the justification for *any* Federal involvement in highway finance. The distinction we wish to draw is simply this: proposed changes to the existing structure of the FAMP may be called for because the initial justification for the Federal role in highway finance is no longer (or has never been) valid, or because the structure of the FAHP is not compatible with the accepted goals of the Federal role in highway finance. The former issue is clearly normative. Although Congressional debate over highway policy is not normally conducted at an abstract level, it may be inferred that current Federal highway legislation does recognize a need for Federal involvement in highway finance, and *is intended to*, *inter alia*, stimulate State expenditures on the Interstate Highway System.

---

1. Fiscal Federalism is a generic title for the study of the distribution of fiscal responsibilities in a decentralized system of governmental units. See Musgrave and Musgrave, PUBLIC FINANCE IN THEORY AND PRACTICE, McGraw-Hill Boook Company, 1973, chapters 26,27, and Due and Friedlaender, GOVERNMENT FINANCE, Richard D. Irwin, Inc., 1973 (5th Edition), Chapter 19.

Accepting this policy statement for the moment, the often expressed criticisms that the current FAHP has stimulated State expenditures on the Inter-State system beyond economically justifiable levels[1] is directed not so much against the provisions of the FAHP as against the implicit national goals from which the FAHP is derived.

On the other hand, if the provisions of the FAHP did not stimulate Interstate Highway expenditures[2] (again accepting this policy for the moment), then there may be ample justification for realigning the provisions of the FAHP. Thus the argument comes full circle. there is a clear distinction between stated (or implicit) national highway policy, and the characteristics of a particular highway program designed to implement that policy. In the broadest sense, the normative issue is to gain consensus on both of these aspects of the Federal Aid Highway Program.

i. The Theory of Intergovernmental Grants

Theoretical considerations can give some indication of the appropriate policy goals to be served by a program of intergovernmental grants. In general, there are three factors inherent in a decentralized system governmental jurisdictions that call for Federal fiscal

---

1. For example, see Testimony of Robert E. Gallamore, Director of Policy Development, Common Cause, Before the Subcommittee on Roads of the Senate Public Works Committee, February 15, 1973.

2. This would be the case if the States' Interstate Highway expenditures would have been at the same level in the absence of Federal grants. In this instance, it may be argued that Federal funds are primarily diverted to other expenditure categories including tax relief in which the Federal government has no officially stated interest.

intervention. The first factor relates to the existence of significant benefit spillovers, i.e., the incidence of benefits (or disbenefits) beyond the boundaries of the jurisdictions responsible for financing public projects. In the case of highway investment, it is clear that at least part of the benefits derived from the provision of road services in any one State are enjoyed by residents of other states. To the extent that one state provides an adequate system of highways, adjoining states benefit from reduced over-the-road interstate transport costs, and increased personal mobility for vacation and business travel.

The problem here is when some of the benefits are external, the level of highway activity provided by any one state is likely to be too small relative to the interests of the country as a whole, if highways are financed locally, and decisions about the quantity to produce are left solely in local hands. Formally, this problem can be stated as follows. Consider a level of highway production Q_i in State i and the associated costs C_i, and benefits B_i (internal benefits) and B_e (external benefits).[1] In abstract terms, we represent highway costs and benefits as continuous functions of the level of highway production as shown in Figure III.2.1. Borrowing the calculus of economic production theory, the optimal scale of highway production

1. This example is solely for illustrative purposes. It is not necessary at this time to distinguish between direct and indirect benefits, nor between benefit incidence on subgroups within the population of a given state. The main thrust here is simply to investigate the allocative consequences of fragmented jurisdictional highway investment decision-making.

INTERNAL AND EXTERNAL HIGHWAY BENEFITS AND COSTS

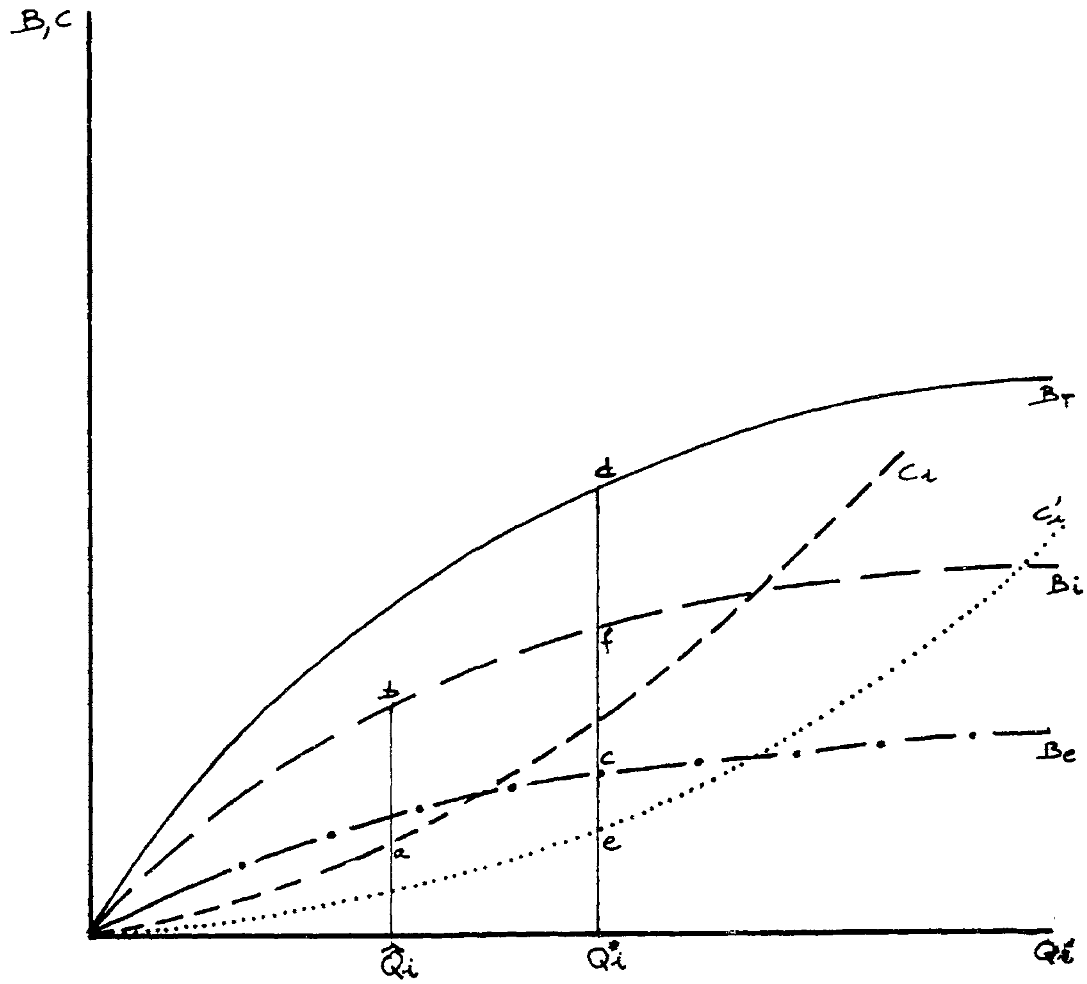


Figure III.2.1

in the absence of external incentives. $\hat{Q}_i$ is determined as that point where the marginal cost of highway production is equal to marginal highway benefits. In particular, if each jurisdiction bases its investment decisions solely on the basis of benefits accruing to residents within its boundaries, we have the optimal production scale condition:

$$\frac{\partial B_i}{\partial Q_i} = \frac{\partial C_i}{\partial Q_i} \tag{1}$$

Graphically, the optimal level of highway production is indicated by the point $\hat{Q}_i$ where the slope of the cost curve and benefit curve are equal. Note that in this solution, no account has been taken of the benefits accruing outside of State i.

If the residents of each jurisdiction were to base expenditure decisions upon benefits to the entire country rather than to their own areas alone, the optimal scale for provision of highways would be guided by the condition:

$$\frac{\partial B_T}{\partial Q_i} = \frac{\partial B_e}{\partial Q_i} + \frac{\partial B_i}{\partial Q_i} = \frac{\partial C_i}{\partial Q_i} \tag{2}$$

where B_T = total highway benefits ($B_T = B_i + B_e$)

In this case, the optimal level of production is Q_i^* resulting in net benefits, $B_i(Q_i^*) - C_i(Q_i^*)$ indicated by line segment cd (see figure III.2.1). This latter solution results in an expansion of highway production in State i from $\hat{Q}_i$ to Q_i^* and more importantly, an increase in net benefits from ab to cd.

Simply stated, the issue is this: in the absence of external financial incentives, it is unrealistic to assume that individual jurisdictions (e.g. states) will pursue a highway investment policy that systematically accounts for benefits accruing beyond their boundaries. In cases where significant benefit spillovers occur, the consequences of this atomistic behavior is an underinvestment in highway facilities.

ii. Functional Grants As Solutions

The above comments serve not only to outline a valid concern for Federal intervention in highway finance, but serve to indicate the appropriate structure for remedial Federal action. Short of an outright transfer of all highway investment activities to the Federal government,[1] the Federal objective is to provide a set of financial incentives that will encourage lower level jurisdictions to account for benefit spillouts in their investment decisions.[2]

To illustrate the mechanics of the appropriate program structure to meet this objective, assume the federal government assumes a

1. By definition, a nationalized highway investment program would internalize benefit spillouts effects.

2. Clearly, counteracting the adverse effects of benefit spillouts on state investment behavior is not the only objective of a Federal Aid Highway Program. In fact, there exist other, conflicting federal objectives. These will be discussed in the following sections.

(matching) share of the cost of the i[th] state's highway program as determined by the ratio of external to total benefits accruing from the provision of highways in State i. Returning to our initial model of optimal highway production scale where State i considers only internal benefits in its investment calculus, we get the optimality condition:

$$\frac{\partial B_i}{\partial Q_i} = \frac{\partial C_i'}{\partial Q_i} = \frac{\partial\left(\frac{B_i}{B_T} C_i\right)}{\partial Q_i} \tag{3}$$

where C_i' = State i's <u>share</u> of the cost of highway production.[1]

Assume for the moment that the external benefits B_e are some fixed proportion of internal benefits B_i, i.e.:

$$\begin{aligned} B_i &= f(Q_i) \\ B_e &= \alpha f(Q_i) \end{aligned} \tag{4}$$

then condition (3) reduces to

$$\frac{B_T}{B_i}\ \frac{\partial B_i}{\partial Q_i} = \frac{\partial B_i}{\partial Q_i} + \frac{B_e}{B_i}\ \frac{\partial B_i}{\partial Q_i} = \frac{\partial C_i}{\partial Q_i} \tag{5}$$

---

1. C_i represents the total cost of highway construction in State i. If the federal government assumes a share of highway cost equal to the ratio of external to total benefits, i.e., $\frac{B_e}{B_T}$, the States' highway cost is just $\frac{B_i}{B_T}C_i$ (see figure III.2.1.).

But assumption (4) also implies:

$$\frac{B_e}{B_i} \frac{\partial B_i}{\partial Q_i} = \frac{\partial B_e}{\partial Q_i} \tag{6}$$

Thus, optimality condition (3) takes the form:

$$\frac{\partial B_i}{\partial Q_i} + \frac{\partial B_e}{\partial Q_i} = \frac{\partial B_T}{\partial Q_i} = \frac{\partial C_i}{\partial Q_i} \tag{7}$$

The important conclusion that can be drawn from the above derivation is that the consequences of a federal highway matching grant program in situations where individual states consider only internal benefits in their investment calculus is allocationally equivalent to the highway production scale implied by states' expenditure decisions (in the absence of grants) based upon benefits accruing to the nation as a whole. Moreover, the production scale implied by optimality condition (2) or (3) represents the most efficient level of highway production.[1]

Thus, to the extent that the provision of highways results in significant benefit spillovers which are not accounted for in individual states' investment decisions, economic theory suggests a justifiable federal policy role in highway finance intended to increase the allocational efficiency of highway investments. Moreover,

---

1. In the terms of figure III.2.1, conditions (2) or (3) imply a production scale Q^*. The net benefits associated with Q^*, $B_T(Q^*) - C(Q^*) > B_T(Q) - C(Q) \; \forall \; Q \neq Q^*$

the economic theory dictates the appropriate program structure of financial incentives designed to implement this policy. In particular, solely on the grounds of allocational efficiency,[1] the federal government should administer grants with the following program characteristics.

<u>conditional</u>

The grants should be restricted to those classes of highways that are characterized by significant external (interstate) benefits.

<u>matching ratios</u>

The grants should be offered on a matching ratio basis. The matching provisions are determined by the nationwide significance of a particular highway class. Thus, for example, the federal government should assume a larger share of the cost of routes of major interstate importance than the share assumed for highways of primarily local or regional significance.

<u>open-ended</u>

The grants should not be limited by a fixed grant ceiling. In light of the theoretical considerations discussed above, open-grants do not imply that States will expand their highway

---

1. It is again stressed that there are other criteria dictating the appropriate structure of the federal highway program. Some of these criteria will be discussed in the following sections.

investments arbitrarily. On the contrary the theory suggests that open-ended grants with the appropriate[1] matching provisions will encourage states to expand their highway investment program only to the point where net (nationwide) benefits are maximized.

iii. Practical Limitations of the External Benefit Criterion.

Although theoretical considerations point to the use of conditional, open-ended, matching grants as a means to internalize benefit spillouts,[2] there are several limitations to the practicality of this approach. Needless to say, the investment criteria discussed in the previous section were somewhat simplistic. And cavalier references to "benefits" quantified as a continuous function of "the quantity of highways" ignores the facts that:

a) highway benefits cannot be quantified by a single measure;

b) nor can we make a neat distinction between benefits which are internal or external to a given state;

c) the benefits derived from the provision of highways is not definable over a continuum of the scale of highway investment;

d) The determination of internal and total highway benefits--however measured--is exceedingly difficult; for any one state,

---

1. We refer here to an adjustment of the matching ratio to reflect the ratio of external to total highway benefits.

2. These grants are often called "optimizing grants."

these measures are conditioned on the level of highway investment undertaken in adjoining states.

Taken together, these facts suggest that any practical application of optimizing grants will of necessity involve compromises and deviations from a rigid adherence to economic theory. The Federal Aid Highway Program described in Chapter 2 may be viewed as one such compromise. In light of the numerous criticisms that have been levied against this program, it is necessary to question whether the complaints constitute a general indictment of grants as an intergovernmental fiscal device, or merely identify inherent structural defects which must be balanced against the benefits of the FAHP.

It has been charged that[1] there are too many separate highway programs imposing excessively complex eligibility requirements and using unduly complicated apportionment formulas. Others claim that the FAHP has misdirected state and local expenditure allocation, rigidified state budgetary processes, and curtailed local autonomy.

All of these charges are, to varying degrees, true. Take for example the alleged distortion of the allocation of local funds among different highway programs. Poorly designed grant programs will have this effect--i.e., to the extent that the matching provisions of the existing FAHP do not reflect the actual distribution

---

1 See for example, Break, George F., INTERGOVERNMENTAL FISCAL RELATIONS IN THE UNITED STATES, Brookings Institution, 1967, Chapter 3, for a good summary of arguments against federal categorical grants.

these measures are conditioned on the level of highway investment undertaken in adjoining states.

Taken together, these facts suggest that any practical application of optimizing grants will of necessity involve compromises and deviations from a rigid adherence to economic theory. The Federal Aid Highway Program described in Chapter 2 may be viewed as one such compromise. In light of the numerous criticisms that have been levied against this program, it is necessary to question whether the complaints constitute a general indictment of grants as an intergovernmental fiscal device, or merely identify inherent structural defects which must be balanced against the benefits of the FAHP.

It has been charged that[1] there are too many separate highway programs imposing excessively complex eligibility requirements and using unduly complicated apportionment formulas. Others claim that the FAHP has misdirected state and local expenditure allocation, rigidified state budgetary processes, and curtailed local autonomy.

All of these charges are, to varying degrees, true. Take for example the alleged distortion of the allocation of local funds among different highway programs. Poorly designed grant programs will have this effect--i.e., to the extent that the matching provisions of the existing FAHP do not reflect the actual distribution

---

1 See for example, Break, George F., INTERGOVERNMENTAL FISCAL RELATIONS IN THE UNITED STATES, Brookings Institution, 1967, Chapter 3, for a good summary of arguments against federal categorical grants.

of internal and external highway benefits, allocational inefficiencies are bound to occur. However, properly designed grant programs will have the opposite effect: these grants will simply serve to finance a level of highway construction activity commensurate with the benefits accruing to the notion as a whole. Related to this question is the criticism that the FAHP has curtailed local autonomy. Here too, while this charge may be perfectly valid for the existing FAHP program structure,[1] an appropriately designed optimizing grant program[2] will not shift state policy responsibilities to Washington, but rather will remove the burden of state taxation for the financing of benefits the states do not directly receive.

It is true of course that the present system of highway grants does complicate the planning and administration of state highway investment programs. Grants are made available for some highway activities (e.g., Interstate Highway construction) but not others (e.g., road maintenance). Each grant comes with restrictions on road

---

1. This criticism stems partly from the assertion that federal highway funds far exceed transit grant availability. Consequently, the local incentives for transit system improvements are curtailed. This criticism does not indict federal grants per se, but serves to underline the need for a realignment of the existing FAHP/transit grant program. If grants for both of these modes were made available on an <u>open-ended</u> basis, such that each recipient could choose the extent of its own participation in highway and transit programs, these criticisms would no longer be valid.

2. Implicit in this discussion is an equity issue. Since the intent of the optimizing grants is to finance the provision of external highway benefits, these grants should be derived from taxes on states as determined by the net <u>spill-in</u> highway benefits they enjoy.

design standards, labor hiring practices, and planning and administration process guidelines. While economic theory may provide the rationale for a federal highway grant program in simplistic terms, it is undoubtedly true that in the inherently complex political and social environment in which they operate, rigid grant procedures, carried out in isolation, no longer yield acceptable solutions.

In a tightly integrated society, where the consequences of one functional grant program directly effect states' performance of other functional activities and where actions taken in one locality or state have widespread impact, a premium is placed on effective fiscal cooperation among all levels of government. In light of the issues raised in the preceeding pages, it is clear that while functional grants are an important instrument for effecting highway investment allocational efficiency, there are numerous ancillary consequences of a Federal grant program that must be considered as well.

Ultimately the normative issues of grant program design must explicitly account for the political and institutional consequences of a system of intergovernmental grants. Although the allocative impacts of specific highway grant programs will be the central focus of this thesis, we will address the institutional questions in a later chapter.

iv. Additional Goals of the Federal Aid Highway Program

In section III.2.ii, it was shown that a system of conditional, open-ended, matching grants were the appropriate fiscal policy tool to address the problem of benefit spillovers. There are other reasons why the Federal government may desire to influence the investment behavior of lower level governments. One example is the case of merit goods[1] -- that is those services deemed to be sufficiently meritorious as to encourage the Federal government to offer incentives for their provision. Implicit in the notion of merit goods is an element of coercion. A Federal program of merit good incentives is intended to redirect states' consumption patterns in those instances where it is considered that states systematically underestimate the value of the services to themselves.[2]

Putting it differently, merit goods may be considered as a special case of Federal fiscal intervention to ensure a certain minimum standard for the provision of public goods.[3] Arguments for merit good subsidies have been frequently aired for non-transportation services, particularly for health and old age care services (e.g.,

---

1. Musgrave and Musgrave, op.cit., page 612.

2. This stands in contrast to benefit spillover situations where states are assumed to systematically underestimate the value of highway services to the nation as a whole.

3. To be more specific, of a national consensus on the minimally acceptable quality of a public service is achieved, Federal merit good subsidies play the role of protecting the interests of the minority in a particular locality where majority decision provides for a substandard level of public services.

Medicare, Medicaid, and Old Age Assistance programs). However, to extend these arguments to the provision of highways is hardly defensible as it would imply that over-the-road transport is an especially meritorious means of travel relative to the service offered by competing modes.

While this rationale for Federal fiscal intervention is not particularly relevant to the transportation sector,[1] it should be noted that conditional, close-ended, matching or block grants are best suited to serve as merit good subsidies. This program structure assures that the grants are selective (i.e., limited to specifically identifiable merit goods) and supportife of only the minimum acceptable level of merit good provision.

In addition to the fiscal objectives of correcting for benefit spillovers, and subsidizing the provision of merit goods--both primarily allocative objectives--the Federal government may wish to pursue a grant program to meet explicit distributive goals. To be sure, grant programs designed to meet reallocative goals are also characterized by distributive consequences, and vice versa. However, there is a clear distinction between grant programs whose rationale is primarily allocative, and those whose rationale is primarily distributive.

---

1. On a limited scale one could present a case for highway grants in the guise of merit good subsidies on the grounds that:
   --safety considerations demand a certain minimal level of highway design standards
   --new modal technologies appear particularly promising, but local authorities are adverse to experimenting with untried techniques.

In the latter case, the Federal government would pursue measures which tend to equalize interstate fiscal strength without interfering with their preferences among alternative public (e.g., highway) services.[1] As in our previous discussion, the important point here is that the design of a particular grant program is strongly related to the adopted set of Federal objectives. In the instance where the Federal goal is strictly distributive, the appropriate federal action is the institution of unconditional, non-matching grants apportioned on the basis of the differences between fiscal need and fiscal capacity among the states.[2] Grants under the general heading of "revenue sharing" have these program characteristics.

The advisability of these grants ultimately rests on the existence of significant interstate differences in fiscal capacity and fiscal needs. The highway sector presents a special case where the interstate variations in fiscal strength are minimal, since both fiscal need and fiscal capacity correlate positively to the level of automobile travel. Given the existing method of gasoline taxation, states with relatively

---

1. That is, grants designed to meet distributional goals would not alter the perceived prices of specific public goods. This is in contrast to the previously discussed matching grants which play the role of price subsidies for specific public goods.

2. This program calls for a measure of fiscal need--i.e., the cost of providing a given level of (highway) services, and of fiscal capacity--i.e., the tax rate required to raise a given level of revenue. The intent of this type of grant would simply be to equalize the tax rates required in various states to render a given level of highway services.

high levels of automobile use (and presumably with correspondingly high capital and maintenance investment requirements) will also enjoy relatively high levels of available taxable income. This relationship stands in contrast to government activities where the level of fiscal need is inversely related to fiscal capacity.[1] While it is simplistic to presume that redistributive-oriented grant programs play no allocative role (and vice versa[2]), there is little justification of the need to structure the highway grant program to meet explicit fiscal equilization objectives.

---

1. Welfare assistance programs are one example. In this case the fiscal requirements of welfare programs are highest in those states and localities with the lowest fiscal capacities. To some extent this relationship holds for the provision of transit services as well, in the sense that transit ridership (and the associate of transit investment requirements) are inversely related to income (see Wells, J.D. et al., ECONOMIC CHARACTERISTICS OF THE URBAN PUBLIC TRANSPORTATION INDUSTRY, Institute for Defense Analyses, February, 1972, Chapter 4).

2. For example, federal aid highway apportionments in fiscal year 1970 were mildly redistributive. The coefficient of correlation between apportionments and state per capita income was -0.1965.

v. Theoretical Aspects of Policy Evaluation

As is evident from the previous discussion, attempts to address the normative issues of Federal highway grant program design along the lines of the underlying economic and institutional structure of the national highway system are not particularly fruitful. We have argued that the traditional rationales for Federal fiscal intervention -- correction for benefit spillover, merit good provision, and fiscal equalization -- are not demonstrably applicable to the existing highway investment environment.

What is clear is that highway policy has developed as an evolutionary process. The highway environment of the early 1900's, when the initial federal-aid highway legislation was passed, was characterized by significant benefit spillover and to some extent merit good and fiscal equalization problems.[1] The policies that have evolved since the Federal Road Act of 1916 (see Chapter 2) have consisted primarily of additions to extant policy (e.g., new Federal-Aid Systems, new institutional and planning requirements). The end result has been an ever increasingly complex system of detailed provisions governing the conduct of numerous federal aid grant programs.

---

1. See Burch, op.cit., for a good discussion of the evolution of highway investment policy.

Against this setting, it is extremely difficult to extract an identifiable set of national highway investment goals. From a normative standpoint, the design of the Federal Aid Highway Program must confront two basic issues:

- can we achieve a consensus on the objectives of the Federal government's role in the provision of highways?
- if these objectives can be achieved by the implementation of a Federal grant-in-aid program, what program design would best serve the Federal goals?

Political realities preclude a meaningful and conclusive response to the first question. Policy formulation at the Federal level is not a static process. Perceptions and priorities change over time. Moreover, in any given year, Congressional declarations of policy[1] are expressed in vague terms, rather than the operational statement of objectives required to pursue a normative analysis of grant program design. In short, the inherent complexity of the intergovernmental finance framework discourages meaningful normative analysis.

Accordingly, the primary focus of this research is in the framework of positive analysis -- a detailed investigation of the consequences of the existing program structure, and an evaluation

---

1. As inferred from Federal highway legislation

of selected (incremental) changes to the existing structure. A theoretical model of grant program design is presented in the following section.

III.3 The Analytics of State Responses to Federal Grants

This section presents a basic model for use in analyzing how a variety of highway grant programs could be expected to influence the short run expenditure patterns of recipient governments. The analysis framework focuses on the highway investment decision-making body -- be it a State Highway Department (SHD), legislature, governor, or a combination of these institutions. In any case, the decision-making body is considered to represent a behavioral unit (BU) in the sense that it exhibits a consistent set of preferences among alternative transportation goods. The preference structure of the BU can be represented by an indifference map among any combination of the transportation goods.[1] Furthermore, we assume that the BU seeks to maximize the utilities inherent in that set of preferences, subject to given prices and the resources available to it. The resources consist of the sum total of all revenue earmarked for transportation expenditure, plus the funds the BU receives from external sources in the form of federal grants. Without loss of generality, resources may represent funds dedicated solely to highway expenditure (i.e., a BU Highway Trust Fund) or a multimodal trust fund. The analysis does presume however that the budgetary and investment functions of the BU operate

1. The analysis is analogous to the consumer theory of an individual's resource allocation. Thus we assume that our indifference maps are convex to the origin and non-intersecting. These maps are not necessarily assumed to represent the true preferences of the voting polity, and thus do not derive from a "social welfare function." Throughout the discussion, references to maximizing utility are in the context of the utility of the BU, whether or not this utility truly reflects societal welfare.

independently of the BU's decision-making activities for non-transportation functions.

i. The Basic Model

Formally, the investment model takes the form:

$$\max U = U(E_1, E_2, \ldots E_n) \tag{8}$$

subject to $\sum_{i=1}^{n} E_i \leq R$

where U is the utility derived by the BU for a given allocation of expenditures amongst transportation goods E_1, E_2, ... E_n,[1] and R is the total resource availability. For clarity, we focus the analysis on the level of expenditure devoted to one specific highway category, X, relative to the resources available for all non-X transportation expenditures.

Thus in figure III.3.1, we display the indifference map of the BU, with the units of X on one axis (e.g. lane miles), and resources for all other transportation uses, Y (in dollar terms) on the other. Each indifference curve represents a distinct set of combinations of X and Y for a given level of utility, i.e.,

$$U = U_i = U(X, Y) \tag{9}$$

where U_i = i^{th} level of utility.

---

1. These expenditure categories may represent distinct classes of highways, for example the various Federal Aid Systems.

HIGHWAY INVESTMENT INDIFFERENCE CURVES

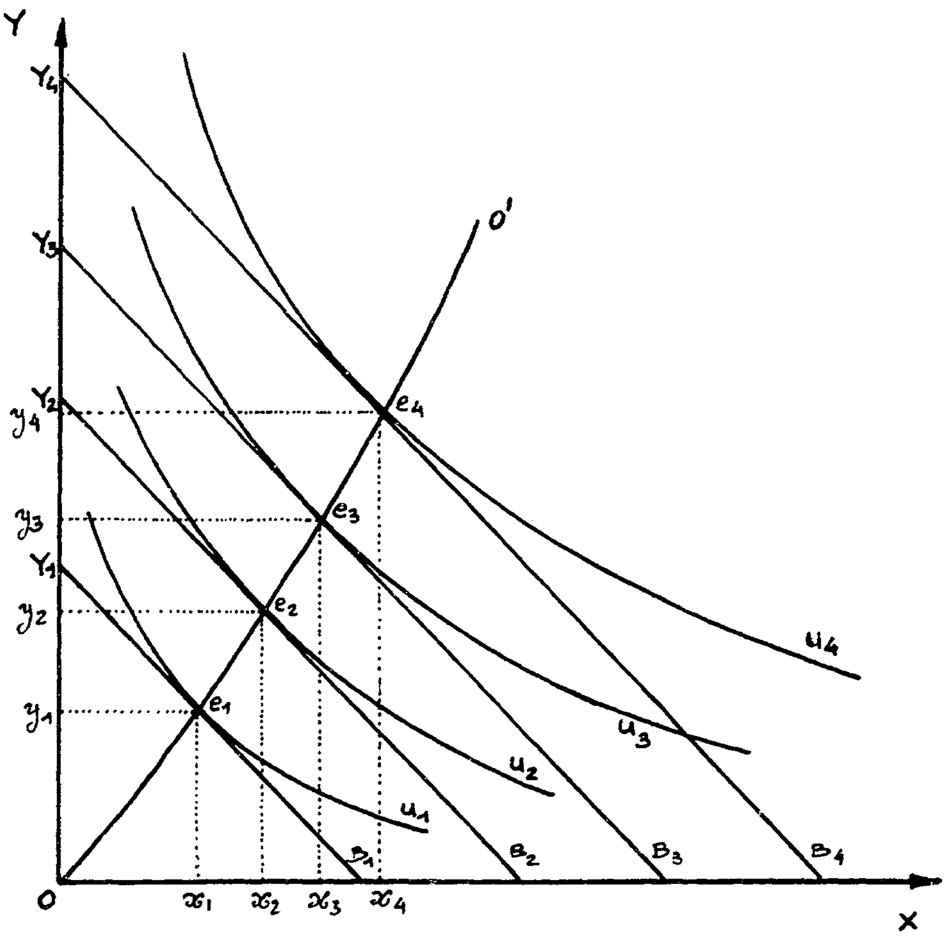


Figure III.3.1

Figure III.3.1 depicts an indifference map at four distinct levels of utility (U_1 - U_4).

Given an initial resource level Y_i, and the price of highway commodity X, we can define a budget line B_i (in the absence of any grants) as:

$$Y = Y_i - p_x X \tag{10}$$

Taken together, the indifference map and the budget lines define an expansion (income-consumption) path of equilibrium resource allocation (00´ on figure III.3.1). Each equilibrium point $e_i = (x_i, y_i)$ satisfies the condition of tangency between the budget line and indifference curve:

$$\frac{\partial U}{\partial X} = p_x \frac{\partial U}{\partial Y} \tag{11}$$

ii. Addition of a Conditional Matching Open-Ended (CMO) Grant.

Figure III.3.2 reproduces the original, pre-grant equilibrium point $e_2 = (x_2, y_2)$. In this case, the BU is devoting y_2Y_2' dollars to highway type X, and Oy_2 dollars to all other highway expenditure categories. Assume now that the federal government has agreed to bear a fixed percentage g of the costs of the local program for highway commodity X. In terms of our initial expenditure model, a grant of this type reduces the BU's perceived price of highway commodity X to the

ANALYSIS OF CONDITIONAL MATCHING OPEN-ENDED GRANTS

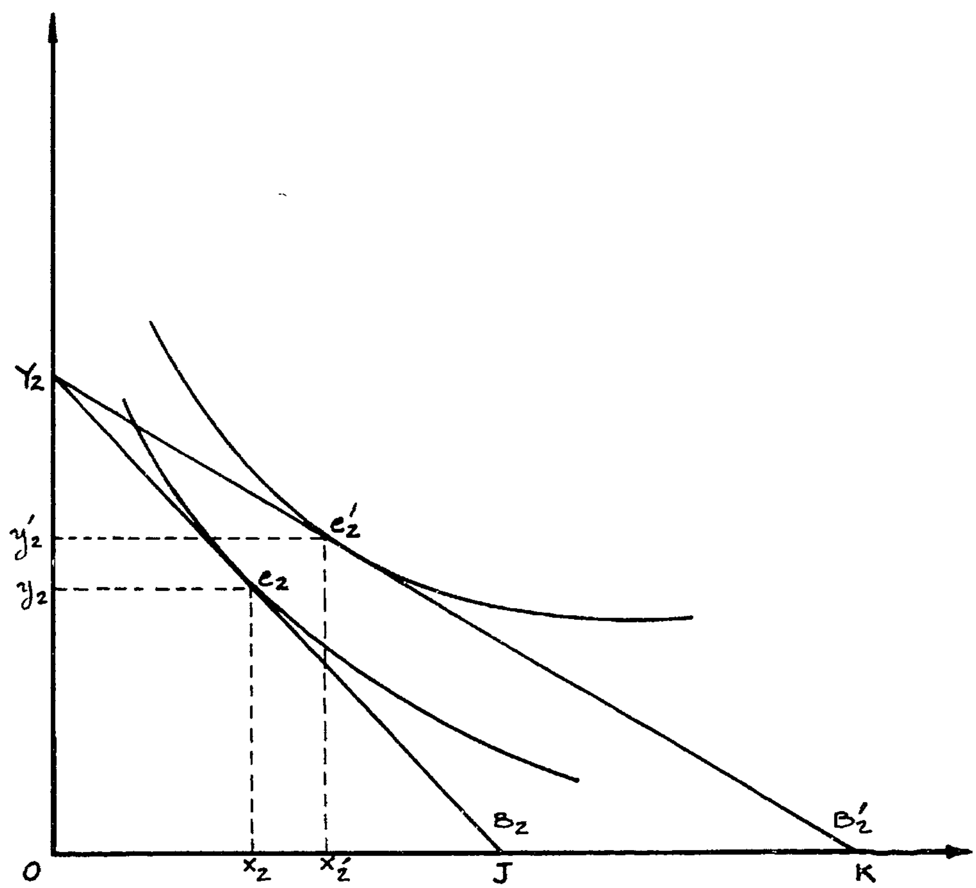


Figure III.3.2

level $(1-g)p_x$. This is shown in figure III.3.2 by a shift in the budget line from Y_2J to Y_2K. Note that the new budget line has pivoted around point Y_2, reflecting the fact that a CMO grant does not increase the resources available to the BU if no expenditures on highway commodity X are undertaken. Furthermore, it is easy to show that the federal matching share g is represented on the figure by the ratio $\frac{JK}{OK}$.[1]

The equilibrium expenditure pattern along the post-grant budget line B_2' is indicated by point $e_2' = (x_2', y_2')$. More units of X have been purchased, but at lower cost to the BU out of its own funds. In particular, the post-grant expenditure pattern takes the form summarized in Table III.3.1

Table III.3.1

Line	Expenditure Descriptor	Pre-Grant	Post-Grant	Change: Post-Grant minus Pre-Grant	
1	Units of X	$0x_2$	$0x_2'$	x_2x_2'	(+)
2	Expenditure on X out of own funds	y_2Y_2	$y_2'Y_2$	y_2y_2'	(-)
3	Expenditure on Y out of own funds	$0y_2$	$0y_2'$	y_2y_2'	(+)
4	Grant money received	--	$y_2'Y_2\ \frac{JK}{0J}$	$y_2'Y_2\ \frac{JK}{0J}$	(+)
5	Total expenditure on X	y_2Y_2	$y_2'Y_2\ \frac{0K}{0J}$	$x_2x_2'\ \frac{0Y_2}{0J}$	(+)
6	Total expenditure on Y	$0y_2$	$0y_2'$	y_2y_2'	(+)

1. The post-grant price of X is $\frac{0Y_2}{0K} = (1-g)p_x = (1-g)\frac{0Y_2}{0J}$. Thus $g = 1 - \frac{0J}{0K} = \frac{0K - 0J}{0K} = \frac{JK}{0K}$.

From the last two lines in this table, it is clear that the CMO grant has resulted in increases in total expenditures on both X and Y. But reference to lines 2 and 3 of Table III.3.1 indicates that in terms of the allocation of the BU's own resources, expenditures on X have decreased relative to the expenditure on non-aided highway commodities (Y). In other words, the net result of the conditional (on X) matching open-ended grant has been a shift of y_2y_2' dollars (formerly devoted to expenditure on highway commodity X) to expenditure on non-X highway activities.

This is not necessarily the case however. The response of the recipient government to the CMO grant will depend in general upon the BU's expressed demand for highway goods, and in particular upon its demand for the grant subsidized activity. More specifically, the response will be a function of the BU's price elasticity of demand for the aided activity.

The generalized grant response is shown in figure III.3.3 where we have again indicated the initial pre-grant equilibrium point $e_2=(x_2, y_2)$, as well as the equilibria corresponding to CMO grants with two different matching ratios.[1] These alternative equilibria trace out a price-consumption curve Y_2Q describing expenditures on X and Y for given grant matching ratios.[2] In the declining portion

1. For clarity, the indifference curves have been omitted from the figure. Budget line B_2' in figure III.3.3 is identical to B_2' in figure III.3.2.

2. Each point on the price-consumption curve represents apoint of tangency between a specific budget line and indifference curve.

GRANT RESPONSES FOR ALTERNATIVE PRICE SUBSIDIES

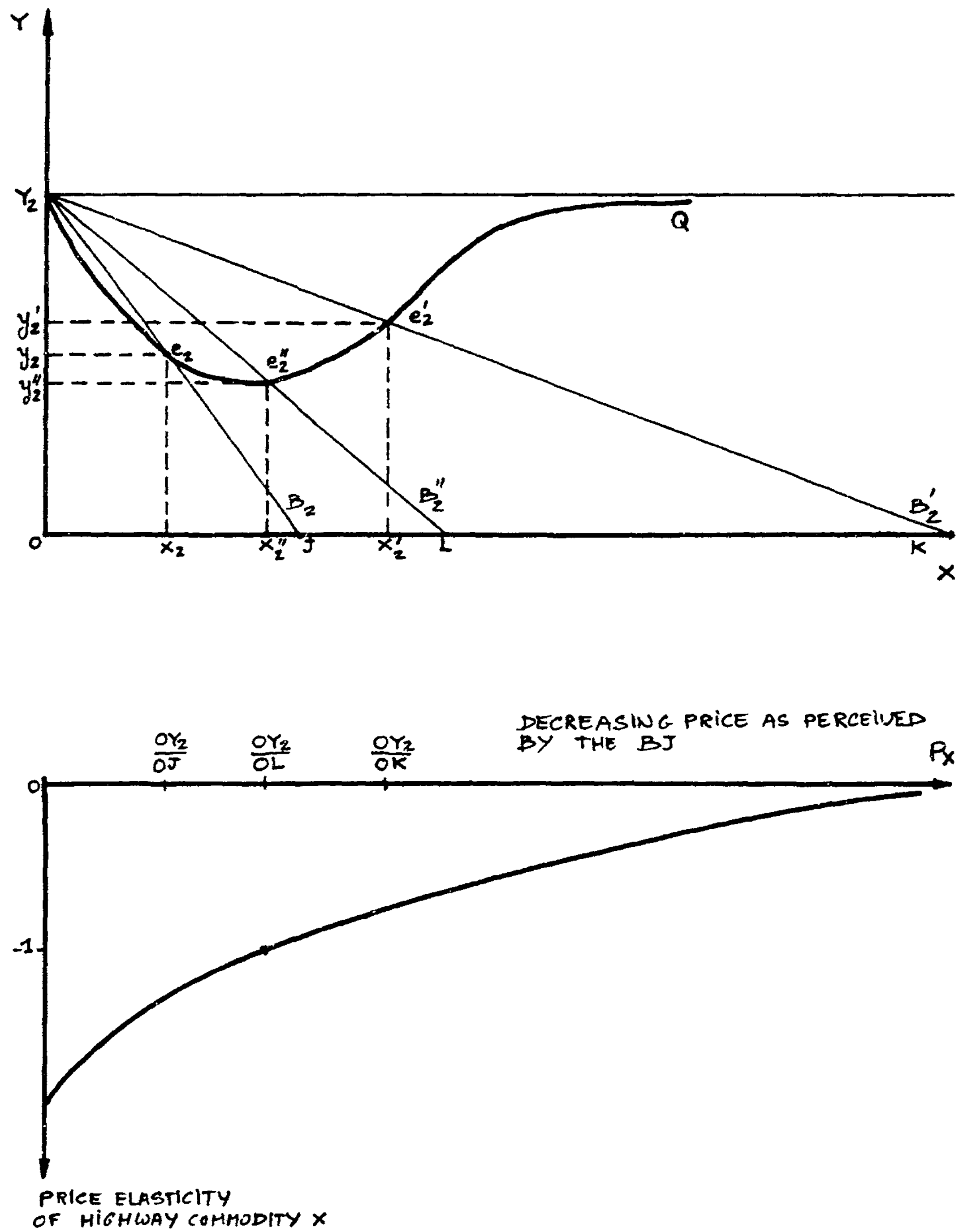


Figure III.3.3

of the price consumption curve, the demand for highway commodity X is price elastic: a decrease in price by g% (i.e., the federal share of a grant for X) will result in a greater than g% increase in consumption of X. In other words, federal grants in this region will stimulate greater levels of expenditures on X from the BU's own resources.

This is clear from the comparison of the pre-grant equilibrium point $e_2=(x_2 y_2)$ and the equilibrium point $e_2''(x_2'', y_2'')$ resulting from a CMO grant with matching ratio $\frac{JL}{0L}$ (figure III.3.3). In the latter case, the BU's own expenditures on X have increased from $y_2 Y_2$ to $y_2'' Y_2$-- the precise amount that expenditures on non-aided highway activities have decreased. In fact, the equilibrium e_2'' corresponds to the unit-elastic point on the price consumption curve (see lower portion of figure III.e.3). CMO grants with federal shares greater than $\frac{JL}{0L}$ -- as represented by budget line B_2' -- will result in a substitution of expenditures on X for Y. In this region of the price-consumption curve, the demand for highway commodity X is inelastic with respect to post-grant price.

Summarily, the theoretical analysis indicates that conditional, matching open-ended grants may result in a stimulation of the BU's own allocation of resources to the aided highway function, or substitution of expenditures from the aided to non-aided functions depending on the price elasticity of the subsidized commodity.

iii. <u>Analysis of Conditional, Matching Close-Ended (CMC) Grants</u>

The analysis of expenditure response to conditional, matching, close-ended grants proceeds in a manner analogous to the previous section. In this instance, we assume that the federal government agrees to bear g% of the costs to provide highway commodity X up to a fixed grant ceiling level. The graphical representation of this grant structure is shown in figure III.3.4, where the pre-grant equilibrium point is indicated by $e_2=(x_2, y_2)$, and the CMC grant has a matching ratio of $\frac{JK}{0K}$. Suppose for example the federal government has agreed to share in the cost of $0x_{D_1}$ units of X--or equivalently has invoked a grant ceiling of Y_2Z_1 dollars.[1] The budget line facing

---

1. This equivalence can be demonstrated in terms of figure III.3.4 as follows:
The total cost of $0x_{D_1}$ units of X is given by line segment Z_0Z_1
If Y_2Z_1 = federal share of this total cost, then

$$Y_2Z_1 \stackrel{?}{=} \frac{JK}{0K} Z_0Z_1$$

But $\frac{Z_0Y_2}{Z_0D_1} = \frac{0Y_2}{0K}$, and $\frac{Z_0Z_1}{Z_0D_1} = \frac{0Z_1}{0J_1}$

Thus $\frac{Y_2Z_1}{Z_0Z_1} = \frac{0J_1}{0Z_1}\left(\frac{0Z_1}{0J_1} - \frac{0Y_2}{0K}\right) = 1 - \frac{0J_10Y_2}{0Z_10K} = \frac{JK}{0K}$

Q.E.D.

ANALYSIS OF CONDITIONAL MATCHING CLOSE-ENDED GRANTS

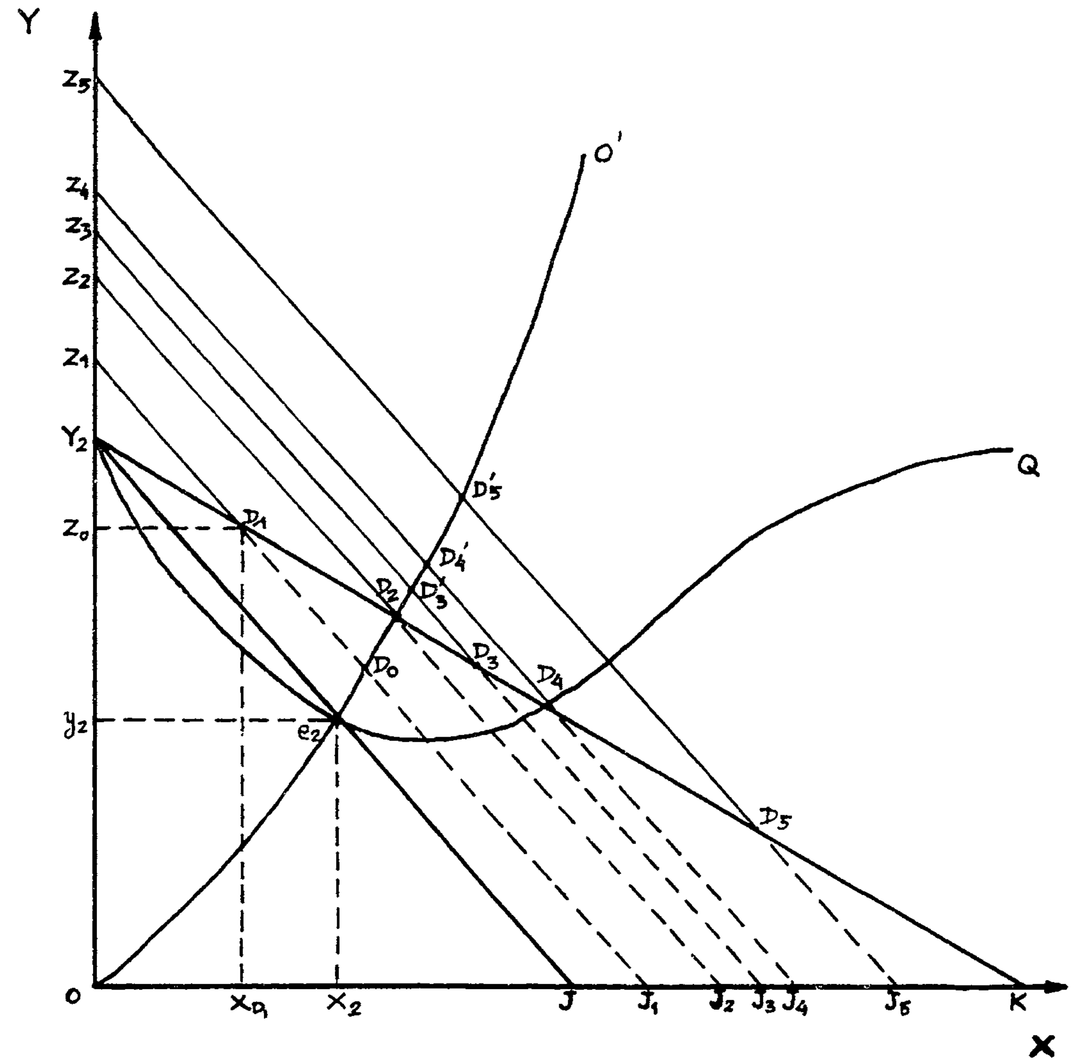


Figure III.3.4

the BU is given by $Y_2D_1J_1$, with consumption of highway commodity X beyond OX_{D_1} units costing the full market price $\frac{OY_2}{OJ}$. Under these conditions equilibrium resource allocation is indicated by point D_0 where the income consumption line intersects the budget line. Note that in this case, where the break or "deflection"[1] point in the budget line falls to the left of the income consumption path, the CMC grant, and an unconditional non-matching, close-ended (UNC) grant of equivalent magnitude (as indicated by budget line $Z_1D_1J_1$) are allocationally equivalent. Thus, in terms of figure III.3.4, CMC grants with statutory ceilings up to Y_2Z_2 dollars yield the same expenditures on highway commodity X as equivalent dollar amount UNC grants.

Beyond this grant ceiling, CMC grants result in greater X expenditures than an equal amount UNC grant, but less than an open-ended matching grant with the same matching ratio as the CMC grant. For example a CMC grant withceiling Y_2Z_3 yields the equilibrium point D_3, which involves a greater expenditure on highway commodity X than the equilibrium point D_3' associated with the equivalent amount UNC grant but less X expenditure than the equilibrium point D_4 associated with an equivalent matching ratio CMO grant (see Table III.3.2).

For a given matching ratio, the grant ceiling ultimately reaches a level at which it is no longer binding on resource allocation. In particular, beyond the grant ceiling Y_2Z_4 where the CMC budget line

1. See Wilde, James A., "The Expenditure Effects of Grant-in-Aid Programs," NATIONAL TAX JOURNAL, VOL. XXI, Number 3.

TABLE III.3.2

COMPARISON OF EQUILIBRIUM POINTS FOR ALTERNATIVE GRANT STRUCTURES SHOWN IN FIGURE III.3.4

[1] Grant Ceiling	[2] Equilibrium with CMC Grant (Matching Ratio $\frac{JK}{0K}$)	[3] Equilibrium with UNC Grant	[4] Equilibrium with CMO Grant (Matching Ratio $\frac{JK}{0K}$)	[5] Change in Expenditure on X([3]-[2])	[6] Change in Expenditure on X([4]-[2])
Y_2Z_1	D_0	D_0	D_4	0	(+)
Y_2Z_2	D_2	D_2	D_4	0	(+)
Y_2Z_3	D_3	D_3	D_4'	(-)	(+)
Y_2Z_4	D_4	D_4	D_4'	(-)	0
Y_2Z_5	D_4	D_5	D_4'	(-)	0

intersects the price-consumption curve (point D_4), CMC grants are allocationally equivalent to CMO grants. Thus increases in the grant ceiling beyond the level Y_2Z_4 will in no way alter the highway expenditure pattern of recipient governments.

In general, the greater the federal matching share of expenditures on highway commodity X, the greater is the upper limit on the binding grant ceiling level. This relationship is shown schematically by curve OP′ in figure III.3.5. The shaded area A above OP′ represents the region in which increases in the statutory grant ceiling for a given matching ratio (for example moving from point III to point IV) will not alter the BU's allocation of resources between X and y. Conversely, the area in B to the right of curve OP′′ represents the region over which increases in the federal matching share for a given grant ceiling (for example, movement from point III to IV) will not effect changes in the BU's consumption of X and Y. Finally, the area C between curves OP′ and OP′′ describes the region over which changes in either the matching provisions, or the statutory ceiling of a CMC grant will result in a reallocation of the BU's resources amongst highway commodities X and Y.[1] The actual allocation

1. In terms of our schematic representation of the allocative impacts of CMC grants in figure III.3.4, regions A , B , and C are defined as follows:
region A --break point in the budget line lies to the right of the price-consumption curve Y_2O
region B --break point in the budget line lies to the left of the income-consumption curve OO′
region C --break point in the budget line lies between the price-consumption and income-consumption curves.

of the BU's resources between X and Y in this region is uniquely defined by the deflection point in the post-CMC grant budget line.

The preceding analysis has served to demonstrate three distinct response patterns to conditional, matching, close-ended grants. In one pattern of CMC grant response, what is nominally conditional matching aid, may in fact have only the influence of an unconditional block grant. This behavior is manifest in region B of figure III.3.5, and is readily observable _ex post facto_ in cases where the recipient government devotes more than enough of its own resources to highway commodity X than the amount required simply to match the federal highway grant. The allocative impact of grants of this type is to induce a shift in the resources the BU would have devoted to highway commodity X in the absence of the CMC grant, to non-aided highway activities.

In those instances where the BU is observed to provide for expenditures on X enabling them to qualify for only part of the total available federal grant, the CMC grant is allocationally equivalent to a conditional, matching, _open-ended_ grant. This behavior is represented in figure III.3.5 by region A, and may result in a greater or lesser expenditure of theBU's own resources on highway commodity X, depending on the price elasticity of the aided function at the pre-grant price level.

Finally, the behavior response manifest in region C results in a greater _total_ expenditure on highway commodity X than equal amount non-matching grants, but less than an open-ended grant with the same

AFFECT OF GRANT CEILINGS AND PRICE SUBSIDY LEVELS

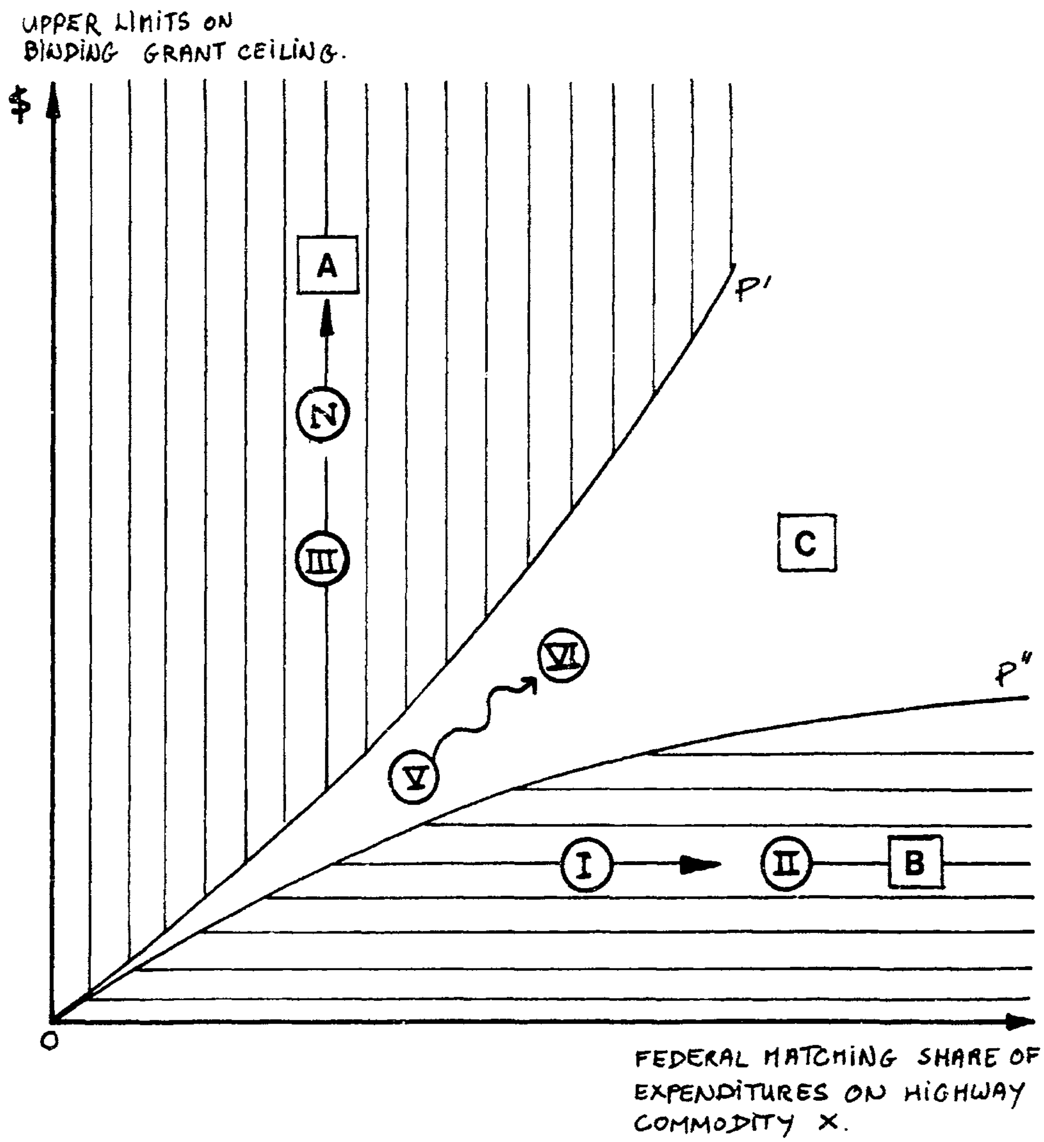


Figure III.3.5

matching ratio. Allocation of the BU's own resources between X and Y in this situation again depends on the price elasticity of the BU's demand for highway commodity X. This response pattern is readily recognizable ex post facto where the BU just matches the full federal CMC grant.

iv. Evaluation of Other Grant Program Structures

It should be evident that the analysis framework presented in the three previous sections may be used to evaluate a wide range of alternative grant program structures. For completeness, this section will briefly evaluate the allocative consequences of two additional cases: conditional, non-matching, close-ended (CNC) grants, and CMC grants applied to situations where the BU has not previously allocated any resources to the aided function.

The former case is illustrated in figure III.3.6, with the pre-grant equilibrium a point $e_2=(x_2, y_2)$. Assume now that the federal government introduces a non-matching grant of y_3y_4 dollars which is restricted to expenditure on hgihway commodity X. This grant is represented by budget line y_3dJ_1, indicating that the CNC grant will wholly finance up to OK_1 units of X. Equilibrium in this case is at point $e_2'=(x_2', y_2')$ (where the income-consumption curve OO′ intersects the budget line y_3dJ_1), the allocational equivalent of an unconditional non-matching grant of the same (y_3y_4) dollar amount. It follows that the specificity characteristic of this CNC grant is not allocationally significant: expenditures on X and Y are the same whether or not the

ANALYSIS OF CONDITIONAL NON-MATCHING CLOSE-ENDED GRANTS

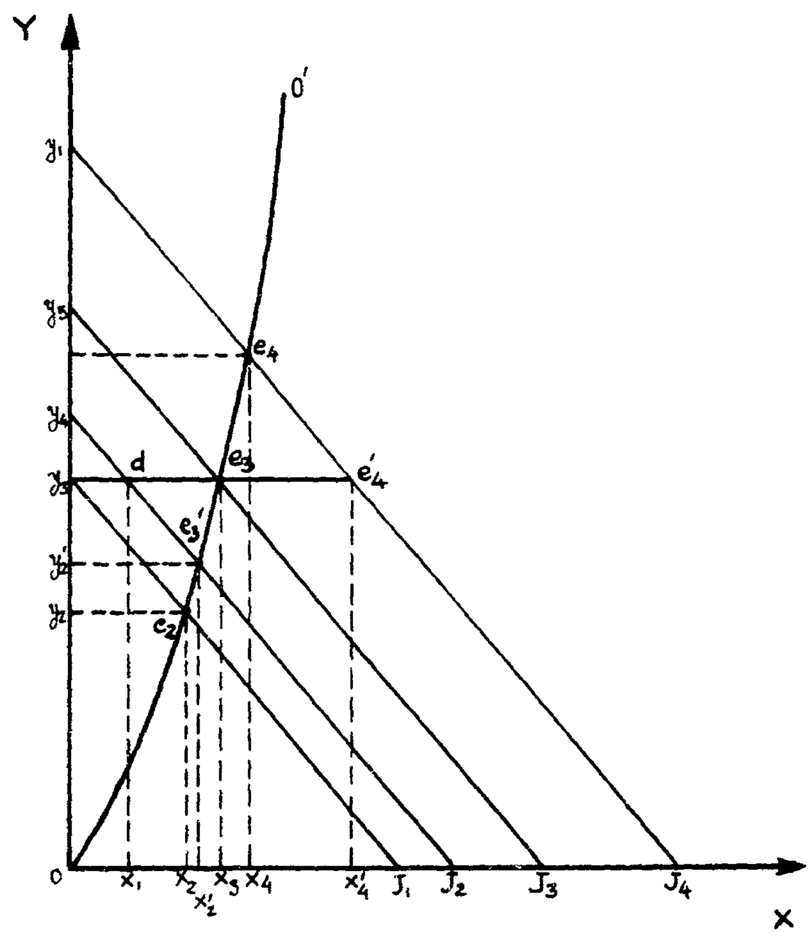


Figure III.3.6

grant is restricted to expenditure on X. This situation occurs wherever the post-grant consumption of highway commodity X exceeds the statutory grant ceiling--i.e., expenditures on X include the BU's own resources. Moreover, it is clear that this grant has increased expenditures on <u>non-aided</u> highway functions by the amount y_2y_3'. Thus although the grant was nominally restricted to expenditure on X, a fraction $\frac{y_2y_2'}{y_3y_4}$ was actually diverted to other uses.

The response to CNC aid will be quite different in cases where the grant ceiling is sufficiently large so as to cause the break point in the post-grant budget line to fall to the right of the income-consumption curve. For example, a CNC grant ceiling of y_3y_6 dollars will produce budget line $y_3e_4'J_4$ with equilibrium occurring at the break point e_4'. In this case, the BU shifts all of its pre-grant expenditures on highway commodity X to the non-aided functions, using only federal grant money for expenditure on the aided function. Thus CNC aid with a sufficiently high grant ceiling results in a greater total expenditure on highway commodity X than an equivalent amount unconditional grant. This situation can be easily identified, since none of the BU's own resources would be observed to support the aided highway function.

The analysis of conditional, matching grants (both open and close-ended) presented in sections III.3.ii and III.3.iii assumed that the BU's pre-grant equilibrium included positive levels of consumption of highway commodity X, and other highway functions Y. This section concludes with a discussion of the response to CMC and CMO grants in cases where the BU <u>has not previously allocated any resources to the aided function</u>.

In terms of figure III.3.7, we assume an initial equilibrium at $e_3=(0,y_3)$. This solution obtains if the indifference curves $(U_1, \ldots U_4)$ are everywhere less steep than the budget line y_3J, i.e.:

$$\left| \frac{\frac{\partial U}{\partial X}}{\frac{\partial U}{\partial Y}} \right| < P_{x_1} \quad \forall\ X > 0$$

Introduction of a conditional matching, open-ended grant is represented by the budget line y_3K, and yields a new equilibrium at $e_4=(x_4, y_4)$.[1] Expenditures on highway commodity X in this case total y_4y_5 dollars. Of this amount, y_4y_3 dollars derive from the BU's own resources, representing a diversion of expenditures originally devoted to the non-aided function. The remainder of the total post-grant expenditures on X, y_3y_5 are supplied by the federal government.

If the grant had been of the CMC variety, equilibrium would occur at either e_4 or the break point in the CMC budget line, whichever comes first. It should be noted that of all the grant structure/response patterns discussed in the previous sections the case presented here is the only one in which the post-grant reallocation of the BU's resources always involves an increase in expenditures on the aided function from the BU's own revenues

1. Assuming that the slope of the indifference curve O_4 at y_3 is steeper than the new budget line y_3K.

ANALYSIS OF RESPONSES TO GRANTS FOR FUNCTIONS
NOT PREVIOUSLY UNDERTAKEN BY STATE GOVERNMENTS

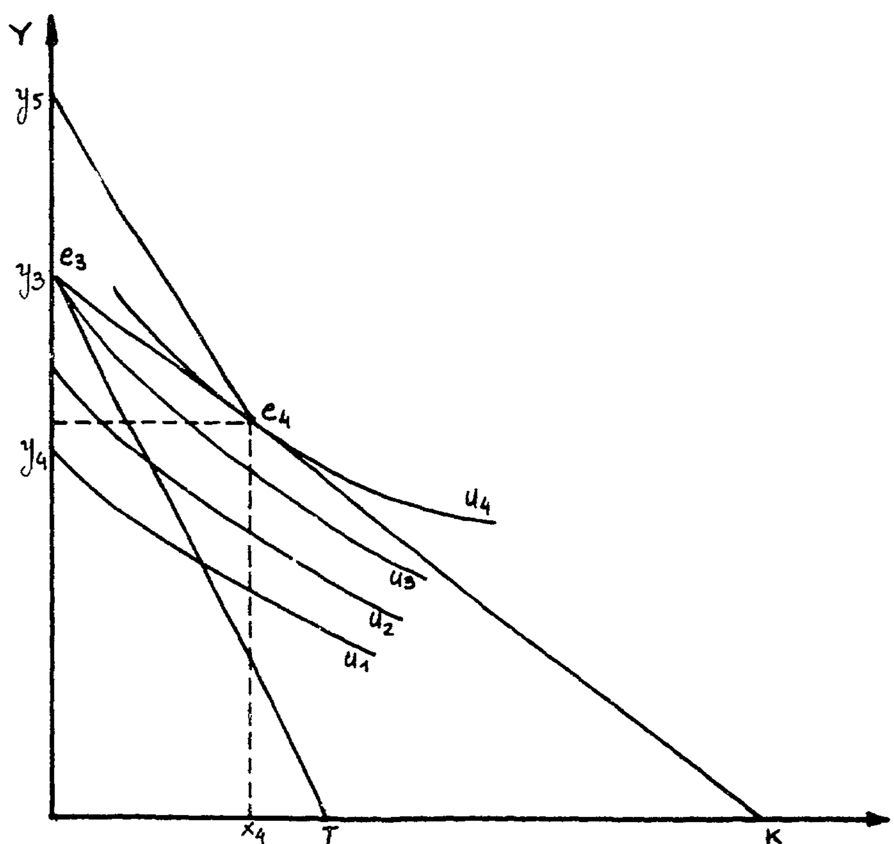


Figure III.3.7

v. Summary of the Responses to Alternative Grant Structures

In the preceding sections, an attempt has been made to provide a descriptive theoretical framework for the analysis of State Highway expenditure responses to alternative Federal-Aid grant structures. While it is clear that the model presented here presumes a degree of economic "rationality" that ignores the administrative and political realities of State Highway investment decision making, the analyses do advance a set of hypotheses that may be modified to account for specific qualifications.[1] To the extent that a relaxation of the underlying assumptions do not alter the fundamantal logic of the models, these analyses serve to place bounds on the expected pattern of State Highway expenditure behavior.

Figure III.3.8. a summarizes the relative impacts of alternative grant structures on State Highway expenditures. The horizontal axis measures the magnitude of Federal grants, while the vertical axis describes the post grant total (Federal + State) expenditures on highway commodity X. It follows that point E describes the BU's pre-grant expenditure level on X.

In comparing the responses to various grant programs, it is useful to distinguish between two different behavioral patterns: expenditure stimulation and expenditure substitution. The former

---

[1] A discussion of the critical assumptions of the preceding analyses and possible modifications to the model results is presented at the end of this section vi.

SUMMARY OF STATE RESPONSES TO ALTERNATIVE FEDERAL GRANT STRUCTURES

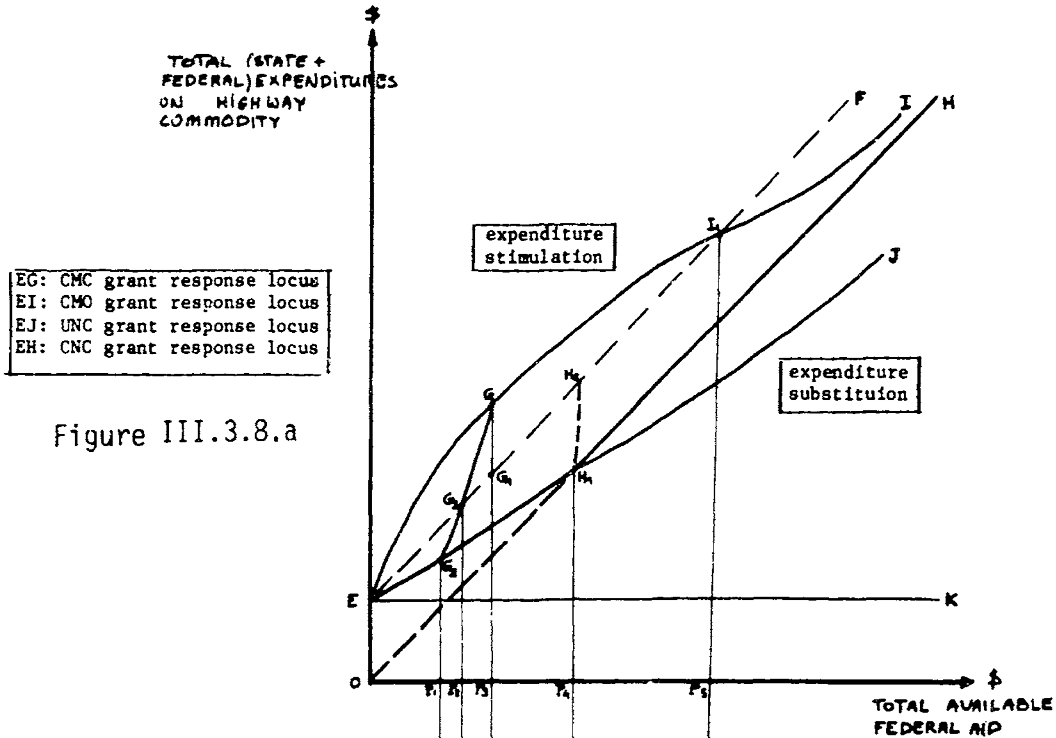


Figure III.3.8.a

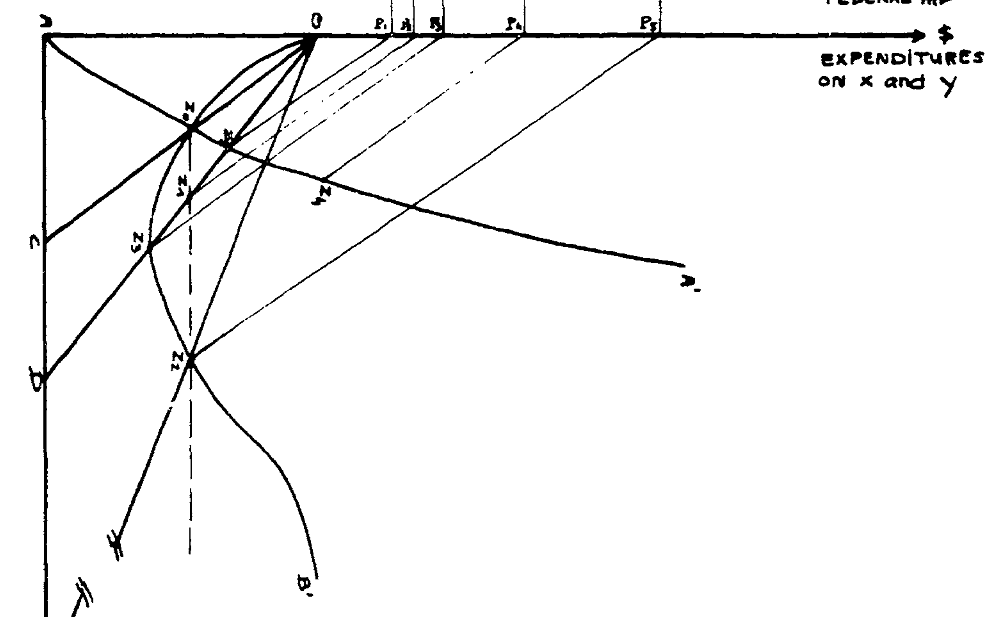


Figure III.3.8.b

case obtains when the effect of the Federal grant is to increase State expenditures on the aided highway function from own sources. In other words, in these situations the State reallocates resources from non-aided functions to expenditure on the aided highway category. The contrary case, expenditure substitution obtains whenever total post-grant expenditures on the aided function increase by less than the amount of the Federal grant. The allocational consequence here is a decrease in the level of State expenditures on the aided function with a commensurate increase in expenditure on non-aided functions. In terms of figure III.3.8.a, the expenditure stimulation and expenditure substitution response patterns are indentified by the regions lying to the left and right respectively of the line EF.

It is evident that of the four grant responses shown in figure III.3.8.a only conditional matching (either open or close-ended) may induce expenditure stimulation on the aided function. The curve EG traces the expenditure response to succeeding by higher levels of CMC grant funding (at a matching ratio of $\frac{CD}{AD}$). We assume that at the pre-grant price of highway commodity X ($\frac{AB}{AC}$),the BU was in the elastic portion of its demand for X.[1] For grant levels below OP. dollars, the CMC grant is allocationally equivalent to the equivalent amount UNC grants, (c.f. section III.3.iii) and thus curve EC begins along the same locus as EJ in the expenditure substitution

[1] This is indicated in figure III.3.8.b by the negative slope of the price consumption curve OB' at the pre-grant equilibrium Z_0.

region. Beyond the grant ceiling OP, the CMC grant yields equilibria at the break points along line segment Z_5Z_1 (figure III. 3. 8.b), with expenditures on highway commodity X from the BU's own resources increasing at the margin. When the grant ceiling reaches the level OP_2, the BU's expenditures on highway commodity X net of grants equals its pre-grant allocation to X (as indicated by point Z_1). Thus, above this level of Federal aid, the CMC grant serves as an expenditure stimulant. Expenditures on X from the BU's own revenues exceed their pre-grant level, ultimately reaching a maximum increase of G_1G dollars at a grant ceiling of OP_3. Beyond the grant ceiling OP_3, no further reallocation of expenditures between highway commodity X_1 and other functions Y occurs.

In a similar fashion, we can construct the curve EI to suggest the locus of expenditure responses to conditional, matching, open-ended grants with succeedingly higher matching ratios. In this case, the higher the Federal matching ratio of the CMO grant, the greater will be the amount of Federal money expended by the BU. Moreover, since the BU was assumed to be initially in the elastic portion of its demand for highway commodity X, expenditures on the aided function begin in the expenditure stimulation region above the threshold line EF. Unitary price elasticity corresponds to aid OP_3 (matching ratio $\frac{CD}{AD}$), beyond which X expenditure substitution obtains at the margin. Ultimately, beyond Federal aid levels of OP_5 dollars (matching ratio $\frac{CE}{AE}$), the CMO grant yields an expenditure substitution response, with post-grant expenditures on X from the BU's own sources falling below their pre-grant level. The limiting case here is a CMO grant with a 100% Federal share--in other words a conditional non-matching grant. Thus, as the Federal share payable approaches 100%, the curve EI approaches the response locus EH associated with conditional, non-matching close ended grants.

The response to unconditional block (i.e. non-matching) grants exhibits the most significant expenditure substitution behavior. In this case, a fraction of the UNC grants would be expected to be devoted to highway commodity X as a direct substitute for the BU's own X expenditures. The curve EJ traces the response locus to UNC grants with succeedingly higher grant ceilings. This curve lies entirely in the expenditure substitution response region, its slope depending on the BU's marginal propensity to consume highway commodity X with higher levels of income.[1] For UNC aid beyond the level OP4 dollars, the BU substitutes its entire pre-grant expenditures on X to non-aided activities Y, exclusively using Federal aid to purchase highway commodity X.

---

[1] The marginal propensity to consume (MPC) is defined as the inverse slope of the income-consumption curve AA'. Two limiting cases serve to place bounds on the UNC response locus EJ. If the income-consumption curve is vertical (MPC=0), then each Federal-aid dollar is substituted one-for-one with the BU's own expenditures on X. The UNC grant response locus in this case is defined by EK in figure III.3.8.a. Conversely, if the MPC=∞ (income-consumption curve horizontal), then each Federal-aid dollar is fully expended on highway commodity X with pre-grant X expenditures remaining fixed. The case is represented by the UNC grant response locus EF.

The expenditure response to conditional, non-matching, close-ended grants is similar to the UNC grant response. As shown by response locus EH, CNC grants are allocationally equivalent to UNC grants below the funding level EP_4 dollars. At that point, leakage of grant money into non-aided highway activities (as measured by H_1H_2, the vertical distance between EH and the 45° line OH) has reached the level of pre-grant expenditures on highway commodity X (OE). Further leakage is prevented as additional levels of CNC funding is wholly devoted to X at the margin, and response locus EH diverges from EJ.

Table III.3.3 summarizes the most significant findings of the preceding analysis. Of paramount importance is recognition of the fact that changes in the structure of a Federal-aid grant program may result in fundamental changes in the recipient government's allocation of resources among alternative transportation commodities. In this context our analysis framework can be used to address questions such as:

1) What is the least expensive means for the Federal government to achieve a specified target expenditure by the recipients on the aided highway functions?

2) For a given ceiling on Federal highway aid, which grant program stipulations would be most favored by the recipient government?

	Grant Response Pattern	Response Locus (Figure III.3.8.a)
1	For relatively high matching ratios and large grant ceilings, the allocative difference between conditional matching and non-matching grants are insignificant.	EI approaches EH at high Federal grant levels
2	Conditional close-ended matching grants may be allocationally equivalent to unconditional block grants for sufficiently low grant ceilings. In these cases, the grants result in expenditure substitution on the aided function.	Segment EG_2 on response locus EG
3	Only conditional matching grants (either open or close-ended) can be expected to increase expenditures on the aided function by more than the amount of the grant.	Segment EI, on response locus EI. Segment G_3G on response locus EG
4	Unless the grant ceiling is not binding, CMC grants have a lesser stimulatory impact than a CMO grant with the same matching ratio.	Response locus EG, and segment EG on response locus EI
5	The specificity requirement on a conditional non-matching close-ended grant may have no allocative significant	Segment EH_1 on response locus EH
6	Expenditure stimulation will be greatest where CMO grants are applied to highway functions not previously undertaken.	Not shown

SUMMARY OF GRANT RESPONSES

Table III.3.3

It is not surprising to note that the answers to these two questions indicate a conflict in the preferences of the donor and donee governments. If one of the goals of the Federal government is to maximize the "return" on their grant (in terms of achieving the greatest expenditure on the aided function for a given level of Federal aid), they will always prescribe matching provisions on their highway grant programs. The States, on the other hand, would always[1] find unconditional or block grants preferable to conditional grants with the equivalent ceiling.

Another related finding of our theoretical analysis is that under certain circumstances grant programs with categorical restrictions are allocationally equivalent to block grants (c.f. lines 1,2 and 5 of table III.3.3). In these instances, the grant programs should be evaluated in terms of their income-redistributive characteristics (e.g. whether they channel higher levels of aid into poorer States), rather than in terms of their allocative efficiency characteristics. These issues will be discussed in greater detail in section III.4.

vi. Qualifications on the Theoretical Analyses

The validity of the theoretical findings derived in the preceding sections ultimately rests on the practicality of the underlying assumptions of our model. Basically, there are three crucial assumptions upon which our theoretical analysis rests:

---

[1] Except under certain restrictive conditions. See line 2 of table III.3.3.

1) There is an identifiable behavioral unit at the State level that expresses a consistent set of preferences among alternative transportation services.
2) These preferences may be represented by a map of <u>continuous</u> indifference curves
3) Grant money receives no special treatment beyond the stipulations made by the Federal government.

The first of these assumptions is perhaps the most difficult to justify. Clearly, our reference to a "behavioral unit" ignores the existence of the numerous political agencies and private forces <u>whose choices among alternative transportation projects often conflict</u>. It is certainly true that on any given transportation project, it would be simplistic to presume that a single individual or a monolithic agency solely determines the investment decisions. However, our model deals with <u>overall budget behavior</u>--that is, decisions on the level of expenditure to be devoted to generic transportation activities. We do not distinguish between the scale or location of individual highway projects, but only between the overall expenditure levels on aided and non-aided highway activities. In this context, our assumption boils down to an assertion that a single State agency (e.g. a State Highway Department/Commission or Department of Transportation) sets forth an investment policy determining the allocation of revenues amongst transportation investment alternatives in broad, generic categories.[1]

It is nonetheless the case that in any given year, these categorical investments are comprised of a finite set of discrete projects whose individual cost may represent a sizable fraction of the total investment. The implications here relate to the second assumption of our analysis, that the indifference curves are continuous functions of categorical highway expenditures. To the extent that the demands for alternative highway commodities are expressed in terms of discrete investment levels, the indifference curves will be piecewise linear rather than continuous. We assume that this qualification does not fundamentally alter the expenditure response patterns indicated by our models.

The validity of the third assumption is not testable in any empirical sense. However, there are two reasons to suspect that the receipt of grant money may have the effect of shifting the recipient government's indifference map.[2] The first reason is the commonly held notion that it is "bad politics" to turn down a Federal grant. This view argues that Federal grants are "some-

---

[1] For example, this policy might be expressed in terms of decisions to spend a certain fraction of revenues on maintenance, another fraction on the State Primary Highway System, and a third fraction on the State Secondary Highway System. In some States these "decisions" are actually dictated by statute. In others, a State highway agency makes these decisions on a (multi-) year to (mūlti-) year basis.

[2] It should be noted that an indifference map describes the tradeoffs amongst alternative goods irrespective of the prices of those goods. As discussed in the previous sections, changes in the prices of the aided highway functions enter into our model through shifts in the budget line, not the indifference map.

thing special," or "free money," to be spent at all costs. Clearly, if this is the case, the States will behave differently than our models predict.

There is another possible explanation for a deviation from our models'predictions which relates to "spin-off effects." Suppose a State must choose between a major intercity freeway project[1] costong $100 million, and an arterial route costing $10 million. After weighing the costs and benefits, assume the arterial route were strongly preferred. At this point, however, the Federal government offers to pay 90% of the freeway costs. With the costs equalized, the State would choose between the two projects solely on the basis of benefits. Let us assume that the State still prefers the arterial project. If that were the extent of the decision, the grant offer would be declined. However, this decision could be reversed by a broader view of benefits. In a macro-economic context, the freeway project has the advantage of bringing an additional $90 million into the State's economy (which translates into increased income and employment). Thus the macro-economic context for aid recipients may be a vital factor in expenditure decisions and grant response.

The implication of the "free money" or "spin-off effect" arguments is that Federal highway grants may induce a greater expenditure stimulation response than our models would predict. But in order for this to be the case, we would have to observe the

---

[1] This example is placed in the setting of project selection, but the same arguments apply to the broader question of overall budget allocation.

States making expenditures on the aided highway functions less than or just equal to amount required to match a full close-ended Federal matching grant (see section III.3.v). Our model would appear to be valid in cases where an expenditure substitution response is associated with the Federal grant. In cases where our model predicts an expenditure stimulation response to a Federal highway matching grant, the arguments advanced above indicate that the model results may understate the expenditure levels on the aided highway functions. As will be discussed in detail in section III.4, the majority of States exhibits an expenditure substitution response to Federal highway grants.

III.4 The Analytics of State Responses to Federal Grants: The Benefit/Cost Investment Model

The previous section discussed the analytics of State responses to Federal grants in terms of the allocation of highway resources amongst alternative expenditure categories. The basis of this discussion was that States allocate resources so as to maximize their perceived benefits (utility).

The question of highway resource allocation can be approached from a somewhat different perspective. In particular, this section will present a benefit/cost investment model which focuses on the level of resources raised from a State's own sources, in response to a variety of Federal highway grant structures.[1]

i. A Hypothetical Example

Assume that a particular State has developed a set of candidate highway projects, and is prepared to expend funds on these projects up to the point where the benefit/cost ratio on the "last" project is just equal to 1.0. More explicitly, we assume that the State has ranked the projects in order of

---

1. For an application of this approach, see Miller, Edward, "The Economics of Matching Grants: The ABC Highway Program," National Tax Journal, Vol. 27, No. 2, June, 1974.

decreasing benefit cost ratio as shown in figure III.4.1.[2]

For the hypothetical values displayed in figure III.4.1 the State is willing to expend a total of \$10 million to implement projects 1 through 10. At this point, assume the Federal government steps in and offers a grant of \$G with the provision that this grant must be matched dollar for dollar by the State government (i.e. the matching rate is 50%). It may be argued that there are three possible responses to the presence of the Federal grant, depending on the size of the grant G:

Case I. $\$0 < G \leq \$5^M$: Pure Income Effect

This case applies where the sum of the Federal grant G and the State's matching share is less than the total amount the State was apparently willing to expend on highways in the absence of Federal grants. For example, assume the Federal grant offered is $\$3.^M$ After providing for the required matching share, the State has expended $\$6.^M$ This leaves a remainder of

---

2. It has often been noted that optimal project selection does not necessarily simply consist of those projects with the highest benefit/cost ratios. (For example, see Pecknold, Wayne M., Evolution of Transport Systems: An Analysis of Time-Staged Investment Strategies Under Uncertainty, Unpublished Ph.D. Thesis, M.I.T. Department of Civil Engineering, 1970, and Newman, Lance, A Time-Staged Strategic Approach to Transportation System Planning, Unpublished S.M. Thesis, M.I.T. Department of Civil Engineering, 1972). In the presentation that follows, we nonetheless make the assumption that States will not choose to implement projects whose perceived B/C ratio is less than unity.

ILLUSTRATIVE EXAMPLE OF THE BENEFIT/COST INVESTMENT MODEL

	Project No.	B/C	Total Cost (Millions of Dollars)	
	1	7.6	1.6	
	2	6.9	2.3	
Region 1	-	-		
	-	-		
	-	-		
	-	-		
	-	-		
	10	1.0	.7	
			10.0	- Cost of projects with B/C $\geq$ 1.0
	11	.97	1.2	
	12	.84	.6	
Region 2	-			
	-			
	-			
	-			
	17	.50	.3	
			5.0	- Cost of projects with .5 $\leq$ B/C $<$ 1.0
	18	.46	.9	
	19	.41	1.1	
Region 3	-			
	-			
	-			
	24	.23	1.0	
			5.0	- Cost of projects with B/C $<$ .5

Figure III.4.1

projects costing $\$4^M$ whose B/C ratio exceeds unity. Since, the Federal grant has been exhausted there is no incentive to expand the highway program beyond the previously determined level of $\$10.^M$ Thus, the net effect of the $\$3^M$ Federal grant has been to reduce the level of resources expended from the State's own sources. Total highway expenditures remain unchanged, as the State's own expenditures are reduced by just the amount of Federal grant. This situation represents the case of a pure income grant, where the close-ended grant is not of sufficient magnitude to create a perceived price reduction at the margin. As far as the State is concerned, the grant has had the effect of providing an additional $\$3^M$ of income to be expended on other State services or "spent" on tax relief.

Admittedly, this conclusion presents a somewhat extreme case. While the overall characterization of this type of grant as an income subsidy remains valid, realistically it is not necessarily the case that State expenditures on highways would be reduced dollar for dollar by the amount of the Federal grant. For one thing, it should again be noted that because of the indivisibility and "lumpiness" of highway investments, the presence of additional highway revenue might substantially alter the project mix (and therefore the total expenditure level) of an optimal highway investment program. Another mitigating factor here is the restriction in most States against expenditure of earmarked highway revenue on non-highway projects. The consequence of this restriction (and particularly in the short run where changes in State revenue raising sources - e.g. tax rates, are not possible) is that at least part of the additional revenue may be expended on the aided highway category, thus increasing total expenditures on this function.

More importantly however, is the fact that any expansion in total expenditures on the aided highway category results from the chosen allocation the additional income derived from the grant as opposed to any perceived price reduction on the aided function. By the same token, it is likely that expenditures on non-aided (highway) functions will be increased from the additional income afforded by the grant.

Case II. $\$5^M < G \leqslant \$7.5^M$ Price Plus Income Effect

For the hypothetical situation depicted in figure III.4.1, once G exceeds the level of $5 million, the grant introduces both a price and income effect on the State's allocation decisions.[1]

---

1. A price effect refers to changes in the allocation of resources deriving from a change in the perceived price of one or more expenditure items. Allocational shifts also derive from an income effect where the State allocates additional income on highway commodities whose perceived prices remain unchanged. A grant may introduce a pure income effect or a combination of a price effect and income effect. For a more detailed discussion of these concepts see Henderson J.M. and R.E. Quandt, Microeconomic Theory: A Mathematical Approach, McGraw-Hill Book Company, New York, 1958.

To see this, assume the Federal grant offered, G is $7 million. Since the State was apparently willing to expend $10 million from its own sources, it is clear that at least $5 million of the grant will be used. At this point total expenditures amount to $10 million, all projects with B/C greater than one have been programmed, and $2 million of Federal grants remain available. The remaining Federal grant has the effect of reducing the cost of additional highway construction to the State by one-half. In other words, the perceived B/C ratio of projects remaining on the candidate list increase by a factor of two. Since the B/C ratio of projects in Region 2 (see figure III.4.1) fall in the range 0.5 to 1, the availability of Federal grants increase the perceived B/C ratio of these projects over unity.

Following the simple criterion that all projects with (perceived) B/C 1 will be programmed, it is clear that the State will employ the remaining Federal grant, bringing total expenditures on the aided function to $14 million. Once the entire Federal grant has been employed, there is no longer any incentive for expansion of the highway program, since the State must now bear the full cost of projects whose B/C ratio is less than one.

While the net effect of this grant has been to increase total expenditures, for a Federal investment of $7 million, total expenditures increase by only $4 million (from $10 million in the absence of grants to \$14 million with the grant). The expenditure increase derives from the price effect of the matching grant at the margin (i.e. at the point where the State decides to program projects in region 2 of figure III.4.1). It should also be noted that total expenditures from the State's own sources decrease from \$10 million in the pre-grant situation to \$7 million in the post-grant situation. As in Case I, the saving in State resources may be spent on other services, or translated into tax reductions.

Case III $G > \$7.5^M$: No Effect at the Margin

Following the same reasoning as presented in Case II, it is clear that the State will not have an incentive to employ Federal grants in excess of \$7.5 million. Since all projects in region 3 of figure III.4.1 have a B/C ratio less than 0.5, the availability of 50% Federal matching grants will not bring the perceived B/C ratio of region 3 projects over one. Thus, for this hypothetical example, the maximum grant level that will willingly be employed by the State is $\$7.5^M$ (this amount will cover half the costs of all projects in region 1 and region 2). At this grant level, total expenditures on the aided function amount to $\$15^M$ divided evenly between State and Federal funds. This situation represents an increase in total expenditures by $\$5^M$, but a decrease in State's own expenditures by $\$2.5^M$.

ii. A Diagrammatic Description

These three cases can be summarized diagrammatically as in figure III.4.2. We assume that the State expresses a demand for highway construction represented by the demand schedule D_1D_1. Thus, for the full price of highway construction (i.e. in the absence of grants), the State will purchase Q_1 units of highway at a total cost of $ObcQ_1$ dollars. Case I of our previous discussion is represented by the price line arsp. In particular, 50% matching grants are available up to a ceiling of Q_0 highway units. Beyond this level of highway expenditure, the State again faces the full price of highways. As previously noted, the State response to this grant is to maintain its previous production scale of Q_1 units. Total expenditures from the State's own sources is indicated in the figure by area $OarQ_1$ (the full cost borne by the State of highway construction up to the level Q_1). This represents a decrease in State expenditures by Q_0rdQ_1 dollars.

For the larger grant ceiling described in Case II, the relevant price line is depicted by aefp. The response in this instance is to expand production up to Q_2 highway units at a total cost to the State of $OaeQ_2$ dollars. As in the previous situation, State expenditures decrease from the pre-grant situation - in this case by the difference between areas abcd and Q_1deQ_2.

Finally, the price line corresponding to Case III is

DIAGRAMMATIC DESCRIPTION OF THE BENEFIT/COST INVESTMENT MODEL

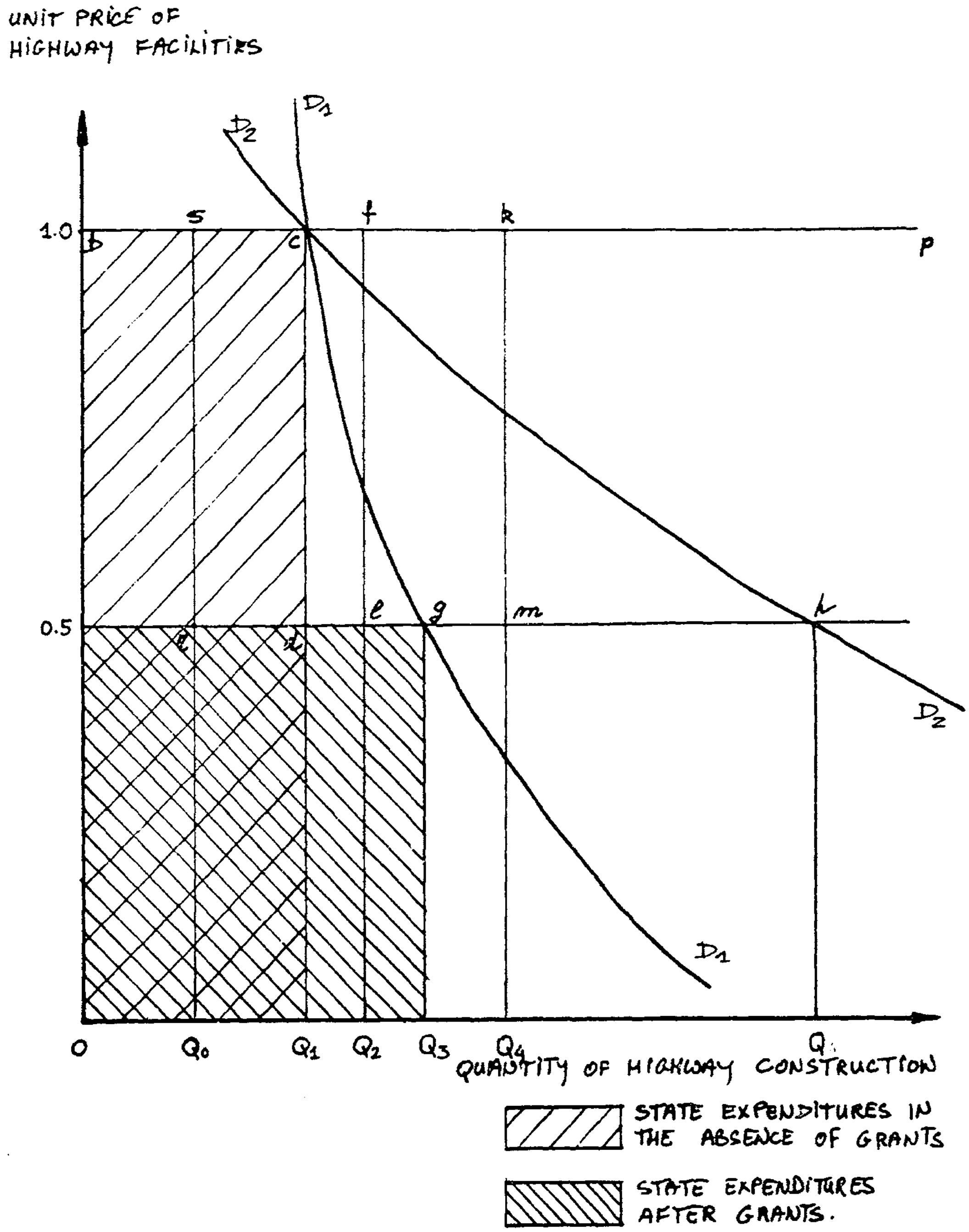


Figure III.4.2

shown as amkp. Since this price line intersects the demand schedule D_1D_1, the State will expand its highway program only as far as Q_3 units, leaving Q_3gmQ_4 dollars of the Federal grant unexpended. Total State expenditure in this case is $OagQ_3$, a decrease of abcd - Q_1dgQ_3 from the pre-grant situation.

iii. Conclusions From the Benefit/Cost Investment Model

An immediate conclusion that can be reached from the preceding analysis is that:

> Whereas the Federal government provides categorical grants presumably for those types of activities in which it perceives a national interest in stimulating expenditures (i.e. in inducing construction that may not have been undertaken in the absence of the grant), the net result may be the expansion of expenditures (or contraction through tax relief) in other (non-aided) areas in which the Federal government has no officially stated interest.

This conclusion derives from the income effect of close-ended matching grants, which under certain conditions such as Case I of the preceding analysis, serve only as a non-categorical income subsidy to the States.[1] In fact, in the preceding hypothetical example, regardless of the ceiling of a 50% Federal matching grant, post-grant State expenditures decrease from their pre-grant level (and thus the savings incurred may be expended in

---

1. As described in Section III.3, as long as the grant ceiling of a close-ended matching grant is low enough so as to be non-binding on the States investment calculus, the categorical restrictions of the grant are irrelevant. The allocational consequences of a grant of this type are identical to a simple block grant of like amount.

other areas).

This expenditure response pattern need not have been the case however. As shown in figure III.4.2 (and in the analysis describing figure III.4.1), the States demand for highway facilities, expressed by the schedule D_1D_1 represents inelastic demand. That is, a decrease in price by one-half results in less than a doubling of total expenditures. It is entirely possible that a State's expressed demand for highway construction may be elastic, for example as depicted by the schedule D_2D_2 in figure III.4.2. In this case total State expenditures following the offer of a 50% Federal matching grant with a ceiling in excess of $OahQ_4$ dollars exceed pre-grant expenditures by the amount Q_1dhQ_4 - abcd (c.f. Section III.3.ii). However, regardless of the elasticity properties of the State's expressed demand for highway facilities, if the Federal grant in question has the properties described in Section III.4.ii as Case I, the unambiguous conclusion is that the categorical restrictions of the matching grant are non-binding, resulting in a stimulation of State expenditures on non-aided functions. For grants with ceilings sufficiently large to fall into the categories described as Case II and Case III, State expenditure response indeed depends on its elasticity of demand for highway construction. For these cases, elastic (inelastic) demand will result in a increase (decrease) of State expenditures from their pre-grant levels.[1] In the next section, a brief analysis of actual highway expenditure data will be presented to illustrate the conclusions discussed above.

---

1. Several factors influence the price elasticity of a State's demand for highway construction including the level and growth in traffic on State roads, and tax capacity of the State (i.e. the propensity of the State to tap additional revenue sources or the willingness to increase levies on existing revenue sources. In the context of the illustrative examples presented in this section, the price elasticity as expressed by the State's response to a Federal matching grant is determined solely by the number of projects in region 2 of figure III.4.1. Specifically, if in developing a list of mutually exclusive candidate projects for its highway investment program, a State perceives numerous projects marginally unattractive in benefit/cost terms (i.e. projects with B/C slightly less than one), then a relatively small Federal price subsidy may elicit a large expansion in the State's highway investment program (representing price elastic demand for highway facilities).

III.5 Observed Expenditure Patterns: The Impact of the ABC and Interstate Programs

The analysis in Section III.4 proceeded on the basis of a State developing a highway investment program in the absence of Federal highway grants, and then altering their investment decisions in response to the offer of Federal matching grants. Three possible response patterns were described (Cases I, II and III), each dependent on the matching provisions and magnitude of the grant offer.

In examining data indicating the States' total expenditure levels on Federal Aid System construction and Federal highway grant availability, it is clear that we are merely observing the States' expenditure responses to Federal highway grants rather than - in any direct fashion - observing how expenditure decisions changed due to the existence of Federal grants.

However, by simply comparing the magnitude of Federal grant availability, and the level of expenditure from the State's own resources (on Federal Aid Systems), it can be straightforwardly inferred which of the three previously cited expenditure response patterns obtain (c.f. Section III.4.ii).

For grants which have a pure income effect (Case I), we should observe a State consistently expanding their own highway expenditures beyond that level minimally required to match available Federal grants. In this case, the size of the grant is not of sufficient magnitude to introduce a perceived price reduction at the investment margin. By inference, this type of grant simply provides additional non-categorical income to the State, which may be expended on any highway function.

If on the other hand, the data indicate that State expenditures consistently just equal the minimal amount required to match available Federal grants, then a price plus income effect may be inferred. In this case (Case II), the grant has had the effect of stimulating additional expenditures on the aided category, and increases in the size of the Federal grant may be expected to further stimulate State expenditures.[1]

Finally, if the data indicates that States consistently do not exhaust all available Federal Aid, then it is clear that Case III obtains. It should be noted that we can immediately rule out the relevance of Case II since in only one isolated instance has a State (actually, "State" in question was Washington, D.C., who forfeited a portion of available Interstate aid in 1971) failed to obligate the entirety of available Federal highway grants.

i. Data Analysis of the ABC Highway Program

Table III.5.1 displays (for each of the 48 mainland

---

1. As opposed to (small) increases in Case I - type grants where total expenditures on the aided function would not be expected to increase significantly.

STATE	EXCESS FRACTION
ALA	0.289507
ARIZ	0.375106
ARK	0.235334
CALI	0.636863
COLO	0.188915
CONN	0.645065
DEL	0.360464
FLOR	0.578587
GEO	0.196594
IDA	0.086208
ILL	0.142846
IND	0.122115
IOWA	0.472978
KANS	0.237851
KENT	0.401687
LOUS	0.519069
ME.	0.203455
MD.	0.693403
MASS	0.454965
MICH	0.387245
MINN	0.359732
MISS	0.314645
MSRI	0.389025
MONT	0.053528
NEB.	0.109797
NEV.	0.193299
N.H.	0.321408
N.J.	0.245089
N.M.	0.128208
N.Y.	0.530505
N.C.	0.263533
N.D.	0.033898
OHIO	0.545156
OKLA	0.255555
ORE.	0.364490
PENN	0.532504
R.I.	0.197607
S.C.	0.276288
S.D.	0.270003
TENN	0.421665
TEX.	0.391798
UTAH	0.194422
VER.	0.293234
VA.	0.516324
WASH	0.477908
W.V.	0.573908
WISC	0.430931
WYO.	0.157235

STATE EXPENDITURES OVER AND ABOVE MINIMAL MATCHING REQUIREMENTS EXPRESSED AS A FRACTION OF TOTAL EXPENDITURES ON "ABC" SYSTEMS

TIME PERIOD: 1954-1970

Source: Yearly Editions of HIGHWAY STATISTICS (1954-1970), U.S. Bureau of Public Roads, Washington, D.C.

Table III.5.1

States, over the time period 1954-1970) expenditures over and above minimal matching requirements, expressed as a fraction of total expenditures on "ABC" systems. More significantly, each table entry is defined as:

$$ef = \frac{(E_T - P_F) - \left[\frac{1-M_F}{M_F} P_F\right]}{E_T} \qquad (12)$$

where: ef = excess fraction (i.e. the table entries)

E_T = total expenditures by a given State over the 17 year sample period on ABC Systems (State and Federal monies)

M_F = Federal matching share for a given State[1].

P_F = Payments of Federal ABC monies from the Highway Trust Fund to a given State over the 17 year sample period

The term in brackets in equation (13) expresses the expenditure level from the States' own sources required to qualify for receipt of P_F Federal Aid dollars. Thus, the numerator expresses

---

1. As shown in figure , the Federal share payable is not equal for all States. The 13 Public Land States receive ABC grants with Federal shares payable ranging from 53.5% (Washington) to 95.0% (Alaska). The remaining States all are subject to 50/50 ABC grants. Additionally the Federal share of grants to Public Land States change slightly from year to year in response to these States' total acreage of National Parks, Indian Reservations, etc. The data in figure III.5.1 employed the Federal share payable in 1962 - the median year in the 17 year sample period.

the States' own excess expenditures beyond minimally required matching monies.

The excess expenditure fractions in table III.5.1 range in value from 3.4% in North Dakota to 69.4% in Maryland. In the latter case, of the total (State plus Federal monies ABC system investment by Maryland, between 1954 and 1970 nearly 70% represented expenditures net of minimal matching requirements.

In fact, only three of the forty eight States (Idaho, Montana and North Dakota) had excess expenditures totaling less than 10% of the their total ABC expenditures. The inescapable conclusion here is that for the great majority of States, the ABC grant program has served the role of non-categorical income subsidies. Neither the categorical restrictions, nor the matching provisions have been allocationally significant. In terms of the States' investment calculus, the determination of total ABC system expenditures have been based on the full cost of the marginal project rather than a price subsidized (50%) cost. Inferentially, it makes little difference whether the Federal share payable were 50% or some higher value - say 70%.[1] To see this, consider the example of New York's ABC

1. In fact, the Federal share payable on ABC systems was increased from 50% to 70% effective July 1, 1974.

system expenditure and grant availability in 1963 (table III.5.2) Given a 50% Federal matching share, it would cost New York $60,315,000 to match the Federal payments made available. But considering that New York was willing to expend over $200 million on ABC system construction (from its own sources), it makes little difference whether the first $60 million or the first $26 million went towards matching available Federal funds. Only the price at the margin is important. Thus it is apparent that for New York and most other States, we should expect increases in ABC grants to have a relatively small impact (through an income effect) on total ABC systems expenditures.

ii. Data Analysis of the Interstate Highway Program

As discussed in Section II.2 , the Interstate highway program differs in three important respects from the ABC highway program. In magnitude, Federal grants for the Interstate program exceeded ABC grants over the period 1954-1970 by 231%. Additionally, the basic Federal share payable for the Interstate program amounts to 90% as compared to a 50% share payable towards ABC projects. But perhaps the most fundamental difference - at least in terms of States' expenditure responses to Federal grants - is the fact that, unlike the ABC program, the Interstate program represents a closed system. Total system mileage and general corridor locations for the system were

ABC System Expenditures/Grants

New York: 1963

(1000's of dollars)

	50% Federal Share	70% Federal Share
Federal payments	60315	
Required State matching funds	60315	25849
States' own expenditures	200964	
"Excess expenditures"	140649	175115
Percentage excess expenditure	53.8%	67.0%

Table III.5.2

determined years before the first Federal dollar was expended on the system. Moreover, Federal Interstate grants are awarded to the States on the basis of the relative cost to complete their portion of the approved system, unlike ABC grants which are fixed without regard to the level of investment chosen by the State.

For these reasons, it may be inferred that States have little incentive to expand Interstate highway construction significantly beyond the level provided for by the Federal grants. This expectation is borne out by the data in table III.5.3 indicating the States' expenditures over and above minimal matching requirements, expressed as a fraction of total expenditures on the Interstate system over the period 1954-1970 (refer to equation 13). The excess expenditure fractions range from a low value of 0[1] (North Dakota) to a high value of 37.7% in Rhode Island. It is immediately clear that relative to expenditures made on the ABC system, most States expend little more than the minimally required amount necessary to qualify for

---

1. The negative value appearing for North Dakota indicates an error in the data reported in HIGHWAY STATISTICS. Note that an excess expenditure fraction less than zero would suggest a State not meeting its minimal matching requirement for the receipt of Federal Funds. We shall assume that the excess expenditures for North Dakota are essentially zero.

STATE	EXCESS FRACTION
ALA	0.033706
ARIZ	0.141695
ARK	0.042172
CALI	0.260211
COLO	0.093779
CONN	0.105866
DEL	0.119580
FLOR	0.113527
GEO	0.116668
IDA	0.067219
ILL	0.057098
IND	0.116334
IOWA	0.175011
KANS	0.065520
KENT	0.071806
LOUS	0.056850
ME.	0.055336
MD.	0.095672
MASS	0.166204
MICH	0.112119
MINN	0.067162
MISS	0.055157
MSRI	0.000028
MONT	0.003678
NEB.	0.081941
NEV.	0.076883
N.H.	0.038050
N.J.	0.081553
N.M.	0.094687
N.Y.	0.071708
N.C.	-0.043332
N.D.	0.028562
OHIO	0.097182
OKLA	0.092277
ORE.	0.042853
PENN	0.093673
R.I.	0.376995
S.C.	0.025138
S.D.	0.047225
TENN	0.041191
TEX.	0.104352
UTAH	0.174613
VER.	0.026371
VA.	0.009704
WASH	0.104955
W.V.	0.096852
WISC	0.150828
WYO.	0.055882

STATE EXPENDITURES OVER AND ABOVE MINIMAL MATCHING REQUIREMENTS EXPRESSED AS A FRACTION OF TOTAL EXPENDITURES ON INTERSTATE SYSTEMS

TIME PERIOD: 1954-1970

Source: Yearly Editions of HIGHWAY STATISTICS (1954-1970), U.S. Bureau of Public Roads, Washington, D.C.

Table III.5.3

receipt of Interstate grants. Fully thirty three out of the forty eight States devote less than 10% of their total Interstate investment towards expenditures beyond the minimal matching requirement. And with the exception of California and Rhode Island, all States exhibit an excess expenditure fraction less than 20%.

Thus, it may safely be concluded that for the vast majority of States, Interstate grants have been characterized by a price and income effect. Following the analysis of Section III.4., we may infer that Interstate grants have induced State expenditures on projects that would not have been made in the absence of grants. And by the same token, small increases in the level or price subsidization of Interstate grants may be expected to stimulate additional expenditures on the Interstate system from the States' own resources.

III.6 Summary and Conclusions

This chapter has attempted to define both the normative and positive analytic issues involved in an investigation of the Federal Aid Highway Program (FAHP). Two related findings merit particular attention:

- the design of the FAHP should be related to the objectives the Federal government hopes to accomplish through its grant program
- States' expenditure responses depend significantly on the structural characteristics of Federal grants.

The former finding derives from the discussion in Section 2 on the normative aspects of the Federal Aid Highway Program. Summarily, it should be noted that the selection of the appropriate mathcing ratio - indeed the very choice of a Federal matching grant as opposed to a block grant must be related to the perceived fiscal problem the grant attempts to rectify. This type of perspective gives direction to arguments for and against alterations to the existing FAHP. For example, it may be argued that the stipulations in the 1973 Federal Aid Highway Act allowing for the construction of mass transit facilities under the same grant provisions as the Urban (highway) System[1] is not the appropriate form of transit aid.

The relevant issue here is that the primary rationale for

1. Close-ended categorical matching grants with a Federal share payable of 70%

Federal highway grants is entirely different from the rationale fore transit aid. In the former case, the existence of significant interstate benefit spillovers call for external financing to move towards an efficient allocation of highway resources. In the latter case, it is primarily the fiscal disparity between different cities (i.e. the ability of a city to raise sufficient revenue to provide for a given level of transit service) that indicates the need for Federal financing. As discussed in Section 2, in the one instance, Federal matching grants are in order; in the other, block funding is more appropriate.

The second major finding of this chapter is the relationship between State expenditure responses, and structural characteristics of Federal grants. It has been shown that categorical matching grants will always stimulate greater expenditure levels than non-categorical block grants of like amount. In fact, Section 5 presented evidence that the ABC program has failed to serve as a stimulus for additional construction on the aided systems. In light of this finding it is important to question the objectives of the ABC highway grant program. If the intent of Federal grants for the ABC system was to "accelerate the construction of Federal-aid highway systems .... since many of such highways or portions thereof, are in fact inadequate to meet the needs of local and interstate commerce"[1], the program has apparently failed

1. Subpart A, Title 23, United States Code, Chapter 1, Section 101(b): Declaration of Policy.

to do so. By the same token, the ABC grant program does not appear to be necessary to ensure a minimal level of provision of such systems (c.f. Section III.2.iv), since the great majority of States invest funds far in excess of their minimal matching requirements. Indeed, the primary consequences of the ABC grant program appears to be merely to have provided the States with additional highway revenue - an outcome that could be achieved in a more straightforward manner by the institution of non-categorical block grants.[1]

Needless to say, it is important to verify the theoretical findings in this chapter with empirical evidence. The remaining chapters of this thesis will discuss a series of econometric models designed to assess the impacts of the Federal Aid Highway Program on State highway expenditures.

1. Although this assertion reraises the initial question posed in this section: What are the objectives to be accomplished by the FAHP.

CHAPTER IV

DEVELOPMENT OF THE TOTAL EXPENDITURE MODEL

IV.1 Introduction

There are two fundamental dimensions of States' highway expenditure behavior: long run revenue or total expenditure policy formulation, and short run allocation (programming) determination. The distinction between revenue policy as a "long-run" phenomenon and allocation policy as a "short-run phenomenon derives from the fact that changes in the determinants of State highway revenue(e.g., tax rates, bond sales, etc.) tend to be infrequent relative to the expression of a State's allocation policy (e.g., year-to-year capital budgeting decisions). The empirical models developed in this research attempt to explain the factors influencing States' total highway expenditures, and allocation decisions amongst alternative highway expenditure categories. Naturally, the central focus of the research is an evaluation of how Federal grants have affected States' expenditure behavior.

In this chapter, the development of the total expenditure model (TEM) is presented. Attempting to build on the common use of "Needs Studies" as a long run fiscal planning device, Section 2 presents a derivation of the TEM based on capacity utilization theory. The major focus of this model is to trace States' total highway expenditure responses to the presence of Federal highway grants.

Following the derivation of the model, Section 3 explores the estimation problems inherent in the use of a pooled data set.

While it would have been desirable to estimate the TEM for each State individually -- as 48 separate time series -- lack of sufficient historical data precluded this approach. Accordingly, we describe a practical approach to estimating the model with both time series and cross sectional data.

Section 4 describes the definitions and sources of data employed in our TEM estimation. In many instances, data which would have been desirable from a theoretical standpoint was not directly available. The use of proxy information is fully described in this section. Next, a short discussion is presented on considerations for interpreting the empirical results. Hypotheses to be tested are discussed in terms of the signs and magnitudes of specific parameter estimates.

Section 6 describes the actual estimation results of the total expenditure model. Several alternative specifications are presented and applied to an experiment where the entire sample was divided into two distinct subsets. The results convincingly demonstrate the States' differing expenditure responses to the Interstate and ABC grant programs.

Finally, the major results and policy implications derived from the estimation of the total expenditure model are set forth in Section 7.

IV.2 Derivation of the Model

It is convenient to conceptualize States' highway expenditure behavior in terms of two dimensions:

1. decisions relating to the determination of the magnitude of the States' highway budget in any given year, and

2. decisions relating to the allocation of that budget amongst alternative types of highway expenditure categories (e.g. Interstate, Primary System, maintenance, administration, etc.)

In fact, it may be argued that this analysis perspective is not merely an artificial construct. While the administrative and political realities of altering tax rates and debt obligation (and thus altering total expenditure levels) inhibit quick adjustments to changes in costs and demand,[1] the program selection (programming) process operates on a relatively short cycle time.[1]

We focus here on the derivation of a model to explain the derivation of a model to explain the first of the two dimensions of State behavior: the determination of total highway expenditures. An immediate starting point is an examination of the "Needs Study" process. The highway needs process has been incorporated into the U.S. Department of Transportation's biennial National Transportation Studies, required of all States as of 1968. But prior to this time to this time several States conducted explicit internal highway needs studies for their own fiscal planning purposes at varying intervals.

In its simplest terms, a (highway) needs study involves the

---

[1] Highway bond sales are usually issued over a two to five year period. The average duration between tax rate adjustments is ever longer. Over the fifteen-year period, 1951-1965, the average duration between the States' tax rate adjustments was somewhat over ten years.

determination of the desired ("needed") level of highway physical plant based on structural and functional deficiencies in existing inventories, present and future design standards, traffic growth rates, and anticipated highway functional classification. Highway needs studies do not represent a radically innovative methodology to guide States' investment behavior. In fact, conceptually the needs study process may be considered as a specific application of the general economic theory explaining the investment behavior of a behavioral unit (be it a firm, industry or State Highway Department).

This is an important point, since we are attempting to model the highway investment behavior of States, regardless of whether they conducted explicit needs studies during the course of our analysis period (1957 - 1970). The most general statement of the factors influencing total highway investment behavior (of which a needs study is one application) may be expressed by:

$$(1) \quad R_t = f(K_t^* - K_{t-1})$$

where R_t = total revenues devoted to highway expenditure (State plus Federal funds)
K_t^* = desired capital stock in year t
K_{t-1} = actual capital stock at the end of year t-1

Equation (1) asserts that the level of (total highway) investment in a given year t is a function of the gap between a "desired level of highway plant" at the end of year t and the existing level of capital stock at the beginning of year t.

The conceptual basis of this investment relation has been advanced under the general heading of "capacity utilization theories."[1] Most commonly, the dependent variable is expressed in terms of (a firm's) investment in capital stock. In our application, we are more interested in a State's total (capital plus non-capital) highway investment. However, equation (1) remains perfectly general. We would expect higher levels of total highway investment to be associated with higher "gaps" between desired and existing highway plant. Note that R_t in equation (1) is just the sum of the States' own resources R_t^o and the amount of available Federal highway grants G_t:

(2) $R_t = R_t^o + G_t$

But G_t is equal to the sum of unexpended Federal grants in years t-1, t-2, . . . and Federal grants made available in year t:

(3) $G_t = UBG_{t-1} + g_t$

where UBG_{t-1} = unexpended balance of Federal grants as of the end of year t-1

g_t = highway grants made available in year t

Substituting equations (2) and (3) into equation (1) yields:

(4) $R_t^o = f(K_t^* - K_{t-1}) - (UBG_{t-1} + g_t)$

which expresses the revenues raised for highway expenditure in a

---

[1] For a good summary of the various applications of these theories, see Kuh, Edwin, CAPITAL STOCK GROWTH: A MICRO-ECONOMETRIC APPROACH, North Holland Publishing Company, 1971, especially Chapter 2.

State in year t as a function of the gap between desired and actual highway capital stock and Federal grants.

The capacity utilization theory expressed by equation (4) has a clear relationship to the classical Needs Study Process of long run fiscal planning. In effect, we are arguing that States adjust their long run highway investment policy in response to their perception of highway "needs" (K_t^* in our terminology), the existing inventory (K_{t-1}) of highways, and the available level of external funding (G_t). Needless to say, the empirical measurement of "desired" (and even actual) capital stock represents a formidable conceptual problem.

Several factors influence a State's perception of highway needs[1] (desired capital stock), including traffic and congestions levels, demographic characteristics, and a variety of institutional characteristics. Symbolically, we assume desired capital stock -- "needs" -- can be expressed as:

---

1 It should be emphasized that our modelling framework does not assume that State highway expenditures will be adjusted to meet the cost perceived highway needs from year to year. On the contrary, the expenditure model employed here explicitly recognizes the continuing existence of a "gap" between perceived needs and actual highway capacity. It is the existence of this discrepancy between desired and actual highway plant that influences State decisions on the magnitude of total highway investment. Presumably, the greater the gap between "needs" and existing inventory in any given year, the greater will be the expenditures in that year.

(5) $K_t^* = K_t^* (SEC, IC)$

Where SEC= a vector of socio-economic characteristics of a State (e.g., urban density, population, traffic congestion levels, per capita income, and various State growth measures)

Where IC= a vector of institutional characteristics describing a State's highway financing conventions (e.g., the extent of <u>local</u> participation in highway maintenance and construction, the extent of toll road finance, and the degree of debt-service financing

Introducing equation (5) into (4) leads to the basic form of the total investment model estimated in this study:

(6) $R_t^o = f(K_t^* (SEC, IC) - K_{t-1}) - g(UBG_{t-1} + g_t)$

where f and g are assumed to be linear functions of the arguments

Note that the last term above is written as a function, rather than the simple sum of UBG_{t-1} and g_t as in equation (4). The reason for the more general specification here is to allow for an explicit test of the effect of Federal grants. In other word, equation (6) permits an assessment of the impact of Federal grants on the level of <u>total highway</u> expenditures derived from States' own sources. The major hypothesis to be evaluated empirically is relative degree of <u>expenditure stimulation</u> resulting from Interstate versus non-Interstate grants. In the hypothetical model presented in Chapter III, preliminary data analysis indicated that Interstate grant increases would most likely be associated with increases in States' own expenditures. This behavior was contrasted with the ABC grant program, where it was hypothesized that States would view increases in ABC grants as a substitute for their own expenditures on these Federal Aid Systems. The empirical results presented in Section IV.6 will validate the theoretical hypotheses.

IV.3 Estimation Techniques for the Total Expenditure Model

While it would have been desirable to estimate the total expenditure model (TEM) for each State individually (i.e. as forty-eight separate time series), lack of sufficient historical data precluded this approach. The specification of the TEM incorporated as many as twelve explantory variables (including the constant term). Given only fourteen years in our analysis period (1957-1970), individual State estimation is clearly infeasible.

Accordingly, the possibility of grouping our observations in a pooled data set consisting of time series and cross-sectional data merits special attention. One of the first investigations of this problem was advanced by Theil and Goldberger,[1] who demonstrated that the estimation of time series parameters can be designed to incorporate additional information oabtainable from cross-sectional data.

In principle, the reasons for pooling data are simple: provided that we cna take proper statistical account of individual regional and/or time effects that may be present in the data, the use of pooled data (by virtue of the large increase in available degrees of freedom) yields more effecient model paramter estimates. In our application, the use of pooled data increases the number of available observations from 14 (years) to 672 (14 years x 48 States).

[1] Theil, Henri, and A.S. Goldberger, "On Pure and Mixed Statistical Estimation in Economics," International Economic Review, Volume II, No. 1, January, 1961

To clarify the statistical problems inherent in estimating models employing pooled data, let us rewrite equation (6) of Section IV.2 in matrix form to stress the fact that an observation is specific to a particular State and year:

$$\text{(7)}\quad R^o = \begin{vmatrix} R^o_{11} \\ \vdots \\ R^o_{1T} \\ \vdots \\ R^o_{N1} \\ \vdots \\ R^o_{NT} \end{vmatrix} = X\beta + u$$

$$= \begin{vmatrix} X^{(1)}_{11} & \cdots & X^{(K)}_{11} \\ \vdots & & \vdots \\ X^{(1)}_{1T} & \cdots & X^{(K)}_{1T} \\ \vdots & & \vdots \\ X^{(1)}_{N1} & \cdots & X^{(K)}_{N1} \\ \vdots & & \vdots \\ X^{(1)}_{NT} & \cdots & X^{(K)}_{NT} \end{vmatrix} \begin{vmatrix} \beta_1 \\ \vdots \\ \beta_k \end{vmatrix} + \begin{vmatrix} u_{11} \\ \vdots \\ u_{1T} \\ \vdots \\ u_{N1} \\ \vdots \\ u_{NT} \end{vmatrix}$$

where:

N = number of States (48) in the sample

T = number of years (14) in the sample

K = number of explanatory variables in the model

R = a vector of observations (NTx1) of total highway expenditures from State n's own sources in year t

Thus we have observations on N (=48) States, n = 1, 2 . . ., N taken over T (=14) years, t = 1, 2, . . . T. Our dependent variable R is assumed to be explained by K truly exogenous varibales X. The statistical properties of our parameter estimates B, and indeed the very meaning of our model is determined by what we assume about the properties of the residual vector U.

The standard assumptions of econometric theory (i.e. if ordinary least squares (OLS) are to yield best linear unbiased parameter estimates) are that the residuals are distributed with mean 0 and variance $\sigma^2 I$. However, if a model is estimated with pooled data, there are strong reasons to suggest that these assumptions are not valid. When cross section and time series observations are combined in the estimation of a regression equation, it is likely that certain systemmatic shift effects are present in the data. Specifically, we refer to the presence of factors not explicitly accounted for by the included explanatory variables which nonetheless influence the dependent variable.

Two categories of "extraneous influences"[1] may be present. One relates to the presence of pure regional effects -- i.e. factors outside the model which serve to determine the behavior of individual States. Growth rate policies, political culture variables, "belief in the future,"[2] and auto/transit biases are examples of factors that, although important in determining individual State expenditure behavior, are difficult to explicitly model at the aggregate level of analysis considered in this thesis. A second extraneous influence relates to the presence of time dependent shifts -- i.e. those factors which may affect all States at any given point in time, but vary from year to year. The most obvious examples of this affect are macro-economic influences: interest rates, degree of inflation/regression, unemployment rates, etc.

A common method to account for these "extraneous influences" is to introduce explicitly into the equation individual shift variables. The rationale for this approach is that the observations contain an additive effect specific to the individual State or year.

To account for such effects, dummy variables corresponding to

---

[1]Kuh, Edwin, and J.R. Meyer, "How Extraneous are Extraneous Estimates," The Review of Economics and Statistics, Volume 39 (November, 1957).

[2]The importance of this factor was discussed by Mead, Kirtland, DESIGN OF A STATE WIDE TRANSPORTATION SYSTEM PLANNING PROCESS: AN APPLICATION TO CALIFORNIA, Unpublished Ph.D. thesis, M.I.T. Civil Engineering Department.

each State or year[1] may be explicitly introduced into the model. The problem with this approach is that it reduces the degrees of freedom by N without adding in any real sense to the explanatory power of the model. Moreover, it is often found that the dummy variable approach "overcompensates" for the individual effect by drastically reducing the magnitude and significance of the explanatory variables.[2]

Error Component Analysis

Another technique to account for the presence of individual State and/or time shift effects is with error component analysis.[3] Since we are assuming the presence of economic forces specific to an individual State and/or year, not otherwise accounted for in our model specification, it is reasonable to expect that these forces "show up" in the residual term. To state this formally, we assume

---

[1]Obviously it would not be possible to introduce a specific dummy variable for each State and for each year. The most common practice is to focus on the presence of regional effects by introducing explicit State dummy variables. For an example of this approach, see Balestra, Pietro, and M. Nerlove, "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, Volume 34, Number 3 (July, 1966).

[2]This is particularly true of those variables that vary significantly from State to State, but exhibit little variance in any given State over time. The dummy variable approach was attempted in this research and abandoned for the above reason. For a further discussion of this point, see Balestra and Nerlove, op. cit., especially pages 590 - 593.

[3]Balestra and Nerlove, op. cit., Theil and Goldberger, op. cit., Kuh, op. cit.

each residual U_{nt} may be decomposed into three statistically independent components: an individual State effect μ_n, a time shift effect δ_t, and a remainder ν_{nt}:

(8) $$u_{nt} = \mu_n + \delta_t + \nu_{nt}$$

Since the residuals are assumed to have zero mean, and the components of u_{nt} are independently distributed, it must also be true that:

(9) $$E[\mu_n] = E[\delta_t] = E[\nu_{nt}] = 0$$

We further assume that there is no serial correlation among the error components, and that they are independent from one State and year to another:

(10)
$$E[\nu_{nt}\mu_n] = 0 \qquad E[\nu_{nt}\nu_{n't'}] = \begin{cases} \sigma_\nu^2 & \text{if } n=n' \text{ and } t=t' \\ 0 & \text{otherwise} \end{cases}$$

$$E[\nu_{nt}\delta_t] = 0 \qquad E[\mu_n\mu_{n'}] = \begin{cases} \sigma_\mu^2 & \text{if } n=n' \\ 0 & \text{otherwise} \end{cases}$$

$$E[\mu_n\delta_t] = 0 \qquad E[\delta_t\delta_{t'}] = \begin{cases} \sigma_\delta^2 & \text{if } t=t' \\ 0 & \text{otherwise} \end{cases}$$

Accordingly, we may express the variance-covariance (an NTXNT matrix) Ω of the residuals (u_{nt}) by:

(11) $$\Omega = E[u_{nt}u'_{nt}] = \begin{vmatrix} \omega_1 & \omega_2 & \cdots & \omega_2 \\ \omega_2 & \omega_1 & \cdots & \omega_2 \\ \vdots & \vdots & & \vdots \\ \omega_2 & \omega_2 & \cdots & \omega_1 \end{vmatrix}$$

where:

$$\omega_1 = \begin{vmatrix} 1 & \rho & \cdots & \rho \\ \rho & 1 & \cdots & \rho \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \rho & \rho & & 1 \end{vmatrix}$$

$$\omega_2 = \begin{vmatrix} \tau & 0 & \cdots & 0 \\ 0 & \tau & \cdots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & \cdots & \tau \end{vmatrix}$$

$$\sigma^2 = \sigma_\nu^2 + \sigma_\mu^2$$

$$\rho = \sigma_\mu^2/\sigma^2$$

$$\tau = \sigma_\delta^2/\sigma^2$$

Equation (11) follows directly from our assumption that the covariance of all the cross products of the error components are identically 0. Note that the variance-covariance matrix Ω has a repetitive block structure. The diagonal blocks are T x T, and represent the variance-covariance structure of the individual State effect and remainder error component. The off-diagonal blocks, also T x T are all diagonal matrices, whose single parameter τ represents the time shift effect.

It is clear from the form of equation (11) that the variance-covariance of the residuals derived from estimation on pooled data is not scalar. Accordingly, although ordinary least squares estimates of the coefficients would be unbiased and consistent, they would not be the most efficient (i.e. least variance estimators. In fact, the best linear unbiased estimators are the generalized least squares parameter estimates β_{GLS} which explicitly incorporate the non-scalar variance-covariance matrix:

$$(12) \qquad \beta_{GLS} = (X'\Omega^{-1}X)^{-1} X'\Omega^{-1}R^{0}$$

A straightforward technique for deriving generalized least square estimators where the error term structure assumes the form of equation (8) has been advanced by Zellner.[1] Essentially, the technique involves a two-step estimation procedure: first estimate the model with ordinary least squares (OLS), and use the OLS residuals and equation (11) to determine the parameters of Ω. Second, a generalized least squares estimation is performed by making the appropriate transformation of the original data.

In our application, a simplified generalized least squares estimation procedure was adopted. Specifically, no account was taken of the separate time effect δ_t. This error component was dropped for two reasons. First, allowing for a time shift effect would "<u>greatly</u>

[1]Zellner, A., "An Efficient Way of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," Journal of the American Statistical Association, Volume 57 (1962).

complicate the analysis without adding any essential generality."[1] It is obvious from the form of equation (11) that the development of generalized least squares estimators requires inverting an NTXNT matrix. Although the form of Ω inclusive of δ_t is sparse (c.f. equation (11)], the inverse matrix Ω^{-1} does not assume or simple pattern.[2] In fact, inversion of a 672X672 matrix proves to be unwieldy and expensive.

A second reason for dropping the individual time shift effect is that when estimations were performed using time shift dummy variables, the parameter estimates of these dummy variables did not prove to be significant. In short, the most important "extraneous influence" in our estimation problem was the presence of an individual State shift effect.

The application of our simplified error component estimation procedure was straightforward. Following the notation of equation (11), we now assume that:

$$(13) \qquad \Omega = \sigma^2 \begin{vmatrix} \omega_1 & 0 & \cdots & 0 \\ 0 & \omega & \cdots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & & \omega_1 \end{vmatrix}$$

---

[1] Balestra and Nerlove, op.cit., p.504.

[2] That is, there was no simple (and inexpensive) way to invert

Remembering that each T x T matrix ω_1 is specified in terms of a single parameter ρ, it may be shown that $\hat{\rho}$ can be estimated as a function of OLS residual estimates:[1]

$$(14) \qquad \hat{\rho} = \frac{\sum_{n=1}^{N} \sum_{t=1}^{T} \sum_{t'=1}^{T} \hat{u}_{nt}\hat{u}_{nt'} - \sum_{n=1}^{N} \sum_{t=1}^{T} \hat{u}_{nt}^{2}}{N\,T\,(T-1)\,\hat{\sigma}^2}$$

where: $\hat{u}_{nt}$ = OLS residuals for State n (=1,...,N) in year t (=1,...,T)

$\hat{\sigma}^2$ = estimated variance of the OLS regression

The actual estimation of generalized least squares (GLS) estimates involves OLS estimation on suitably transformed data. The first step is to determine the Choleski decomposition[2] h of Ω^{-1} defined as:

$$(15) \qquad h'h = \Omega^{-1}$$

The original observations X and R are then premultiplied by the Choleski decomposition matrix to define $\tilde{X}$ and $\tilde{R}$:

$$(16) \qquad \begin{aligned} \tilde{X} &= hX \\ \tilde{R} &= hR \end{aligned}$$

---

[1] Equation (194) simply expresses the average value of all those elements of $\hat{u}\hat{u}'$ corresponding to where ρ appears in our assumed structure of Ω .

[2] For an operational algorithm for determining Choleski decomposition matrices, see Faddeev, D.K., and Fadeeva, V.N., COMPUTATIONAL METHODS OF LINEAR ALGEBRA, W.H. Freeman, San Francisco, 1963.

It follows directly that OLS estimation on the transformed data yields GLS estimates of our model coefficients.[1]

In summary, the estimation of the total expenditure model followed a simplified error component analysis which explicitly allows for the presence of individual State shift effects in our pooled data set. Once the structure and properties of the residuals are specified [equation (8)], GLS estimation involves a straightforward application of a two-step procedure employing OLS residuals to estimate the parameter of an assumed structure of the non-scalar variance-covariance matrix.

---

[1] $\tilde{\beta}_{OLS} = (\tilde{X}'\tilde{X})^{-1}\tilde{X}'R = (X'h'hX)^{-1}X'h'hR^0$

But from (15), $h'h = \Omega^{-1}$

Thus $\tilde{\beta}_{OLS} = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}R^0 = \beta_{GLS}$

Returning to the basic form of the total expenditure model derived in Section IV.2, we noted that States' own highway expenditures were functionally related to perceived investment needs, existing highway inventories and Federal grant availability:

(17)

While equation (17) suggests the basic explanatory relationship, the problem remains to specify the socio-economic factor (SEC), and institutional characteristic (IC) arguments of the highway needs term K_t^*. Moreover, a practical means of representing existing inventories K_{t-1}, and Federal grant availability must also be determined. This section will discuss the definitions and sources of each of the variables incorporated into the estimated total expenditure model.

Several alternative specifications of the total expenditure model were estimated in this research using both deflated and undeflated data.[1] The basic form of the model is presented in Figure IV.4.1. The first eight variables in the model correspond to the set of socio-economic and institutional characteristics which influence a State's perception of "desired" highway capacity. The variable KSTK serves as a proxy for existing highway inventories [i.e. the measure of K_{t-1} in (17)]. Finally, the availability of

---

[1]That is, expenditure levels, Federal grants and per capita income variables were deflated by the consumer price index.

THE TOTAL EXPENDITURE MODEL

$$R^o = a_o + a_1 * \begin{Bmatrix} MFC \\ SPOP \\ VMT \end{Bmatrix} + a_2 *UFAC + a_3 *GPOP + a_4 *PCY$$

$$+ a_5 *GINI + a_6 *RLTOT$$

$$+ a_7 *TOLPCT + a_8 *BIPTCX + a_9 *KSTK$$

$$+ a_{10} *AVNIGP + a_{11} *AVIGP + U$$

where

R^o = State expenditures on highways exclusive of Federal per capita grants

a_o = constant term

a_1 = estimated coefficients

VMT = State vehicle miles of travel

SPOP = State Population

MFC = State motor fuel consumption

UFAC = percent of population residing in urban areas

GPOP = State population growth rate

PCY = per capita State income

GINI = index of income inequality

KSTK = present discounted value of highway capital stock per capita

RLTOT = percent of total expenditures (all units of government) contributed by local (i.e., county and municipal) governments

BIPTCX = percent of total capital expenditures provided for by debt financing

AVNIGP = apportioned "ABC" grants (three year moving average) per capita

AVIGP = apportioned Interstate grants (three year moving average) per capita

U = error term

Figure IV.4.1

Federal highway aid is represented by AVNIGP and AVIGP -- a three-year moving average of non-Interstate and Interstate grants respectively.

i. The Socio-Economic Descriptors

Five variables were employed to describe the socio-economic characteristics of each State: a basic State size variable (SPOP or MFC or VMT), a measure of urbanization (UFAC), an indicator of State growth (GPOP), and two income characteristics (per capita income PCY, and income distribution GINI).

a. SPOP, MFC and VMT

It is reasonable to expect that, ceteris paribus, State expenditures should increase with increasing levels of traffic demand. For one thing, higher traffic levels will generate increasing levels of earmarked State highway revenue. But more fundamentally, higher levels of auto use require increased construction, maintenance policing and aministrative expenses.

Three alternative measures of State size were employed as a proxy for the scale of auto travel. The first indicator, State population (SPOP), was derived from yearly editions of the Survey of Buying Power.[1] SPOP was entered into the model with a one year lag -- i.e. State expenditures during year t were related to population at

---

[1]Sales Management, SURVEY OF BUYING POWER, 1950 - 1970 (Yearly Editions), Bell Brothers Publications.
This publication is the only source of year-to-year, State-by-State socio-economic descriptor data. The Census Bureau does not publish population, income or growth indices for each State on a yearly basis. The Survey of Buying Power's data base is adjusted to conform with the decennial census data.

the end of year t-1. Two alternative State size variables were also tested in the TEM estimations. Vehicle miles of travel (VMT) is perhaps the most direct measure each State's traffic levels. The only source of this information is from yearly editions of the Federal Highway Administrations HIGHWAY STATISTICS. Two problems are encountered in the use of this data. First, the data itself is not directly observed or collected, but estimated from gasoline sales statistics, and assumptions on average vehicle mix (i.e. truck/auto split) and gasoline consumption rates. Secondly, the data, is not published on a yearly basis. Over the course of our fourteen year analysis period, the FHWA published VMT data for only four years (1959, 1962, 1965 and 1968). For our purposes, intermediate (yearly) values of the VMT data were determined by simple straight line interpolation.

Motor fuel consumption (MFC), the third alternative State size measure, was also derived from the FHWA Highway Statistics yearly publications. The data was entered into the model net of fuel deployed for agricultural, marine or aviation use. As with the two previous measures, a simple one year lag was employed.

b. UFAC

The degree of urbanization (UFAC) is an important factor in determining highway investment behavior (i.e. in terms of explaining perceived highway investment needs K_t^*) for several reasons. First, it is a measure of the "compactness" of a State as it serves to distinguish between largely rural/agricultural/sparsely populated States and densely populated urban/industrialized States (see

PERCENT OF POPULATION RESIDING IN

URBAN PLACES WITH GREATER THAN 5000 RESIDENTS (1970)

State	Urbanization Index %	State	Urbanization Index %
Alabama	58	Nebraska	60
Arizona	74	Nevada	75
Arkansas	48	New Hampshire	57
California	86	New Jersey	87
Colorado	75	New Mexico	72
Connecticut	76	New York	84
Delaware	66	North Carolina	42
Florida	75	North Dakota	41
Georgia	56	Ohio	73
Idaho	50	Oklahomo	66
Illinois	82	Oregon	63
Indiana	64	Pennsylvania	71
Iowa	56	Rhode Island	84
Kansas	64	South Carolina	42
Kentucky	47	South Dakota	43
Louisiana	65	Tennessee	54
Maine	52	Texas	79
Maryland	72	Utah	77
Massachusetts	82	Vermont	40
Michigan	73	Virginia	58
Minnesota	65	Washington	68
Mississippi	42	West Virginia	40
Missouri	69	Wisconsin	65
Montana	53	Wyoming	63

Source: Sales Management, SURVEY OF BUYING POWER 1970, Bill Brothers Publication

Table IV.4.1

Table IV.4.1). Secondly, it serves to identify States with highly concentrated urban areas where per lane mile construction costs are relatively high.

On balance, we would expect the degree of urbanization to negatively influence States' per capita highway expenditures. There are two reasons for this. The first reason relates to the indivisibility and "lumpiness" of highway investments. As a State's population decentralizes (e.g. to previously unpopulated places), the need for highway route mileage increases. However, even the minimal provision of two lane rural roadways incurs a relatively large capital outlay.[1]

Secondly, the more urbanized States have been subject to an increasing presence of community opposition to urban roadway construction.

The urbanization index UFAC is defined as the percent of a State's population residing in areas with greater than 5000 residents. The data was derived from yearly editions of the Survey of Buying Power and was entered into the TEM with a one year lag.

---

[1]That is, highway construction is charaterized by high fixed costs. Moreover, highway construction and maintenance rise less than proportionately to increases in the number of lanes (for a given route distance).

c. GPOP

As an indicator of the rate of State growth, a measure of yearly population change was computed from the basic population data described in Section IV.4.i.a. Ceteris paribus, one would expect higher population growth rates to be associated with higher highway investment levels. As it turned out, the population growth rate data was characterized by extreme variability and proved to be a poor explanator of highway investment behavior.

d. PCY and GINI

Two separate measures of State income--per capita income and a measure of income inequality--were employed in the estimation of the total expenditure model. Per capita income (PCY) is correlated positively with auto usage (See Section II.3.ii), and thus we should expect increasing State income to lead to increasing State highway expenditure levels. PCY data was derived from yearly editions of the Survey of Buying Power.

The GINI Index of Income Inequality is derived from Lorenz income distribution curves.[1] As shown in Figure IV.4.2, the Lorenz curves describe the degree of homogeneity in household income within a State. If each household earned exactly the State average income level, then the Lorenz curve would be a straight line rising at 45^{0} from the horizontal (i.e. 20% of the households earn 20% of total income, 40% of households earn 40% of total income, etc.)

As the Lorenz curve plots the percentage of households, ranked

[1] Samuelson, Paul, ECONOMICS, McGraw-Hill Book Company, New York, 8th Edition, 1970.

LORENZ CURVES

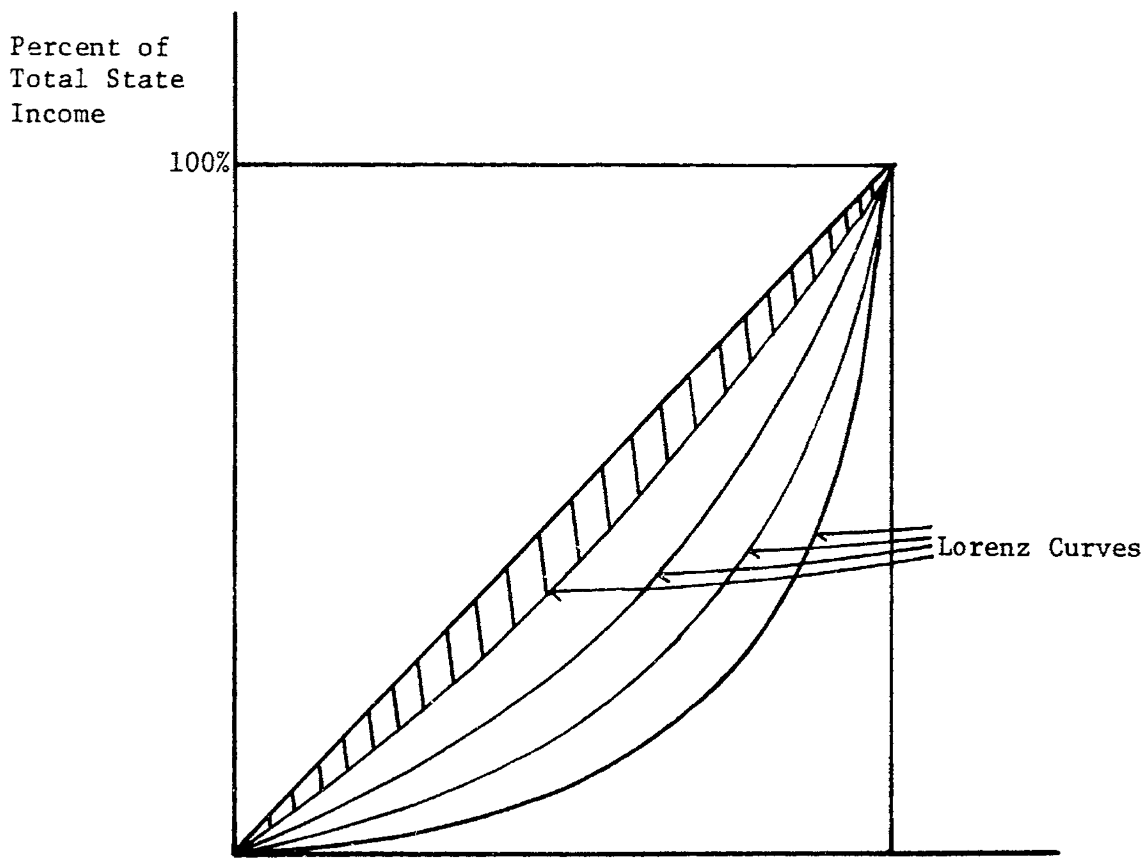


Figure IV.4.2

from poorest up on the horizontal axis and the percentage of income they earn on the vertical axis, it is clear that as the degree of income inequality increases, the Lorenz curves become increasingly concave.

This suggests a measure of income inequality related to the area between a Lorenz curve and the 45^0 (perfect income homogeity) line (e.g. see the shaded area in Figure IV.4.2). In particular the GINI Index of Income Inequality (GIII) is defined as

$$(18) \quad \text{GIII} = \frac{\text{area bounded by a Lorenz curve and the } 45^0 \text{ line}}{\text{area under the } 45^0 \text{ line}}$$

The GINI index varies between 0 and 1 with higher index values indicating a greater degree of income inequality.

The actual GINI indices developed for this research were constructed from piecewise linear Lorenz curves. The Survey of Buying Power data described the number of households in each State (and each year in the 14 year sample period) in each of five income categories -- \$0 - 2499, \$2500 - 4999, \$5000 - 7499, \$7500 - \$10,000 and \$10,000 and over.

The GINI index serves to indicate two characteristics of the States. First the GINI index provides a measure of the number of low income households in each State. For a given level of per capita income, a State with a high GINI index value would have a relatively large number of low (and high) income households. Thus we are accouting for the possibility that the average income level as well as the distribution of income in a State will affect the level of auto usage (and thus ultimately affect the level of State highway expenditure). The GIII also conveys a rough measure of regional characteristics. From Table IV.4.2, which displays the GINI index for each of the forty-eight mainland States in 1963 (the mid-year in our 14-year sample period), southern/agricultural/rural States tend to have a higher degree of income inequality than northern/industrial/urbanized States.

ii. The Measurement of Highway Capital Stocks

The development of time series information on a State's highway capital stock presents a formidable task. An immediate problem is to select the units to describe the capital stock, and the economic conventions to be employed in measuring the change in value productivity of vintage stocks over time.

On theoretical grounds, it is clear that the best measure of capital stock is output capacity. In terms of evaluating highway investment behavior, it may be argued that a State's investment decisions are based, at least in part, on the perceived gap between the demand for existing highway service (e.g. vehicle miles of travel), and the existing supply of the highway plant. Implicit in this decision-making process is the notion of level of service. Herein lies the problem in measuring highway physical plant. The capacity of a highway system, and the quality of the output (i.e. level of service) are inherently related. This relationship stands in contrast to the capital stock measurement problem of manufacturing production processes where output is normally of uniform quality. The only

MEASURES OF INCOME INEQUALITY, 1963

State	Gini Index of Income Inequality
Oklahoma	43.1
Florida	42.8
Kentucky	42.5
Alabama	42.3
Louisiana	42.0
Tennesee	41.9
Texas	41.6
Arizona	41.6
Deleware	41.3
Virginia	40.5
New Mexico	40.2
Iowa	40.2
Mississippi	40.1
Georgia	39,9
North Carolina	39.8
Oregon	39.7
Vermont	39.1
Minnesota	39.0
Missouri	38.9
Kansas	38.9
Washington	38.7
West Virginia	38.5
South Dakota	38.4
New York	38.4
Nebraska	38.3
Nevada	38.2
Ohio	38.1
Maine	37.8
Pennsylvania	37.7
Illinois	37.6
Indiana	37.5
Maryland	37.4
Michigan	37.4
Rhode Island	37.3
South Carolina	37.3
Colorado	37.3
Massachusetts	37.2

Table IV.4.2

State	Gini Index of Income Inequality
North Dakota	37.0
Idaho	37.0
Wisconsin	36.8
Arkansas	36.4
Connecticut	36.1
New Jersey	36.1
New Hampshire	35.6
Utah	35.2
Montana	35.0
Wyoming	34.8
California	32.0

Table IV.4.2 (contd.)

practical problem in capital stock measurement in this case is the selection of an appropriate depreciation formulation to measure the declining value productivity of older capital stocks.

From the above remarks, it is clear that a complete description of highway capital stock requires knowledge of the highway system's value-in-use -- ie. a comprehensive inventory of the physical (e.g. roadway width, surface quality, geometric design, etc.) and operating characteristics (i.e. speeds over the roadway at existing demand levels) of the highway system.

Unfortunately, this data is not available on a time series basis. Moreover, for the few years in which comprehensive inventory data exists,[1] the data set is excessively unwieldy, as it represents a large sample, section-by-section description of all State-administered highway mileage. Considering the fact that this type of information has been largely unavailable to State planners and decision-makers on a year-to-year basis, the relevant question for this analysis is to find a relevant proxy measure for value-in-use highway capital stock, drawing on available time series data.

The primary source of highway mileage data examined in this study is drawn from the yearly editions of Highway Statistics,

---

[1]Highway system inventory data has been collected as part of individual State Highway Needs Studies (HNS). The Federal government required HNS of all States as of 1968. Prior to the time, several States conducted HNS on their own at irregular intervals.

published by the U.S. Bureau of Public Roads. Unfortunately, the organization of this data does not lend itself immediately to proxy measures of highway capital stock suitable for investment analyses. The most important data gap is the lack of information on the vintage distribution of the States' highway plant. Thus, it is not immediately apparent how to depreciate the value-in-use of existing capital. Moreover, yearly additions to States' highway route mileage are reported in units of route mileage rathern than lane mileage, with no distinction made between projects on new rights-of-way, and projects designed to improve existing rights-of-way (e.g. major resurfacing of existing mileage, lane widening, addition of new lanes to existing ROW, etc.).

Clearly, any attempt to measure capital stock in terms of capacity output[1] requires data in lane mileage, rather than route mileage terms. The data on total existing lane mileage is sketchy. In all cases, the mileage figures are reported in discrete categories--2 lanes, 3 lanes, and 4 lanes or more--so that the data are imprecise in the highest lane category. Attempts to identify lane mileage figures with specific Federal-Aid Systems is complicated by lack of data on Federal Aid Secondary lane mileage. The lane mileage (LM) data is broken down into Interstate LM, Federal-Aid Primary LM, and State Primary System LM. The latter category includes portions of all of the Federal Aid System mileage as well as State system mileage not

---

[1] For example, the number of vehicles per day that can be accomodated on the State-administered road system at a given average speed.

incorporated on the Federal-Aid Systems.

In summary, attempts to employ mileage data as a proxy measure of highway capital stock is complicated by a lack of information on the vintage distribution of highway plant, and an incomplete stratification of lane mileage by Federal and non-Federal-Aid System.

Given the above-mentioned difficulties in applying mileage data to the task of measuring capital stock, it is desirable to investigate the use of historical capital expenditure data as a proxy measure of existing highway stock. An immediate issue in applying expenditure data is the proper accounting of the decline of capital productivity over time. As it turns out, the proper treatment of expenditure data as a capital stock proxy measure is far less difficult than the use of the available mileage data. The methodology for constructing highway capital stock measures requires some attention to the choice of an appropriate depreciation methodology.

Depreciation refers to the loss in value of a currently held asset. Two types of depreciation functions are commonly found in the literature: market value functions and efficiency loss functions. The former measure indicates the decline in resale value

---

[1] The benefits of using physical measures of capital stock (i.e. elimination of price delator affects, and the ease of identifying stock retirements) are obvious. Nonetheless, the investment behavior literature is replete with studies employing capital expenditure proxies of capital stock. The main reason for the use of expenditure data is that it is generally more readily available than physical measures of capital.

of fixed plant over time, while the latter measure reflects the losses in efficiency due to wear on the fixed plant. The more relegant measure for highway investment studies is the efficiency loss function.

The techniques for deriving depreciated highway capital stock measures in this study were based on methodology developed by Jack Faucett Associates.[1] The methodology involves applying an efficiency loss depreciation function (ELDF) to the time series of State highway expenditures. The Faucett study hypothesizes that the efficiency loss of highway systems increases over time (i.e. as a highway approaches the end of its service life.[2] The actual ELDF employed takes the form of the lower segment of a rectangular hyperbola:

$$(19)\quad D(t) = \frac{SL - t}{SL - at}$$

where $D(t)$ = percent of a highway system's remaining productivity

t = the age of a highway

SL = the service life of a highway

a = a parameter of the effciency loss depreciation function ($0<a<1$)

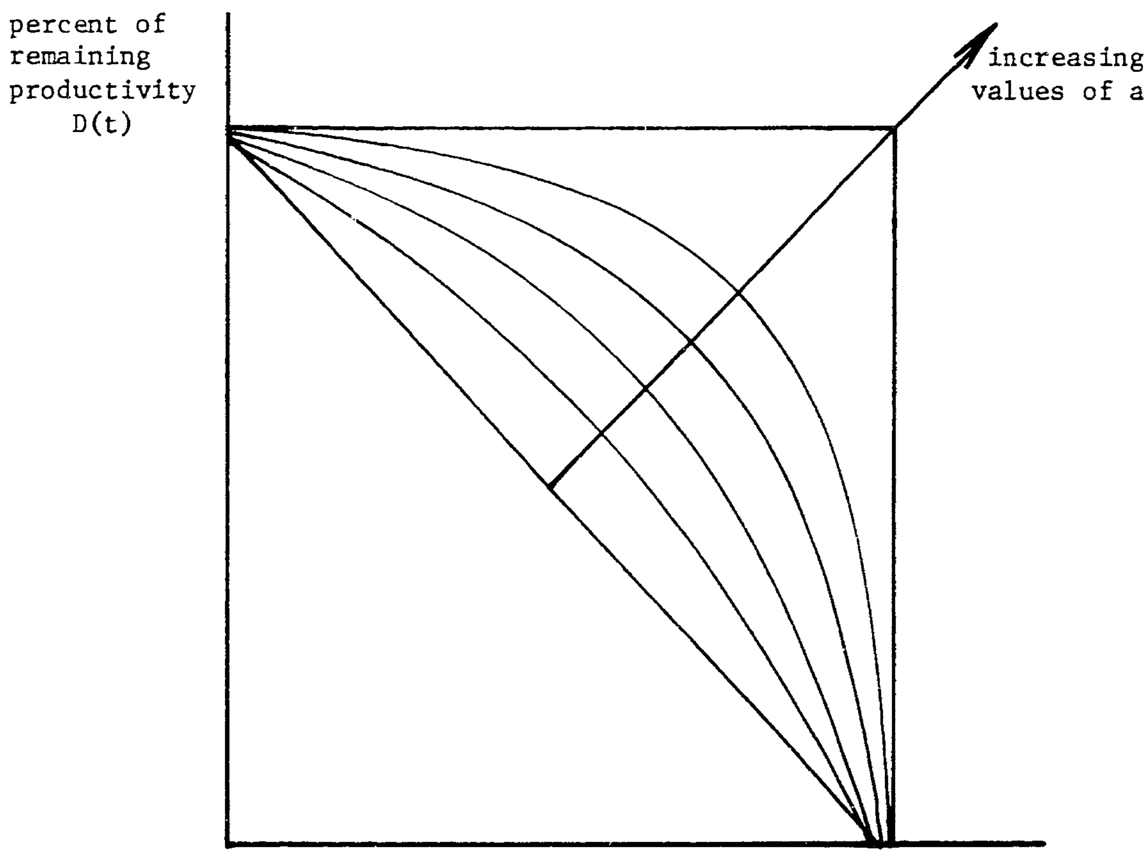
This formula generates a family of depreciation functions as a function of the parameter a (See Figure IV.4.3). Following the conventions of the Jack Faucett study, a 20-year service life was

---

[1]Jack Faucett Associates Inc., CAPITAL STOCK MEASURES FOR TRANSPORTATION, Volume 1, Report No. JACKFAU-71-04-1, 1971.

[2]As manifested by the increasing level of required maintenance expenditures and/or the decreasing level of highway productivity (as measured by vehicle capacity).

DEPRECIATION FUNCTIONS



$$D(t) = \frac{SL-t}{SL-at}$$

Figure IV.4.3

was assumed for State highway system construction expenditures, and the ELDF parameter (a) was set to 0.8.

The efficiency loss depreciation function was applied to a thirty-four year time series[1] of State highway system expenditures to generate the depreciated highway capital stock measures per capita (KSTK)for each State and each year in the 14-year sample period.

iii. Descriptors of Financing Conventions and Institutional Characteristics

Three descriptors of State highway financing conventions were employed in this study: the extent of local participation in highway finance (RLTOT)[2], the importance of toll roads in generating State highway revenues (TOLPCT)[3], and the degree of debt service highway financing (BIPTC X).

Since the dependent variable in the total expenditure model exclusively measures State highway expenditures, we should expect that higher degrees of local participation (as measured by RLTOT) in the provision and maintenance of highway facilities will be associated with lower expenditure levels from State resources. In

---

[1]The expenditure time series covered the period 1937 - 1970. Expenditure data was derived from yearly editions of HIGHWAY STATISTICS.

[2]RLTOT is defined as the ratio of municipal and county highway expenditures to total (all units of government) highway expenditures.

[3]TOLPCT is defined as the percentage of a Stage's highway revenue derived from highway tolls.

[4]BIPTCX is defined as the ratio of bond interest to State highway construction expenditures.

other words, to the extent that a State delegates its highway authority to lower units of government, State highway expenditures should decrease.

The other two indicators of institutional characteristics, TOLPCT and BIPTCX, reflect the degree of flexibility in the States' highway finance program. For a given State gas tax rate, the increasing use of toll road or debt service financing allows a State greater opportunity to raise higher levels of highway revenue. Thus we should expect TOLPCT and BIPTCX to positively influence State highway expenditure levels.

Each of the three financing convention variables, RLTOT, TOLPCT and BIPTCX, were derived from yearly editions of the FHWA's HIGHWAY STATISTICS.

iv. The Highway Grant Terms

Two important characteristics distinguish the treatment of the Federal highway grant terms in our total expenditure model from previous empirical highway expenditure studies (See Section I.3) First, the Federal-Aid Highway Program was broken down into two distinct components: Interstate System grants, and grants on the non-Interstate ("ABC") Systems. The theoretical analyses of Chapter III indicated the strong likelihood of differing State expenditure responses to these two grant types. In fact, it was hypothesized that the Interstate program grant structure would most likely induce expenditure stimulation in contrast to the hypothesized expenditure substitution response to ABC grants. The modelling emplications of these hypotheses are twofold. First, it was considered desirable to explicitly test these hypotheses by separating out the two distinct grant types. Second, it was considered likely that the simple inclusion of a total grant term would "wash out" any empirically identifiable grant response.[1]

A second characteristic distinguishing this study from previous research is in the treatment of the multi-year grant availability problem. As discussed in Chapter II, Federal highway grants are made available over a "grace period" extending from one-half year before the beginning of the fiscal year of the authorization to two years beyond the end of that fiscal year. The use of three year moving averages[2] on the grant terms was employed to represent the grace period FAHP feature. Moreover, the use of moving averages partly accounts for the fact that States may not fully and immediately adjust to changes in Federal highway grant availability.

The basic Federal grant data was obtained from yearly editions of HIGHWAY STATISTICS. Apportionments for the years 1969 and 1970 were adjusted downward in accordance with the imposed OMB fiscal control totals (See Section IV.2). The grant terms were

---

[1]All of the studies cited in the literature survey of Chapter I included only a total highway grant term. Several estimations of our TEM were conducted with a single total grant term. As expected, the estimated grant parameter was extremely small and had a large standard error (See Section IV.6).

[2]Specifically, the three year moving averaged grant terms $\bar{G}_t$ were computed as

$$\bar{G}_t = \frac{1}{3}(G_t + G_{t-1} + G_{t-2}) \text{ for } t = 1954, \ldots, 1970$$

where G_t = States' grant apportionments in year t.

expressed as averaged Interstate grants per capita (AVIGP) and averaged non-Interstate grants per capita (AVNIGP).

v. Price Delflators

This study conducted estimations on both (price) deflated and undeflated data. Specifically, all of the terms in the total expenditure model whose units are expressed in dollars were adjusted by the consumer price index (See Table IV.4.3) according to the following relationship:

$$(20) \quad V^d = \frac{V}{CPI}$$

where: V^d = price deflated variable

V = value of variable in absolute terms

CPI= consumer price index

In addition to deflating the dependent (highway expenditure) variable, the following explanatory variables were deflated by the Consumer Price Index: per capita income (DEFPCY), highway capital stocks (DEFKSTK), Interstate grants (DEFIG), non-Interstate grants (DEFNIG), and total grants (DEFTG).

Consumer Price Index

(1970 base)

Year	Consumer Price Index
1955	.689
1956	.700
1957	.725
1958	.745
1959	.751
1960	.762
1961	.771
1962	.779
1963	.788
1964	.799
1965	.812
1966	.835
1967	.859
1968	.896
1969	.944
1970	1.000

Source: U.S. Department of Transportation, 1974 NATIONAL TRANSPORTATION STUDY: HIGHWAY PLANNING PROGRAM MANUAL, Table II-3

Table IV.4.3

IV.5 Research Strategy and Considerations for Model Interpretation

i. The Total Expenditure Model: Considerations for Model Interpretation

As indicated in the previous section, the basic form of the total expenditure model describes the relationship between States' own per capita highway expenditures, and a set of variables representing States' socio-economic and institutional characteristics (serving as proxies for the "desired" level of highway inventories), a measure of existing highway plant (with a one-year lag) and measures of available Federal highway grants (divided into Interstate and non-Interstate categories). Before presenting a discussion of the emprical results, it is important to clarify the hypotheses which the total expenditure model can address.

Consider first the estimated coefficients of the Federal grant (per capita) terms (refer to Figure IV.4.1). Following the discussion presented in Chapter III, it is clear that sign and magnitude of these coefficient estimates will serve to distinguish the substitution or stimulation effects of Federal highway grants. To see this consider the following possible values of the grant term (a_g) coefficient estimates:[1]

---

[1]The following comments are relevant to the analysis of both the Interstate and non-Interstate grant terms.

1. $a_g < -1$

A value of a_g less than one would indicate that States reduce their own highway expenditures by more than one dollar for each additional grant dollar received. This type of behavior is highly improbable as it would imply that Federal highway grants have served to reduce total highway expenditures.

2. $a_g = -1.0$

This case is symbolic of perfect expenditure substitution wherein each additional dollar of Federal grants is associated by exactly a one dollar reduction in the level of the States' own expenditures. It follows that, in this instance, total highway expenditures (State plus Federal funds) do not change in response to changes in the level of Federal grants.

3. $-1 < a_g \leq 0$

Coefficient values in this range represent an expenditure substitution response. Like the previous situation, States' own expenditures decrease in response to increases in Federal grants, but in this case not on a dollar for dollar basis. In other words, a coefficient estimate in the range - 1 to 0 indicates that total expenditures will increase but by less than[1] the amount of Federal grant increases.

4. $\underline{a_g > 0}$

This grant response is characteristic of expenditure stimulation. In other words, each additional dollar of Federal highway grant elicits an <u>increase</u> in States' own expenditures. It is only for this range in coefficient values (i.e. $a_g > 0$) that total highway expenditures can be expected to increase by more than increases in the level of Federal grant funding.

A second hypothesis to which the total expenditure model can be addressed is a test of the effect of the level of current highway inventories on total highway expenditures.

It is commonly found that the higher the existing stock of capital goods, the lower will be the current desired and actual level of <u>capital investment</u>. While this behavior may pertain in our case, it should be noted that the dependent variable in the empirical model measures capital (i.e., highway <u>construction</u> expenditures) as well as non-capital (e.g. maintenance, administration, highway police and safety, etc.) expenditures. In general, non-capital expenditures tend to increase with increasing levels of existing highway inventory. Thus, the single coefficient of the existing inventory variable

---

[1]Except if a_g is identically 0 in which case, total expenditures would increase by exactly the amount of Federal grant increase.

(KSTK) does not distinguish between capital and non-capital expenditure responses to changes in KSTK. For this reason it is entirely possible to obtain a positive coefficient estimate for the highway inventory variable.

One final note of the form of the model pertains to the interpretation of the parameter estimates of the socio-economic descriptor variables. Since the dependent variable in our model is expressed in terms of expenditures *per capita*, it is not necessarily true that a negative coefficient on a socio-economic variable implies that total expenditures decrease with increasing levels of that variable. For example, a negative sign on the population variable (SPOP) might indicate that highway expenditures do not increase at the same rate as population increases (and thus *per capita* expenditures decrease). Nonetheless, such a coefficient estimate may still imply that total highway expenditures would increase *in absolute terms* in response to population increases.

ii. Data Set Stratification

The theoretical analysis developed in Section III. 4 advanced the hypothesis that the stimulatory impacts of the Federal Aid Highway Program would be greaest in those cases where States expend little more than the minimally required highway matching funds. It was for this reason that the TEM included separate terms for Interstate and non-Interstate grants (the latter grant type less binding than the former). But even within each grant program there exists some variation in the extent to which States exceed minimal matching requirements. (For example, see Tables III.5.1 and III.5.3).

To further test the notion that (ceteris paribus) the magnitude of Federal highway grants relative to State expenditure levels plays an important role in influecning State investment behavior, we divided our data set into two distinct groups. In particular, one subset was defined as the seven States with conspicuously low Interstate highway expenditures over and above minimal Interstate System matching requirements. These seven States whose "excess" Interstate expenditures amounted to less than 4% of their total Interstate investment over the fourteen-year analysis period 1957 - 1970, were Alabama, Missouri, Montana, New Hampshire, North Carolina, North Dakota, South Carolina, Cermont and Virginia (Table III.5.3). The second data subset set was comprised of the 41 remaining States. Thus each of the alternative total expenditure model specifications was estimated on the full pooled data set and two data subsets.

In terms of the estimated parameters of the TEM, the hypothesis that States experiencing more binding Federal highway grants exhibit stronger stimulatory expenditure responses would be borne out if the coefficient of the Interstate grant term is larger for the seven State sample than for the 41 State sample. The empirical models do validate this hypothesis as will be described in in the next section.

IV.6 Empirical Results

In general, the empirical results of the total expenditure model estimations corroborate the theoretical hypotheses advanced in sections III.5, and IV.4. A total of 34 alternative specifications of the total expenditure model were estimated in this research, representing the inclusion of different sets of variables the use of both deflated and undeflated data, the representation of Federal aid by a single total grant variable or as two terms stratified by grant type, and the estimation of the model on the entire data sample as well as two distinct data subsets. Appendix A presents a complete listing of the estimation results. The purpose of this section is to highlight the major findings of the model estimations, and integrate the empirical results with the theoretical hypotheses advanced earlier.

In the figures that follow, each regression run is described by a four character model number $l_1\ l_2\ n_1\ n_2$ where:

$$l_1 = \begin{cases} \text{S - grant terms stratified by type (Interstate and} \\ \quad\ \ \text{non-Interstate)} \\ \text{T - single total grant term} \end{cases}$$

$$l_2 = \begin{cases} \text{U - undeflated data set} \\ \text{D - price deflated data set} \end{cases}$$

$$n_1 = \begin{cases} \text{1 - 48 State/14 year pooled sample} \\ \text{2 - 7 State/14 year pooled sample} \\ \text{3 - 41 State/14 year pooled sample} \end{cases}$$

$n_2 =$ 1,2, ... - model specification number

Figures IV.6.1 through IV.6.4 present the results of the generalized least squares estimation of the TEM using undeflated data on the full 48 State/14 year sample. In particular, Figure IV.6.2 considers the addition of one explanatory variable -- the

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU11

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 258.86 SEE = 5.37 RSQ = 0.779

	CONSTANT	SPOP	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	9.96	-0.650E-06	9.468	-0.601	0.018	0.605
STANDARD ERROR	5.58	0.732E-07	1.124	0.031	0.001	0.124
T-STATISTIC	1.78	8.74	8.41	19.53	17.94	4.88

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.319	0.457	-1.146	0.619
STANDARD ERROR	0.036	0.069	0.091	0.043
T-STATISTIC	8.86	6.62	12.55	14.39

Figure IV.6.1

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU12

GENERALIZED LEAST SQUARES

F-STAT: F(10,661) = 238.10 SEE = 5.32 RSQ = 0.782

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	8.98	-0.597E-06	10.639	-0.599	0.017	0.613
STANDARD ERROR	5.55	0.796E-07	1.206	0.030	0.001	0.123
T-STATISTIC	1.62	7.51	8.82	19.61	17.26	4.97

	RLTOT	TOLPCT	AVNIGP	AVIGP	BIPTCX
ESTIMATE VALUE	-0.298	0.355	-1.123	0.608	0.088
STANDARD ERROR	0.037	0.088	0.097	0.043	0.055
T-STATISTIC	8.05	4.02	11.61	14.14	1.58

Figure IV.6.2

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU16

GENERALIZED LEAST SQUARES

F-STAT: F(9,6621) = 250.79 SEE = 5.44 RSQ = 0.773

	CONSTANT	VMI	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	10.01	-0.137E-03	9.360	-0.600	0.018	0.606
STANDARD ERROR	5.66	0.173E-04	1.128	0.031	0.001	0.126
T-STATISTIC	1.77	7.91	8.30	19.16	17.73	4.81

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.330	0.410	-1.135	0.620
STANDARD ERROR	0.036	0.070	0.093	0.043
T-STATISTIC	9.07	5.83	12.22	14.25

Figure IV.6.3

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU12

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 206.44 SEE = 5.85 RSQ = 0.737

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	20.84	-0.314E-06	16.553	-0.458	0.013	0.337
STANDARD ERROR	6.04	0.844E-07	1.814	0.032	0.001	0.135
T-STATISTIC	3.45	3.72	9.13	14.07	12.29	2.50

	PLTOT	TOLPCT	AVTGP	BIPTCX
ESTIMATE VALUE	-0.418	0.178	0.039	0.259
STANDARD ERROR	0.039	0.098	0.035	0.056
T-STATISTIC	13.62	1.83	1.11	4.40

Figure IV.6.4

degree of debt service financing to the basic set of nine right hand side variables included in Figure IV.6.1.[1] Figure IV.6.3 employs vehicle miles of travel instead of population as the measure of State size. And Figure IV.6.4 includes only a single Federal aid term - total available highway grants, rather than the stratified grant terms employed in the previous specifications.

The total expenditure model was also estimated for two subsets of the full pooled data set. Specifically, Figure IV.6.5 presents the estimation results of one specification of the TEM for the <u>seven</u> states with conspicuously minimal Interstate expenditures over and above required matching funds (c.f. section IV.5). Figure IV.6.6 presents the corresponding model estimation results for the forty one other States.

The remaining estimation results derive from the use of price deflated data on all variables whose units are expressed in dollar terms. Specifically, Figures IV.6.7 through IV.6.8 represent the basic nine variable specification (c.f. Figure IV.6.1) of the price deflated TEM for the full pooled data set, the 7 State sample and the 41 State sample respectively. The most important empirical findings from the total expenditure model are presented in summary fashion below.

i. <u>The Federal Grant Terms</u>

The most striking finding from the total expenditure model is that the <u>ABC grant program has elicited a significant expenditure</u>

---

[1]See section IV.4 for a definition of the variables listed in the following fugures.

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU21

GENERALIZED LEAST SQUARES

F-STAT: F(9, 98) = 21.76 SEE = 6.57 RSQ = 0.690

	CONSTANT	SPOP	KSTK	UFAC	PCY	GINI
ESTIMATE VALUE	97.82	-0.668E-06	0.209	-1.340	0.006	-0.542
STANDARD ERROR	8.94	0.737E-06	0.307	0.227	0.002	0.114
T-STATISTIC	10.95	0.91	0.68	5.90	3.66	4.74

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.127	2.772	-0.310	0.657
STANDARD ERROR	0.090	0.492	0.161	0.061
T-STATISTIC	1.41	5.64	1.92	10.75

Figure IV.6.5

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU31

GENERALIZED LEAST SQUARES

F-STAT: F(9,564) = 241.31 SEE = 5.14 RSQ = 0.794

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	16.15	-0.478E-06	8.274	-0.637	0.018	0.693
STANDARD ERROR	5.55	0.724E-07	1.032	0.034	0.001	0.122
T-STATISTIC	2.91	6.60	8.02	18.50	17.32	5.67

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.524	0.368	-0.856	0.439
STANDARD ERROR	0.041	0.071	0.114	0.057
T-STATISTIC	12.75	5.21	7.51	7.68

Figure IV.6.6

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD11

GENERALIZED LEAST SQUARES

F-STAT: F(9,6621) = 248.72 SEE = 6.92 RSQ = 0.772

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	12.12	-0.857E-06	8.028	-0.738	0.022	0.771
STANDARD ERROR	7.16	0.943E-07	1.050	0.040	0.001	0.159
T-STATISTIC	1.69	9.09	7.65	18.66	17.52	4.84

	PLTOT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.430	0.598	-1.103	0.642
STANDARD ERROR	0.046	0.089	0.092	0.045
T-STATISTIC	9.27	6.75	14.43	12.03

Figure IV.6.7

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD21

GENERALIZED LEAST SQUARES

F-STAT: F(9, 88) = 28.00 SEE = 7.50 RSQ = 0.741

	CONSTANT	SPOP	DEFKSIK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	121.10	-0.623E-06	0.776	-1.783	0.010	-0.679
STANDARD ERROR	9.36	0.879E-06	0.368	0.236	0.002	0.099
T-STATISTIC	12.93	0.71	2.10	7.56	4.97	6.87

	RLTOT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.185	3.590	-0.295	0.666
STANDARD ERROR	0.101	0.502	0.132	0.058
T-STATISTIC	1.83	7.15	2.24	11.50

Figure IV.6.8

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD31

GENERALIZED LEAST SQUARES

F-STAT: F(9,564) = 236.03   SEE = 6.60   RSQ = 0.790

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	19.62	-0.648E-06	8.696	-0.778	0.023	0.869
STANDARD ERROR	7.10	0.928E-07	1.065	0.044	0.001	0.157
T-STATISTIC	2.76	6.98	8.16	17.64	17.01	5.55

	RLTCT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.686	0.444	-0.867	0.440
STANDARD ERROR	0.053	0.091	0.116	0.060
T-STATISTIC	12.99	4.87	7.48	7.33

Figure IV.6.9

substitution response amongst the States, as opposed to the Interstate grant program which has been associated with expenditure stimulation. Taking the nation as a whole, the coefficients of the non-Interstate grant terms in all of the specifications employing undeflated data fall in the range -1.123 to -1.146 (Figures IV.6.1-IV.6.3). In light of the discussion in the previous section, where it was indicated that grant coefficient values less than -1 represented highly implausible behavior, each of these coefficients were tested for the statistical significance of their difference from a value of exactly -1.0.[1] In none of the cases, did the coefficient values differ significantly from a value of -1.0 (at the 5% significance level). Thus for all practical purposes, the total expenditure model indicates that the States exhibit a perfect expenditure substitution response to Federal ABC grants. It is clear that this type of behavior does not characterize the response to Interstate grants. Again referring to figures IV.6.1 through IV.6.3, it can be seen that the Interstate grant coefficients are all significantly greater than 0, ranging in value from .608 to .630. Taking the nation as a whole, this would indicate that an increase in Interstate grants by one dollar would elicit an increase in State expenditures by approximately 60¢.

---

[1]The test involves the formulation of the following t statistic:

$\frac{a_g - 1.0}{se\ (a_g)}$ where se is the standard error of the grant coefficient.

For example, using the values given in Figure IV.6.2 for the estimate of the AVNIGP coefficient, $t = \frac{1.123-1.0}{0.097} = 1.27 < 1.64 = t_{.05,662}$ (single tailed test)

The same behavioral pattern is evident from an examination of the estimation results employing price deflated data (Figure IV.6.7). In fact, the estimated values of the grant terms from the deflated and undeflated data sets are remarkably similar. For the full 48 State/14 year price deflated data set, the coefficients of the non-Interstate grant terms were all slightly less (but not significantly different) than -1.0, while the Interstate grant coefficients assumed values around 0.60.

The inclusion of just a single grant term AVTGP representing a three year moving average of total per capita highway grant availability did not yield significant results. From Figure IV.6.4, the estimated coefficient of the total grant term is 0.039 (indicating mild expenditure stimulation) but this value is not significantly different from 0 at the 5% significance level. These results are not surpirsing in view of our findings that Interstate and ABC grants have essentially opposite effects on State highway expenditure behavior.

It is interesting to note that previous empirical studies of State expenditure behavior have failed to distinguish between different highway grant types. For example in a 1971 study by O'Brien[1] employing a 48 State/9 year (1958-1966) pooled data set, the estimated coefficient of total highway grants was also found to be mild by stimulative (0.067) but not significantly different from

---

[1] O'Brien, Thomas, "Grants-In-Aid: Some Further Answers," National Tax Journal, Vol. XXIV, No. 1 (March, 1971)

0. The more interesting conclusion however is not that increasing total Federal grant availability has induced higher State expenditure levels, but that highway grants with significantly different structural characteristics have been associated with significantly different State expenditure responses.

ii. Differences in Grant Term Coefficients Between the Two Data Subsets

It was hypothesized in chapter III of this research summary that the potential of a grant to stimulate expenditures from States' own sources is greatest in cases where the matching and appointment provisions of a grant are "binding."[1] To test this hypothesis, the full sample of observations was divided into two groups (see § IV.5.ii) From Figures IV.6.5 and IV.6.6, it is evident that the seven States exhibiting the lowest excess Interstate expenditures were more sensitive to increases (or decreases) in Interstate grant funding than the remaining forty-one States. Specifically the Interstate grant coefficient for the seven State sample assumed a value of .657 compared to a value of .439 for the remaining forty-one State sample.[2]

While all of these parameter estimates exemplify expenditure stimulation, it appears that increases in Interstate grants to States coming closest to minimally matching available Federal (Interstate) aid will elicit a greater expenditure response than the response from

[1] In the sense that State is found to minimally meet its required matching expenditures.

[2] A similar pattern was indicated for the runs employing the data subsets with deflated values (see Figures IV.6.8 and IV.6.9).

other States. Perhaps even more striking a result along these lines is the difference in the non-Interstate (i.e. ABC) grant term coefficients between the two data subsets. For example, comparing Figures IV.6.5 and IV.6.6 the coefficient of the non-Interstate grant term assumed values of -.31 (seven State sample) and -.86 (forty-one State sample). One of the reasons for the stronger expenditure substitution response manifested by the forty-one State sample is that, on average they were characterized by a higher "excess fraction" (see section III.5) of ABC System expenditures[1] than the States comprising the seven State sample. Referring to Table III.5.1, 33% of the total ABC System investment by the 41 State sample represented expenditures over and above minimal ABC matching requirements as compared to a figure of 29% for the seven State sample.

iii. Interpretation of the Coefficient Estimates of the and Institutional Descriptor Variables

a. State Size Variables

Results from the total expenditure model indicate that per capita highway expenditures (from States' own sources) decrease with increasing State population (SPOP) and urbanization (UFAC). This pattern runs throughout the estimation results presented in Figures IV.6.1 to IV.6.9. For example, the TEM estimation using undeflated data on the full pooled data set indicates that (Figure IV.6.1):

---

[1] And thus, following the reasoning of Section III, would be more prone to view ABC grants as a substitute for their own ABC System expenditures.

(21) $R^{o}_{pc} = 9.96 - 0.65.10^{-6}$ SPOP - 0.60 UFAC + . . .

Thus, an increase in State population by one million or an increase in urban density[1] by one percent is associated with approximately a 60¢ per capita <u>decrease</u> in State highway expenditures. This does not imply that total (i.e. not per capita) highway expenditures (R^{o}) decrease with increasing population. We can express total State highway expenditures R^{o} as:

(22) $R^{o} = R^{o}_{pc} \cdot \text{SPOP} = (\alpha_0 + 2\cdot\alpha_1)\text{SPOP} + \sum_{k=2}^{K}\alpha_k \text{SPOP}$

where α_0 = estimated constant term
α_1 = estimated coefficient of the population variable

The change in total (own) State highway expenditures with respect to SPOP is given by:

(23) $$\frac{\partial R^{o}}{\partial \text{SPOP}} = \alpha_0 + 2\alpha * \text{SPOP} + \sum_{k=2}^{K}\alpha_k$$

Thus the change in total expenditures with respect to SPOP will be positive as long as:

(24) $$\alpha_0 + 2\alpha * \text{SPOP} + \sum_{k=2}^{K}\alpha_k > 0$$

Using the estimated coefficients in figure 4 and the <u>average</u> value of the variable SPOP[2] yields:

(25) $$\frac{\partial R^{o}}{\partial \text{SPOP}} = 9.96 - 2 * 0.65 * 10^{-6} \cdot 0.38 * 10^{7} + \cdots + = 4.94 > 0$$

---

[1]Percent of a State's population residing in urban places greater than 5000 persons.

[2]Over the 14 year sample period, the 48 State average population was 3.8 million.

This implies that population increases increase States' own highway expenditures by $4.94 per person.

b. The Income Measures

Two separate measures of State income--per capita income and a measure of income inequality--were employed in the estimation of the total expenditure model. Per capita (State) income (PCY) is correlated positively with auto usage and thus we should expect increasing State income to lead to imcreasing State highway expenditure levels. This hypothesis is borne out by the estimation results. For example, referring to figure IV.6.1, an increase in per capita income by one dollar would be associated with a 1.8¢ increase in per capita State highway expenditures.

As discussed in section IV.4, the second income measure employed in this study -- the GINI index of income inequality--provides an indication of both the distribution of State income, and a rough measure of regional characteristics.[1] The estimation results indicate that higher levels of income inequality are associated with higher per capita State highway expenditures. For example, referring to figure IV.6.1, an increase in the GINI index by one unit would lead to a 61¢ per capita increase in State highway expenditures.

c. Institutional Characteristics

Three descriptors of State highway financing conventions were employed in this study: the extent of local participation in highway finance (RLTOT), the importance of toll roads in generating

---

[1] Namely that States with greater income inequality (higher levels of GINI) tend to be Southern/rural/agricultural in nature.

State highway revenues (TOLPCT), and the degree of debt service highway financing (BIPTCX).

Since the dependent variable in the total expenditure model exclusively measures State highway expenditures, we should expect that higher degrees of local participation (as measured by RLTOT) in the provision and maintenance of highway facilities will be associated with lower expenditure levels from State resources. In other words, to the extent that a State delegates its highway authority to lower units of government, State highway expenditures should decrease.

The other two indicators of institutional characteristics, TOLPCT and BIPTCX reflect the degree of flexibility in the States' highway finance program. For a given (State) gas tax rate, the increasing use of toll road or debt service financing allows a State greater opportunity to raise higher levels of highway revenue. Thus we should expect TOLPCT and BIPTCX to positively influence State highway expenditure levels.

These hypotheses were borne out by the estimation results of the total expenditure model. For each percentage increase in the ratio of local to total expenditures, State per capita highway expenditures decrease by more than 30¢ (see Figure IV.6.1 - IV.6.4). Increases in the percentage of toll road financing induce as much as a 47¢ (per 1% increase in TOLPCT) increase in per capita State highway expenditures. And the use of debt service financing was associated with higher per capita highway expenditures--on the order of a 6¢ increase for each percentage increase in BIPTCX (see Figure IV.6.2).

d. The Existing Inventory Measure

The estimation results indicate that higher levels of existing inventory at the beginning of a year lead to higher levels of expenditure on highways during that year. For example, referring to figure IV.6.1, an increase in depreciated capital stock per capita of $1.00 would lead to a $9.48 increase in State per capita highway expenditures.

There are two explanations for this finding. First, the higher the level of existing capital stocks, the higher will be the required level of non-capital expenditures (e.g. maintenance, administration, highway police and safety etc.) to support the existing facilities. Second, it may be hypothesized that the increasing provision of highway facilities tends to divert and attract additional auto ridership which in turn leads to higher levels of highway expenditure.

In summary, the estimation of the total expenditure model generally confirmed the behavioral hypotheses advanced earlier. Most significantly, it was shown that states have viewed the Federal "ABC" grant program as a substitute for their own expenditures as contrasted with the Interstate highway program which has served to stimulate States' own highway expenditure levels. Table IV.6.1 summarizes the effects of each of the variables included in the TEM on State highway expenditure levels.

iv. The Deflated Data Set

It is common practice in empirical studies dealing with time series information to express all monetary data in real dollar

DIRECTION OF THE INFLUENCE OF THE EXPLANATORY VARIABLES ON TOTAL STATE HIGHWAY EXPENDITURES

Variable	Direction of Influence on Total State Highway Expenditures
SPOP	+
UFAC	-
PCY	+
GINI	+
KSTK	+
RLTOT	-
TOLPCT	+
BIPTCX	+
AVNIGP	-
AVIGP	+

+: indicates that increasing levels of the variable are associated with increased highway expenditure levels

-: indicates that increasing levels of the variable are associated with decreased highway expenditure levels

Table IV.6.1

terms for two reasons. First, price deflation converts expenditure data to a common base, indicative of the fact that one dollar of highway investment in 1957 differs from a one dollar investment in (for example) 1970 in terms of corresponding physical output. Secondly, price deflation introduces some notion of the price of the provision of highway facilities in models where it is difficult or infeasible to include an explicit price term.

In our application, the choice of an appropriate price deflator was complicated by the fact that inflation rates differed significantly among the various highway activities undertaken by States. For example, over the last two decades price increases have been more rapid for Federal aid highway construction than for maintenance and operational activities.[1] Moreover the structure of the total expenditure model does not distinguish between individual expenditure items; the dependent variable merely measures total highway expenditures. As described in section IV.5, a somewhat simplistic approach to price deflation was adopted in this research. All data whose units are expressed in dollar terms were deflated by the Consumer Price Index.

Examples of estimation results using deflated data are shown in Figures IV.6.7 - IV.6.9.[2] The results do not differ significantly

---

[1]Federal Highway Administration (FHWA) Notice HHO-34, "Highway Maintenance and Operation Cost Trend Index," 12/14/72. FHWA Office of Highway Operations, PRICE TRENDS FOR FEDERAL-AID HIGHWAY CONSTRUCTION, Second Quarter, 1973.

[2]These Figures correspond to the undeflated model runs shown in Figures IV.6.1, Iv.6.5 and IV.6.6 respectively.

from the estimation runs on the undeflated data set. All of the variables maintained the same sign and roughly the same magnitude, the largest difference occurring in the coefficient of the population variable. Most significantly, estimation of the TEM with the price deflated data set again corroborated the basic finding that the ABC grant program has been associated by expenditure substitution, while the Interstate grant program has induced State expenditure stimulation.[1]

v. Tests of Equality Between Coefficients in the Two Data Subsets

The empirical results reported in the previous paragraghs have been based on the use of a pooled 48 State/14 year data set as well as two data subsets comprising seven and forty one States (over 14 years) respectively. This raises two related statistical issues:

- the validity of pooling our seven State sample with the forty one State sample, and
- the significance of the difference between the estimated coefficients (taken as a whole) from the seven and forty one State samples

In effect, while we have attempted to account for individual State preferences by the GLS error component procedure (section IV.3), it may nevertheless be the case that _as a group_, our seven State sample exhibits significantly different behavior than the 41 State

[1] For example, referring to Figure IV.6.7 representing estimation of the TEM on the 48 State deflated data set, the coefficient of the ABC grant term (DEFNIG) was - 1.103, while the coefficient of the Interstate grant term (DEFIG) assumed the value . 642

sample. To state this premise formally we wish to test the null hypothesis H_0:

(26) $\beta_1 = \beta_2$

where: β_1 = the set of regression coefficients from a sample with T_1 (=7 States x 14 years = 98) observations

β_2 = the set of regression coefficients from a second sample with T_2 (=41 States x 14 years = 574) observations.

The null hypothesis leads directly to the specification of a <u>restricted model</u> where no allowance is made for differing values of β_1 and β_2:[1]

$$(27) \quad R^0 = \begin{bmatrix} R_1^0 \\ R_2^0 \end{bmatrix} \quad \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \beta + \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = X\beta + u$$

where i refers to the subset of T_i observations on own expenditures R_i^0, explanatory variables X_i, and residual terms u_i

In an obvious extension of (27), the unrestricted model with explicit allowance for differing β_1 and β_2 may be written as:

[1] In fact the restricted model (and notation) referred to here is just our original model specification presented in equation (17).

$$(28)\quad R^0 = \begin{bmatrix} R_1^0 \\ R_1^0 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} u_1^* \\ u_2^* \end{bmatrix}$$

where u_i^* = residuals from the unrestric- model

The test of the equality (in the statistical sense) between β_1 and β_2 may be expressed by an F-statistic and is presented here without proof:[1]

$$(29)\quad F(k,T_1+T_2-2k) = \frac{(u'u - u^{*\prime}u^*)\ /\ k}{u^{*\prime}u^*\ /\ (T_1+T_2-2k)}$$

where k = the number of variables in our model

$u'u$ = the sum of squared residuals from the restricted model

$u^{*\prime}u^*$ = the sum of squared residuals from the unrestricted model

T_i = number of observations in sample i

$F(k,T_1+T_2-2k)$ = the computed F-statistic with parameters (degrees of freedom) k and T_1+T_2-2k

In our application, construction of the relevant F-statistic is straightfoward. The sum of squared residuals (SSR) from

---

[1]Fisher, Franklin M., "Tests of Equality Between Sets of Coefficients in Two Linear Regressions: An Expository Note," Econometrica, Vol. 38, No. 2 (March, 1970)

the unrestricted model derives from summing the squared residuals from the separate regression runs on the two data subsets. Thus for example, referring to Figures IV.6.1, IV.6.5, and IV.6.6, where the Standard error of estimate (SEE) from the 48 State (restricted) sample, and the 7 and 41 State (unrestricted) sample are 5.37, 6.57, and 5.14 respectively,[1] the corresponding F-statistic is computed as:

$$F(10,652) = \frac{\dfrac{19450 - (4230 + 15164)}{10}}{\dfrac{19394}{652}} = 0.18$$

Since this computed value of F is significantly less than the critical value of the F distribution at the 5% significance level ($F_{.05}(10,1000) = 1.84$), we are unable to reject the null hypothesis that $\beta_1 = \beta_2$. In other words, the practice of pooling our observations -- at least in terms of combining our 7 and 41 State sample for the given specification of the TEM (Figure IV.6.1) on the undeflated data set appears valid. The computed F-statistic for each of the alternative specifications explored in this thesis is prsented in Table IV.6.2

[1]As presented in the Figures, the sum of squared residuals is equal to SEE squared times the number of observations in the sample.

TESTS OF SELECTED SUBSET COEFFICIENT EQUALITIES

(Table entries represent computed F-statistics for the model numbers appearing in Appendix A)

	Undeflated Data		Deflated Data	
	Model No.	F-Stat	Model No.	F-Stat
Stratified Grant Terms	SU11	0.18*	SD11	3.55
	SU12	1.75*	SD12	1.44*
Total Grant Term Only	TU11	6.94	TD11	4.26
	TU12	4.93	TD12	5.48

*not significant at the 5% level

Table IV.6.2

IV.7 Summary and Conclusions

The estimation results of the total expenditure model (TEM) generally confirmed the previously advanced theoretical hypotheses regarding the differing impacts of the Interstate and non-Interstate gramt programs, the expected responses among States whose expenditures are low relative to Federal grant availability, and the influence of the socioeconomic and institutional characteristic variables.

While the data set used in calibrating the models describe conditions over the fourteen year period 1957-1970, the empirical finding may be interpreted in the broader sense of suggesting guidelines for future Federal-Aid Highway Program (FAHP) policy. Toward this end, we have shown that a major component of the FAHP has not been significantly influential in stimulating State highway expenditures. To the extent that States view a grant as a substitute for their own expenditures, one must view the Federal-aid from the perspective of its value as a tax-relief program rather than its merits in accomplishing an explicit reallocational goal. Along these lines we have shown (see chapter II) that the Interstate Highway Trust Fund is financed by non-progressive excise taxes, and apportioned in a somewhat arbitrary fashion which fails to accomplish a significant redistribution of State income.

In conjunction with the theoretical analyses of chapter III, the empirical results of this chapter demonstrate that substitutive vs. stimulative impacts of Federal aid (at least for aid in the form of close-ended, conditional matching grants) depend critically on the level of Federal grants in relation to State expenditures on the aided system.

We have focused on the differing structural characteristics between the Interstate and non-Interstate grant programs and the corresponding differences in State expenditure responses. But these results have general applicability. Close-ended, conditional matching grants whose provisions are not binding on current or projected State expenditure levels may be expected to be viewed as a substitute for States' own investments.

From a Federal policy stand points the empirical findings in this chapter raise several important points. First, with our clearer understanding of the dynamics of State expenditure responses to Federal-aid, the fundemental issue of the objectives of the Federal Aid Highway Program is called into question. In effect, the imposition of Federal highway taxes and the pursuant distribution of categorical highway grants represents an explicit expression of Federal policy. It is not the intent of this research to argue the economic viability of the Federal governments support for particular highway facilities.[1]

---

[1]For example, our findings demonstrate the <u>success</u> of the Interstate grant program in "accelerating" the construction of Federal Aid Systems (as measured by increasing State highway expenditure levels), if in fact the intent of the this program was to stimulate highway expenditures. However, it remains open to question whether the ensuing expenditure response to the Interstate grant program represents an economically viable investment of funds by benefit/cost or other relevant investment criteria. Our concern has been to merely trace expenditure responses, not to evaluate their economic consequences, as this latter point has been adequately treated in the literature. Se for example Friedlaender, Ann F., THE INTERSTATE HIGHWAY SYSTEM, North Holland Publishing Company, Amsterdam, 1965, especially chapter 3.

Suffice it to say that the restrictions on the use of Federal funds for only certain types of facilities tends to identify those projects whose provision is deemed to be in the national interest. Guaranteeing a minimally acceptable provision of important transportation facilities or stimulating road construction necessary for interstate commerce are valid Federal objectives. But we have shown that for the ABC program, the former objective may not be appropriate, and the second objective is not being accomplished.

To be sure, the Federal Aid Highway Program is characterized by other (non-allocational) consequences--ensuring adherence to Federal labor and contracting regulations, promoting the implementation of transportation planning and process guidelines, and redistributing income. An in fact, we are arguing that greater attention needs to be paid to these "ancillary" impacts in view of the failure of specific components of the FAHP to effect a significant increase in State highway expenditures. Our results indicate that restructuring the FAHP with a relaxation of the specificity of the categorical restrictions, and eliminating the built-in matching provisions would not significantly alter State expenditure levels. In fact, over our analysis period, the ABC program has <u>effectively</u> operated as a non-categorical block grant system.

As described in section II.2.viii, the 1973 Highway Act has incorporated several provisions designed to reduce the specificity of the FAHP, most notably in terms of increasing the allowable fund transfers between distinct Federal Aid Systems, and providing Urban System aid for transit as well as highway construction. The logical extension of the 1973 provisions would be to completely remove all categorical and matching provisions from those components of the FAHP where it is either not the intent or not a reasonable expectation (given projected State expenditure levels and Federal grant availability) for Federal grnats to <u>stimulate</u> State expenditure levels.

CHAPTER V

DEVELOPMENT OF THE SHORT RUN ALLOCATION MODEL

V.1 Introduction

In this chapter, we present a model to explore the factors influencing States' highway budget allocation. We have already traced the impacts of Federal grants and socio-economic and institutional characteristics on total highway expenditures. The empirical analysis of chapter IV has been useful in verifying our hypotheses on the substitution and stimulation effects of Federal highway grants. Now we turn our attention to the issue of the determinants of expenditure levels devoted to specific types of highway activities. Again, the central focus of the research is the evaluation of how Federal grants have affected States' expenditure behavior.

The short run allocation model (SRAM) developed here can be used to asses for example the impacts of Interstate grants on Interstate highway expenditures. Alternatively, we can investigate whether increasing Federal highway grant availability on any of the Federal and highway systems has been associated with increases or decreases in highway maintenance or State highway system construction. In short, the SRAM allows us to explore the dynamics of States' expenditure behavior in terms of decisions relating to the allocation of a fixed budget amongst alternative types of highway expenditures categories (e.g. Interstate, Primary System, maintenance, administration, etc.).

Section 2 develops the derivation of the short run allocation model, building on the consumer allocation theory presented in section III.3. The derivation discusses the appropriate treatment of alternative grant structures, and fixed State highway budget constraints. The resulting estimatable equations take the form of a share model with six distinct structural equations -- one for each expenditure category. Section 3 discusses the statistical problems inherent in estimating a share-type model. Essentially, since the sum of the expenditure shares must equal 1.0, the six equations are not independent. This section develops an estimation technique which explicitly accounts for the joint interaction between shares.

Section 4 presents the definitions and sources of data employed in the SRAM. Much of this data was also used in the estimation of the total expenditure model (Chapter IV). Thus particular attention will be given to data not previously described. The estimation results from the SRAM are presented in section 5. As with the empirical analysis of total expenditures, estimations of the SRAM were performed on a full pooled 48 State/14 year data set as well as two selected data subsets representing differing Interstate expenditure behavior.

The empirical results from the SRAM are not easily or directly interpretable. Accordingly, section 6 discusses the application of derivatives and elasticities to explain State highway expenditure behavior. This section presents a derivation of the derivative and elasticity measures as functions of the estimated SRAM coefficients and evaluates the behavioral implications of the actual results.

An obvious extension of the previous section is to incorporate the findings from the total expenditure model (TEM) into the empirical analysis of allocation behavior. At this point we are able to explain <u>both</u> dimensions of State highway expenditure behavior:

- decisions relating to the determination of the magnitude of States' highway budget in any given year, and
- decisions relating to the allocation of that budget amongst alternative highway activities.

Accordingly, section 7 presents the results from the TEM and SRAM in terms of derivatives and elasticities of expenditures on each of the six highway categories, as a function of the explanatory variables employed in the analysis. The results of this analysis are contrasted with the hypotheses advanced in the theoretical models of State highway expenditure behavior developed in chapter III.

Finally, section 8 presents the conclusions and policy implications stemming from the empirical analyses developed in Chapters IV and V.

V.2 Derivation of the Short Run Allocation Model.

Before setting forth the analytical derivation of the short run allocation model, it is important to describe the nature of the decision environment we are attempting to model. It is convenient to conceptualize States' highway expenditure behavior in terms of two dimensions: the determination of total highway expenditure levels, and decisions relating to the allocation of total expenditures amongst broadly defined highway activities (e.g. Interstate construction, maintenance, etc.) It should be clear at this point that we are not attempting to explain the decision process governing project selection at the aggregate level of analysis adopted in this research. In modelling States' expenditure behavior, our data does not distinguish between decisions to implement a construction or maintenance project in a specific region within a State. Indeed, it may well be argued that the complexity of individual project evaluation -- from decisions relating to corridor determination to detailed location studies and the formulation of specific construction versus maintenance policies -- requires an analysis at a more detailed level than that adopted in this research.

Nonetheless, the expression of States' investment behavior in terms of generically defined highway activities remains a valid and important analysis issue. This is particularly true from the perspective of the Federal government. The Department of Transportation administers several highway grant programs restricted to use on a variety of broadly defined highway activities. Our interest in developing the short run allocation model is to explain the impact of the FAHP on States' expenditure levels on aided and non-aided highway activities rather than investigating the dynamics of the decision process governing individual project selection.

In light of these observations, we may assert that States allocate their fixed highway budget with consideration of existing traffic levels, highway stock in place, socio-economic and institutional characteristics, and available Federal aid, so as to maximize their perceived benefits (utility).

The formal statement of this behavioral representation takes the form:

$$(1) \quad \max \; U_t = U_t\,(E_t^1, E_t^2, \ldots E_t^n)$$

$$\text{subject to} \quad \sum_{i=1}^{n} E_t^i = R_t$$

where E_t^i = expenditures on highway category i in year t

U_t = utility derived from the allocation of expenditures amongst the n highway activities

R_t = the available resources for highway expenditure in year t.

Although equation (1) is a perfectly general statement, the representation of a State as a utility maximizer implies rather heroic assumptions on the political and administrative realities of State highway expenditure behavior. In particular, the use of social indifference maps imply the existence of a well defined and consistent set of preferences for publically provided goods. Furthermore, we must assume that the often conflicting preference orderings of different governmental agencies can be subsumed into one -- in some sense "final" -- utility mapping. These maps are not necessarily assumed to represent the true preferences of the voting polity, and thus do not derive from a "social welfare function". Throughout the derivation, references to maximizing utility are expressed in the context of the utility of a behavioral unit ("BU" -- a State Highway Department, Legislature, Department of Transportation, etc. [see chapter III]), whether or not this utility truly reflects societal welfare[1]. Finally, we must assume that the existence of Federal highway grants alter a BU's resource allocation strictly through price and/or income effects. In other words, we ignore the possibility of shifts in the utility function due to "spin-off effects" or "free money perceptions" introduced by highway grants (see section III.3.vi).

---

1. Here again we emphasize the aggregate level of analysis adopted in this research. We do not attempt to trace the dynamics of project selection involving the resolution of conflicting preferences among several decision-makers. Only the aggregate level of expenditures on all Interstate projects or maintenance projects are considered here. Moreover, the analysis is not normative in the sense that no attempt is made to reflect societal preferences.

Accepting these provisions, we may proceed to derive estimatable highway investment functions from our generalized utility specification. Specifically, we are not direcly concerned with the utility function itself, but with the conditions under which this function is maximized. Adopting a Cobb-Douglas utility function specification and dropping the subscript t represting time (for clarity), we may rewrite equation (1) as:

$$\max \quad U = U(E_1, E_2, \ldots E_n) = \prod_{i=1}^{n} E_i^{\alpha_i}$$

$$(2) \qquad \text{s.t.} \quad \sum_{i=1}^{n} E_i = R$$

where α_i = parameters ("weights") of the utility function

First order maximization conditions[1] may be determined by the Lagrange multiplier technique. Thus defining:

$$(3) \qquad \tilde{U} = U - \lambda(\Sigma E_i - R),$$

the function U will be maximized when:

$$\frac{\partial \tilde{U}}{\partial E_1} = \frac{\alpha_1}{E_1} U - \lambda = 0$$

$$\vdots$$

$$(4) \qquad \frac{\partial \tilde{U}}{\partial E_n} = \frac{\alpha_n}{E_n} U - \lambda = 0$$

$$\frac{\partial \tilde{U}}{\partial \lambda} = \Sigma E_i - R = 0$$

Forming the ratio of any two of the first n equations of (4) yields

---

1 The second order maximization conditions on the function U are guaranteed by our assumption of utility functions convex to the origin.

(5) $$\frac{\alpha_i}{\alpha_j} = \frac{E_i}{E_j} \quad \text{-or-} \quad E_i = \frac{\alpha_i}{\alpha_j} E_j \quad \text{for } \begin{matrix} i=1,\ldots,n \\ j\neq i \end{matrix}$$

Summing over the index i, we get

(6) $$\Sigma E_i = \frac{\Sigma\alpha_i}{\alpha_j} E_j = R$$

Rearranging terms, we may write:

(7) $$\frac{E_j}{R} = \frac{\alpha_j}{\sum_{i=1}^{n}\alpha_i} \quad \forall\, j$$

From (7) it is immediately apparent that at optimality, the States' observed expenditure <u>shares</u> (the left hand side of equation 7) are a function of their utility function parameters α_i . In fact, for the special case of utility functions homogeneous to degree one, the model has the property that the parameters of the utility function are just equal to the shares of each expenditure category[1].

The basis for the development of estimatable investment relations is that the parameters of the utility function, α_i represent "weights" -- i.e. the relative importance a State attaches to expenditures on each of the highway categories. Thus we may consider each α to be a function of several exogenous variables describing traffic patterns, existing highway stock, socio-economic

---

1 Tresch (op.cit.), in his study of State expenditure behavior estimated investment functions based on utility functions homogeneous to degree one. We will not make any a priori assumptions on the homogeneity properties of the States' utility functions.

and institutional characteristics, and Federal grant availability. Formally:

(8) $\alpha_j = f_j\ (Z,\ U_j) \qquad \forall_j$

where Z = set of independent variables in function f_j

U_j = error term in f_j

Using the functional representation of (8) in equation (7), we may write the jth expenditure share s_j as

(9) $$S_j = \frac{E_j}{R} = \frac{f_j(z,U_j)}{\sum_{i=1}^{n} f_i(Z,U_i)} \qquad \forall\ j$$

So far the derivation of the SRAM has centered on the rationale for the general form of the model. Equation (9) represents the basic structural equation of our model. The left hand side of the equations are the directly observable highway expenditure shares in each State and year. And the right hand side factors are a set of exogenous explanatory variables. However as written, equation (9) is highly non-linear, and therefore unsuitable for OLS or GLS estimation. Rather than employing costly non-linear estimation procedures, we may perform a simple transformation on our structural equations to put them in the form of a linear system. Specifically, we "normalize" each share s_j by a selected share s_k:

(10) $$\frac{s_j}{s_k} = \frac{E_j}{E_k} = \frac{f_j(Z,U_j)}{f_k(Z,U_k)}$$

Taking the logarithms of both sides of equation (10) leads to:

(11) $$ln\left(\frac{E_j}{E_k}\right) = ln\ [\ f_j(Z,U_j)\ ]\ -\ ln\ [\ f_k(Z,U_k)\ ]$$

The last step in our derivation requires an assumption on the functional form of f_j. In our research, the SRAM was estimated for two alternative forms of f_j, product form:

(12) $$f_j = \prod_{i\, f_j} Z_{ji}^{\beta_{ji}} U_j$$

and exponential form:

(13) $$f_j = \prod_{i\, f_j} e^{\beta_{ji}} e^{U_j}$$

It should be clear that substituting either of the two functional forms of f_j into equation (11) leads directly to an estimatable specification of the short run allocation model:

(14) $$ln\left(\frac{E_j}{E_k}\right) = \sum_{i\varepsilon j} \beta_{ji}\, ln\, Z_{ji} - \sum_{i\varepsilon k} \beta_{ki}\, ln\, Z_{ki} + U_j - U_k$$

(product form specification of f_j)

-or-

(15) $$ln\left(\frac{E_j}{E_k}\right) = \sum_{i\varepsilon j} \beta_{ji}\, Z_{ji} - \sum_{i\varepsilon k} \beta_{ki}\, Z_{ki} + U_j - U_k$$

(exponential form specification of f_j)

In this form, our n basic structural equations (see equation 9) have been transformed into n-1 log-linear equations. The variables of the "normalizing share" k appear identically in each of the remaining n-1 equations. In order to determine a unique set of parameter estimates for the kth share we must constrain the B_{1i} to be euqal in each of the remaining shares. This may be accomplished by performing a constrained estimation as represented by the matrix form in figure V.2.1.[1]

Two more problems must be addressed before proceeding to the actual estimation of the short run allocation model. First of course is the selection of the exogenous variables to be incorporated in the analysis. The discussion has thus far been concerned only with the form of the model. And in fact, the theory does not dictate which variables should comprise the functions f_j. Section V.4 will discuss the a priori reasoning behind the specification of each of our share equations.

The second analytical issue relates to the proper treatment of Federal grants in constructing the dependent (share) variables. In chapter III, we presented a detailed discussion on the price and/or income effects associated with alternative types of Federal grants. In terms of our empirical analysis, modelling alternative grant structures requires the correct specification of the numerator and denominator in our expenditure share terms. To see this, we may rewrite the budget constraint of equation (1) of this section in terms of prices and physical output measures, rather than in the form of expenditures E_i on alternative highway activities:

---

1 Figure V.2.1 is displayed for the exponential form specification.

CONSTRAINED ESTIMATION FORM FOR THE SHORT RUN ALLOCATION MODEL

$$\begin{pmatrix} \ln \frac{s_1}{s_k} \\ \\ \ln \frac{s_2}{s_k} \\ \\ \vdots \\ \\ \ln \frac{s_{n-1}}{s_k} \end{pmatrix} = \begin{pmatrix} Z_{1,1} & Z_{1,2} & \cdots & 0 & 0 & \cdots \cdots & 0 & 0 & Z_{k,1} & Z_{k,2} & \cdots \\ \\ 0 & 0 & \cdots & Z_{2,1} & Z_{2,2} & \cdots \cdots & 0 & 0 & Z_{k,1} & Z_{k,2} & \cdots \\ \\ \vdots & \vdots & & \vdots & \vdots & & \vdots & \vdots & \vdots & \vdots & \\ \\ 0 & 0 & \cdots & 0 & 0 & \cdots \cdots & Z_{n-1,1} & Z_{n-1,2} & \cdots Z_{k,1} & Z_{k,2} & \cdots \end{pmatrix} \begin{pmatrix} \beta_{11} \\ \beta_{12} \\ \vdots \\ \beta_{21} \\ \beta_{22} \\ \vdots \\ \vdots \\ \beta_{n-11} \\ \beta_{n-12} \\ \vdots \\ \beta_{k1} \\ \beta_{k2} \\ \vdots \end{pmatrix} + \begin{pmatrix} U_1 - U_k \\ \\ U_2 - U_k \\ \\ \vdots \\ \\ U_{n-1} - U_k \end{pmatrix}$$

Figure V.2.1

(16) $$\sum_{i=1}^{n} E_i = \sum_{i=1}^{n} p_i X_i = R^O$$

where P_i = price of highway activity i

X_i = some physical output measure of highway activity i (e.g. lane miles)

R^O = states' own highway resources (i.e. exclusive of Federal grants)

Equation (16) expresses a budget constraint in the absence of the availability of Federal grants, so that expenditures E_i and resources R^O represent States' own funding. The introduction of a Federal grant will alter the form of the budget constraint (and the corresponding expenditure shares) in one of two ways, depending on the structure of the grant.

Conditional Matching Grants - Open Ended

In this case the price of the aided category is reduced by the Federal share payable. Assume for example that an open ended matching grant is provided for highway commodity 1, with the Federal government assuming g% of all expenditures on this function. Budget constraint (16) now takes the form:[1]

---

[1] This follows from tracing through the derivation presented in equations (2) through (7). Tresch (op.cit.) presents a good discussion of these points in chapter 2 of his thesis.

$$(17) \qquad p_1X_1\ (1-g) + \sum_{i=2}^{n} p_iX_i = R^o$$

The first term in (17) represents States' own expenditures on the aided category. Thus, the budget constraint is still satisfied strictly in terms of States' own resources R^o. It can be shown that the derivation of our SRAM in this case would lead to a specification of the numerator in the first expenditure share in terms of States' own expenditures.[1]

Block Grants - Close Ended

This type of grant does not alter States' perceived prices of highway activities. However the total resources available to a State are increased by the amount of the grant. Thus

$$(18) \qquad \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} p_iX_i = R^o + G$$

where G = the level of Federal grant funding.

---

[1] As is evident from equations (14) and (15), our normalizing procedure renders the dependent variable in the estimatable SRAM equations in terms of a ratio between expenditure categories. Since we never deal explicitly with allocation shares, our task here is to determine the proper form for representing the share numerators- i.e. expenditures on each highway category. This task boils down to determining whether these expenditures should enter the model exclusive or inclusive of Federal grants.

Proper representation of expenditure shares in this case calls for the specification of expenditures inclusive of Federal grants.

The type of Federal highway grant encountered in this research, close-ended conditional matching grants is, in a sense a hybrid of our two above cases. We have detailed the argument (section III.3.V) that as long as States exceed minimal grant matching requirements, a close ended conditional matching grant is allocationally equivalent to a like amount conditional block grant. Moreover, we have shown that for the ABC program, and to a lesser extent for the Interstate program as well, State expenditures have in fact far exceeded minimal matching requirements (see figures III.5.1 and III.5.3). Accordingly, we have chosen to model the dependent variables in the SRAM as if Federal highway aid were provided on a conditional block grant basis (i.e. States expenditures enter the model inclusive of Federal grants).

For the Interstate grant program, our modelling convention may be somewhat suspect. In certain States, Interstate expenditures have apparently been set at a level indicative of a "corner solution" (see figure V.2.2). In other words, when State expenditures just equal minimal grant matching requirements (as indicated in figure V.2.2 by the tangency of utility curve UU^1 at the break point in the close-ended matching grant budget line R_0 a R_1'), it is unclear whether small changes in the level of Interstate grant funding would result in States reacting along the locus of budget line $R_2bR_2^1$ (as our modelling convention assumes) or R_0bR_2'.

CORNER SOLUTIONS IN THE SRAM

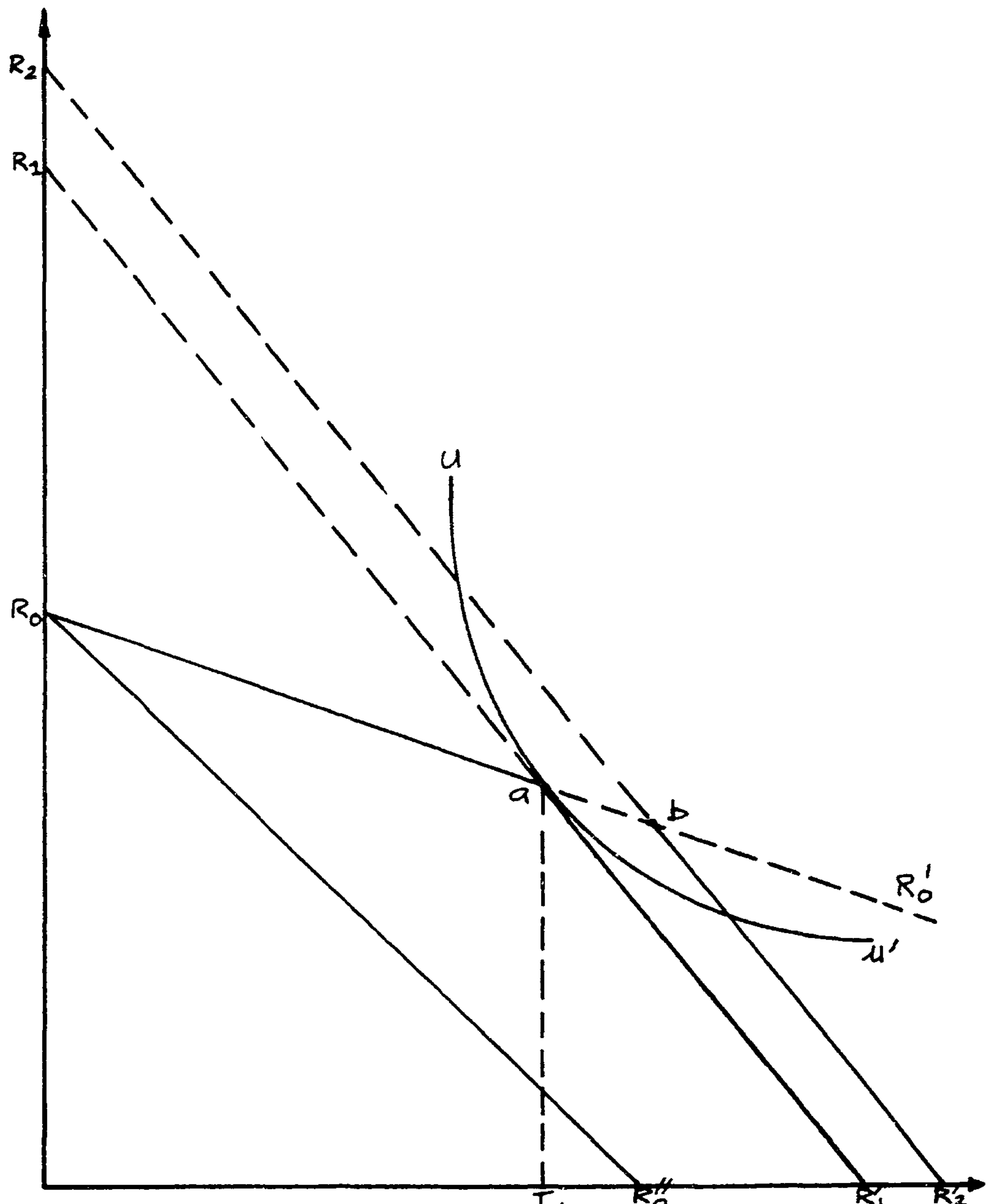


Figure V.2.2

Fortunately our convention of modelling Interstate grants as conditional block grants should not create any major problems. All States have exceeded minimal Interstate matching requirements over the course of our fourteen year study period. Although these "excess" expenditures are often relatively small, it should be noted that the Federal matching rate for the Interstate program -- as high as 95% -- approaches conditional block funding (100%) in any event.

It is useful at this point to summarize our development of the short run allocation model. The model is appealing for several reasons. First it derives from an explicit representation of State expenditure behavior that takes explicit account of the joint interaction between expenditure shares. The incorporation of a budget constraint in our analysis recognizes the fact that the decision to increase expenditures in one activity must be compensated with reduced expenditures in at least one other activity.[1] Second it provides a convenient framework for evaluating any number of allocation categories. For example, while we have not chosen to divide our highway construction categories (e.g. Interstate, Primary, Secondary Systems) into urban and rural components, dividing aggregate categories into several subcategories is easily facilitated. Finally, the SRAM takes explicit account of alternative grant structures.

---

[1] In fact our adoption of a utility function with no a priori assumptions on homogeneity properties guarantees that the expenditure shares sum to one regardless of the parameter estimates of the SRAM.

Although our application was restricted to the representation of Federal aid as conditional block grants, the analysis framework is perfectly general in the way it treats differing grant structures.[1]

---

1 For example, Tresch (op.cit.) employed a model similar to the SRAM to evaluate the impacts of open-ended conditional matching Welfare grants.

V.3 Statistical Properties and Estimation Procedures

In the derivation of the short run allocation model presented in the previous section, care was taken to account for the joint interaction between State highway allocation decisions. Specifically, our explicit representation of a States' highway budget constraint implies that the decision to increase highway expenditures on one activity (share) must be "compensated" by a decrease in expenditures devloted to at least one other activity. The choice of this analysis framework places special requirements on both the manner in which the individual structural equations enter the model, and the proper estimation techniques to ensure efficient, unbiased parameter estimates.

We have already briefly discussed the former issue. Because the sum of a States' expenditure shares must equal 1.0, it is clear that the individual share equations are not independent. Operationally, this implies that it is not possible to separately estimate each share equation. In fact, as displayed in figure V.2.2, the entire set of expenditure shares are estimated in one equation. This matrix representation of the SRAM ensures proper treatment of the joint interaction between allocation decisions, and provides a unique set of estimates for the coefficients of the "normalizing share"

While the structure of the short run allocation model has appealing theoretical properties, it is clear that our behavioral assumptions create inherent problems in obtaining efficient and unbiased parameter estimates. Specifically, in light of the interaction between shares, it is generally not appropriate for the estimation procedure to ignore these interrelationships as <u>ordinary least squares</u> must necessarily do.[1]

To clarify the statistical problems inherent in estimating the SRAM, it is convenient to rewrite the error term specification in figure V.2.2 as U_{nts} to emphasize the representation of our individual observations in terms of a specific State, year and share. In this notation:

n = 1, ...N = State number

t = 1, ...T = year

s - 1, ...S = share number

In the pooled data set where the 48 States and 14 years are combined in a single regression, the variance-covariance matrix of the residual terms may be written as:

$$(19) \qquad \Omega = E[u_{nts}u'_{nts}]$$

---

[1] The "interrelationships" between shares imply a covariance between the residuals of our individual structural equations. Thus the variance-covariance matrix of the error terms is not scalar, and ordinary least squares estimation is not appropriate.

$$= \begin{vmatrix} \omega_{11} & \omega_{12} & \cdots & \omega_{1s} \\ \omega_{21} & \omega_{22} & \cdots & \omega_{2s} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \omega_{s1} & \omega_{s2} & \cdots & \omega_{ss} \end{vmatrix}$$

where: ω_{ii} = an NTxNT matrix of variances and covariances between the residuals of the N States over T years for share i (i=1,...S)

ω_{ij} = an NTxNT matrix of covariances between the residuals of share i and share j for N States and T years.

Following the discussion of the previous section, it is reasonable to assume that within a State in a given year, errors across expenditure categories (shares) <u>are</u> correlated. This statement merely expresses in econometric terms the basic SRAM premise that allocation decisions are interrelated. As a computational necessity, we have been forced to qualify the above statement by assuming that errors are independently distributed across States and years and inter-share covariance terms are distributed identically for all States and years:

(20)

$$E[u_{nts}u'_{n't's'}] = \begin{cases} \xi_{ss'} \text{ if } n=n' \underline{\text{ and }} t=t' \\ 0 \text{ if } n \neq n' \text{ and/or } t \neq t' \\ \phi_{ss} \text{ if } n=n' \text{ and } t=t' \text{ and } s=s' \end{cases}$$

While the simplification in the assumed error structure represented by equation (20) may be questioned, it must be remembered that we are dealing with an extremely large variance-covariance matrix. The ultimate use of generalized least squares estimation requires the inversion of the NTSxNTS matrix Ω. In our application where N=48, T=14 and S=5[1], Ω (3360x3360) contained over 11 million elements. We have attempted to model the most significant behavioral interactions in keeping with an operation estimation procedure.[2]

---

[1] Actually, the short run allocation model incorporated six distinct expenditure categories. But as discussed in section V.2, our "normalizing" procedure transforms transforms the basic structural specification into a single regression equation with S-1 shares

[2] Perhaps the most dubious assumption inherent in equation (20) is that within a given State, errors are distributed independently over time. It may also be hypothesized that (at least for bordering States) within a given year for a given share (particularly for the Interstate share), errors between States are correlated. We have actually tried to explicitly model these interactions. These experiments proved to be exceedingly expensive and impractical.

Substituting the assumptions inherent in equation (20) in equation (19) yields the basic structure of the variance-covaraince matrix of the SRAM residual terms. Using the notation of equation (19) we may now assert the basic form of Ω :

$$(21) \qquad \omega_{ss} = \begin{vmatrix} \phi_{ss} & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & \phi_{ss} & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ 0 & 0 & \cdot & \cdot & \cdot & \phi_{ss} \end{vmatrix}$$

$$(22) \qquad \omega_{ss'} = \begin{vmatrix} \xi_{ss'} & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & \xi_{ss'} & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ 0 & 0 & \cdot & \cdot & \cdot & \xi_{ss'} \end{vmatrix}$$

The development of generalized least squares parameter estimates, given the assumed structure of the variance-covariance matrix (equations 21 and 22) is straightforward. Following the procedure outlined in section IV.3, we first perform an OLS estimation of the short run allocation model. Using the OLS <u>estimates</u> of the residual terms U_{nts}, and the assumed structure of the variance covariance matrix, we may derive the parameters of Ω by:[1]

$$(23) \qquad \phi_{ss} = \frac{1}{NT} \sum_{n=1}^{N} \sum_{t=1}^{T} \hat{u}^2_{nts} \qquad s=1,\ldots,S$$

$$(24) \qquad \xi_{ss'} = \frac{1}{NT} \sum_{n=1}^{N} \sum_{t=1}^{T} \hat{u}_{nts}\hat{u}_{nts'} \qquad \begin{array}{l} s=1,\ldots,S-1 \\ s'=2,\ldots,S \end{array}$$

The estimates of ϕ_{ss} and $\xi_{ss'}$ are then employed in determining the Choleski decomposition of Ω (see equation (15) of chapter IV). Finally, our original data set is transformed by the Choleski decomposition matrix and another regression is performed to produce generalized least squares parameter estimates.

In summary, we have attempted in this section to derive an operational procedure for estimating efficient and unbiased parameter estimates of the short run allocation model. Particular attention has been given to the proper econometric treatment of the assumed interaction between expenditures on individual highway activities. The next section presents the actual specification of variables employed in the SRAM that was estimated in this research.

---

[1] Equations (23) and (24) express the average value of all elements of $U_{nts}U'_{nts}$ corresponding to where ϕ_{ss} or $\xi_{ss'}$ appear in our assumed structure of Ω.

V.4 Modelling Considerations and Data Requirements

The short run allocation model consists of six distinct structural equations corresponding to expenditures devoted to Interstate System construction, Primary System construction, Secondary System construction, non-Federal-Aid System construction, maintenance activities (an all road systems) and on "other" category capturing State expenditures administration, highway police and safety, bond interest and grants to local governments. These six shares are representative of the three major Federally aided highway activities, and the three major non-aided State highway functions. As such, we are able to trace not only how a Federal grant effects expenditures on the aided functions, but the resulting tradeoff and complementary allocation responses among all major activities as well.

The dependent variable in each of the SRAM (structural) equations represents the share of a State's total expenditures devoted to a particular highway activity. The explanatory variables, as in the total expenditure model (Chapter IV) fall into four categories: socio-economic indicators (e.g. population and per capita income), highway system characteristics (e.g. highway capital stocks and congestion levels), institutional characteristics (e.g. local government participation and toll road financing conventions), and Federal grant availability.

The actual form of the short run allocation model is displayed in Figure V.4.1 for the product form specification.[1] Several

---

[1] A similar specification of variables was also employed in estimating an exponential form model (c.f. equation 13).

characteristics of the SRAM are immediately apparent. First, we have represented Federal highway grant availability in terms of each of the major Federal-Aid-Systems - Interstate, Primary and Secondary.[1] Contrastingly, the total expenditure model of the previous chapter disaggregated grant availability only in terms of an Interstate and non-Interstate designation. A second characteristic of the SRAM is that individual constant terms have been incorporated in all but one of the share equations. The exclusion of a constant from the maintenance equation (which in fact was chosen as our "normalizing share") was dictated by the fact that in a shares-type model specification the matrix of explanatory variables will not be of full column rank if a particular variable appears in each structural equation.[2]

Finally, it should be noted that in estimating the short run allocation model, the maintenance equation was chosen to normalize each of the five remaining shares in the manner described by equation (10). The choice of a particular normalizing share will

---

[1] Grants for extensions of the Federal Aid Primary and Secondary Systems in urban areas ("C" funds) were added to terms representing Primary and Secondary System grant availability. This modelling convention reflects the fact "C" funds may be used for either Primary or Secondary system construction.

[2] Thus it may also be noted that the population variable, SPOP appears in all but the share representing construction expenditures on non-Federal-Aid Systems (see Figure V.4.1).

in general affect the empirical results.[1] Ultimately, the maintenance equation was selected as the normalizing share for no other reason than that expenditure data on this function appeared to be less reliable than for the remaining categories.[2]

Before presenting the estimation results derived from the SRAM, it is useful to set forth a brief description of the variables employed in each of the expenditure shares. Figure V.4.1 displays the form of the entire set of SRAM equations.

---

[1] Regardless of which equation is chosen as normalizing share, our estimation procedures should provide efficient and inbiased parameter estimates. Nonetheless, <u>for a given data sample</u>, we may expect small differences in the estimated model parameters depending on the choice of a normalizing share.

[2] Some variability exists in the States' data reporting conventions. A project considered to be a maintenance activity in one State might be reported as a construction expenditure by another State.

THE SHORT RUN ALLOCATION MODEL

SHARE 1: $$\frac{E_1}{E_T} = a_{10} SPOP^{a_{11}} UFAC^{a_{12}} KSTK^{a_{13}} TOLPCT^{a_{14}} AVIG^{a_{15}} AVNIG^{a_{16}}$$

SHARE 2: $$\frac{E_P}{E_T} = a_{20} SPOP^{a_{21}} UFAC^{a_{22}} KSTK^{a_{23}} AVPG^{a_{24}} AVIG^{a_{26}}$$

SHARE 3: $$\frac{E_S}{E_T} = a_{30} SPOP^{a_{31}} UFAC^{a_{32}} GINI^{a_{33}} TSPMR^{a_{34}} PCCRMT^{a_{35}} AVSG^{a_{36}} AVIG^{a_{37}}$$

SHARE 4: $$\frac{E_N}{E_T} = a_{40} UFAC^{a_{41}} PCCRMT^{a_{42}} RLTOT^{a_{43}} AVIG^{a_{44}}$$

SHARE 5: $$\frac{E_M}{E_T} = a_{50} SPOP^{a_{51}} KSTK^{a_{52}} PCMF^{a_{53}} RLTOT^{a_{54}} AVTG^{a_{55}}$$

SHARE 6: $$\frac{E_O}{E_T} = a_{60} SPOP^{a_{61}} PCY^{a_{62}} KSTK^{a_{62}} RLTOT^{a_{63}} AVTG^{a_{64}}$$

Figure V.4.1

E_I = total State Interstate expenditures (State and Federal)

E_P = total Primary System expenditures

E_S = total Secondary System expenditures

E_N = non-Federal-Aid System construction expenditures

E_M = maintenance expenditures

E_O = "other" expenditures (administration, grants to local govts., miscellaneous expenditures)

E_T = total expenditures: sum of the above expenditures

SPOP = State population

UFAC = percent of population residing in urban areas

KSTK = present discounted value of highway capital stock

TOLPCT = percent of total State revenues raised on State-administered toll roads

AVIG = apportioned Interstate grants (three year moving average)

AVNIG = apportioned "ABC" grants (three year moving average)

AVPG = apportioned Primary System grants (three year moving average)

AVSG = apportioned Secondary System grants (three year moving average

AVTG = apportioned total grants (three year moving average)

GINI = index of income inequality

TSPMR = State rural primary system mileage

PCCRMT = percent of rural primary system mileage carrying more than 10,000 ADT

PCMF = percent of total primary system mileage carrying more than 5,000 ADT

RLTOT = percent of total expenditures (all units of govt.) contributed by local governments

PCY = State per capita income

aij = estimated coefficients

Figure V.4.1 (contd.)

Equation 1 - The Interstate Construction Share[1]

Six variables in addition to a constant term were employed in the Interstate construction expenditure share equation. State size and urban density are characterized by the variables SPOP and UFAC respectively. With regard to the latter variable, we may expect higher levels of urban density to positively influence Interstate expenditure allocations, in light of the sharply increased costs of urban versus rural highway construction of Interstate standards.[2] A measure of existing highway stock in place is afforded by the variable KSTK, derived according to the conventions presented in section IV.3. An institutional characteristic bearing particular importance on a States' Interstate expenditure behavior is the extent of toll road financing, TOLPCT. In the early years of the

---

[1] Throughout the following presentation, unless otherwise indicated the definitions and sources of data employed in the SRAM are the same as previously described in the development of the total expenditure model (see section IV.3).

[2] The relatively high costs of urban Interstate construction stem from the marked difference between ROW acquisition costs in urban and rural areas. Moreover, Interstate expenditures are particularly sensitive to land costs, since this System's design standards require more ROW than other highway systems.

Interstate program, several States chose to finance Interstate highway construction through the use of revenue bonds based on toll road operation. In fact the responsibility to construct and maintain these Interstate route segments was often delegated to a quasi-public Turnpike Authority.[1] As such, all toll-financed Interstate activities are not reported in our data as State expenditures. Accordingly, we should expect the extent of toll-road financing (TOLPCT) to negatively influence a States' allocation of resources to construction on the Interstate System.

The final two variables in the Interstate equation reflect Federal grant availability on the Interstate (AVIG) and non-Interstate (AVNIG) Systems. Results from the total expenditure model (TEM) indicate that Interstate grants tend to stimulate State (total) expenditures. The SRAM allows us to determine the extent to which these grants have increased States' allocations specifically to Interstate construction. The States' Interstate expenditure response to the presence of non-Interstate grants may actually take one of two directions. On the one hand, we might expect increasing levels of non-Interstate grants to "draw away" resources that would otherwise have been devoted to Interstate construction. However, as we have shown in chapter IV, the ABC grant program has been viewed by the States as a substitute for their own ABC expenditures. In

---

[1] It should also be noted that toll-financed Interstate roads are not eligible for Federal aid as stipulated by Title 23, United States Code, Section 301.

this perspective, increasing levels of ABC grants may "free up" State resources that may be allocated on Interstate construction as well as other State highway activities. In the SRAM, we will appeal to the data to verify the latter hypothesis.

Equation 2 - The Primary System Construction Share

This equation contains the same socio-economic and highway capital stock measures employed in the Interstate equation. However, we should expect the States' Primary System expenditure responses to these variables to differ from the expected responses expressed by the Interstate share equation. For example, the urban density measure should not exhibit as marked a positive influence on Primary System expenditures because of the previously noted difference in Primary System and Interstate System right of way requirements.

Federal aid availability in this equation was represented by two terms -- the level of Primary System grants (AVPG) and the level of Interstate System grants. The direct effect of Primary System grants on State Primary System expenditures must be positive.[1]

---

[1] Note that the dependent variables in the SRAM reflect total expenditure levels inclusive of Federal grants. Even assuming that States need not raise their expenditure levels on the Primary System to match increasing Federal Primary System grant availability (because current State expenditure levels far exceed minimal matching requirements), it is extremely unlikely that States would decrease their own resource allocation to the Primary System by more than the amount of Federal grant increases. This point will become clearer in section V.6 where elasticity measures are presented for the SRAM. Suffice it to say here that we expect small increases in Primary System grant availability - say 1% - to increase States' Primary System expenditure allocation, but most likely by an amount less than 1% (indicative of a substitutive grant response).

The more important question is how these grants have influenced States' own resource allocation on the Primary System. The empirical results presented in the following sections will serve to verify our previous hypotheses on the substitutive expenditure impacts of Primary System grants. As for the States' Primary System expenditure response to Interstate grants, we should expect a negative influence. That is, our findings to this point suggest that the Interstate grant program has increased State highway investment levels. The SRAM estimation results will indicate the extent to which these increased investment levels have come at the expense of resource allocation to other State highway activities.

Equation 3 - The Secondary System Construction Share

Eight variables (including the constant term) were used to express the factors influencing States' Secondary System allocation decisions. Since the relative importance of the Secondary System in a State's highway network is greatest in the predominantly rural/agricultural States,[1] we should expect the population variable SPOP, and the urban density measure UFAC to negatively influence Secondary System expenditure allocation. By the same reasoning the GINI index of income inequality (which was shown to be highest in rural/agricultural States -- see figure IV.4.2) should relate positively to Secondary System expenditure levels.

---

[1] As noted in section II.2.iii, the Federal-Aid Secondary System comprises farm-to-market roads, rural mail routes, public school bus routes, local rural roads, county roads, and township roads.

In addition to these socio-economic indices, two descriptors of the States' rural highway systems were included in the Secondary System SRAM equation. The first, total State rural highway mileage[1] (TSPMR), indicates the scale of the existing rural highway network. A second measure, PCCRMT provides a measure of the level of congestion on the States' rural roads.[2] Specifically, this variable represents the percent of a State's rural highway mileage carrying more than 10,000 vehicles per day. We should expect higher levels of rural highway traffic to influence a State to increase Secondary System construction expenditures.

---

1 This variable describes total State (i.e. exclusive of roads under county or municipal jurisdiction) highway mileage. Data were derived from yearly editions of the Federal Highway Administration's HIGHWAY STATISTICS (op. cit.)

2 HIGHWAY STATISTICS (op. cit.) reports traffic volume data in terms of seven distinct ADT categories, ranging from a State's mileage carrying less than 5000 ADT to the number of miles bearing greater than 40000 ADT. The variable PCCRMT was derived from this source by dividing the rural mileage carrying greater than 10000 ADT, by total rural mileage.

The final two variables in the Secondary System share equation describe Federal grant availability for the Secondary (AVSG) and Interstate (AVIG) Systems. The expected expenditure responses in this instance should follow our discussion of hypothesized grant response in the Primary System equation. Specifically, increased in Federal Secondary aid should raise States' Secondary expenditures, but by an amount less than a grant increase. Interstate grants on the other hand may be expected to decrease States' Secondary expenditure levels.

Equation 4 - The Non-Federal Aid System (NFAS) Construction Share

In addition to their construction of Interstate, Primary and Secondary System highways, States also (wholly) finance the construction of roads apart from the Federal-Aid System designation. This activity represents a relatively minor expenditure of funds (averaging less than 10% for our 48 State/14 year sample), and most commonly represents rural highway construction. Four variables (and a constant term) were included in this expenditure share. Perhaps the most significant factor explaining the level of non-Federal-Aid System expenditures is the degree of local highway participation in highway finance (RLTOT). States differ markedly in the extent to which counties and municipalities assume the authority to construct and maintain local road networks. Since the SRAM is structured strictly in terms of State activities, we would expect RLTOT to negatively influence (State) expenditures on non-Federal Aid System roads. The parameter estimate of the urban density measure, UFAC should also be negative, reflecting the high incidence of non-Federal Aid System construction in rural areas.

Our discussion so far provides the basis for the expected signs of the parameter estimates of the two remaining variables included in this expenditure share -- the degree of rural road congestion (PCCRMT) and Federal Interstate grant availability (AVIG). Again noting the relatively high incidence of NFAS construction in rural areas, we should expect the presence of rural road congestion to induce higher expenditure levels on this activity. Increases in Interstate grant availability should, on the other hand decrease State expenditures on NFAS construction, as States devote an increasing share of their highway budget to expenditures on the aided function.

Equation 5 - The Maintenance Expenditure Share

The maintenance expenditure share contains five explanatory variables -- State population (SPOP), depreciated highway capital stocks (KSTK), a highway congestion measure (PCMF), the extent of local participation in highway finance (RLTOT) and the level of total Federal grant availability (AVTG). As in the previous share equation, to the extent that a State delegates highway authority to county and municipal governments, (State) maintenance expenditures should decrease. That is, we should expect a negative coefficient for the RLTOT term.

Although we might expect both of the highway system characteristics variables, KSTK and PCMF to positively influence States' maintenance expenditures, this response pattern need not necessarily pertain. We refer here to the differing State policies regarding the performance of highway maintenance activities. If all

States practiced a uniform maintenance policy,[1] then increasing congestion levels and/or increasing highway capital stocks would increase highway maintenance requirements. But we may also observe that some States adopt a highway policy favoring construction (as opposed to maintenance) expenditures. Thus, relatively high levels of existing capital stock actually (may) signal an explicit policy of constructing highway facilities "at the expense" of maintenance operations.[2] Similarly, higher congestion levels may induce States to increase construction expenditures rather than maintenance operations. The SRAM allows for a specific test of these conflicting hypotheses.

We have also included a term in the maintenance share equation representing total Federal highway grant availability. The intent here is to assess whether the presence of Federal aid has tended to divert State expenditures from non-aided (i.e. maintenance) highway activities.

---

[1] For example, attempting to implement a specific policy to maintain uniform road surface quality. See Findakly, H.K., A DECISION MODEL FOR INVESTMENT ALTERNATIVES IN HIGHWAY SYSTEMS, Unpublished ScD Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, September, 1972.

[2] As reported in our data, a major resurfacing project would be recorded as a construction expenditure. Maintenance expenditures are reported for patching, sealing and filling of road surfaces.

Equation 6 - The "Other" Expenditures Share

The final share in our SRAM formulation captures expenditures on all other State highway activities not included in the first five equations. Specifically, this category is comprised of expenditures on administration, highway police and safety, debt service payments, and grants to local governments. Five variables (plus a constant term) were incorporated in this SRAM equation. The first three, SPOP, PCY and KSTK should all positively influence "other" expenditures since States with relatively high populations, per capita incomes and existing highway networks can be expected to support relatively large highway-related administrative organizations (e.g. State Highway Departments and State Departments of Transportation).

As in our previous share equations, the delegation of highway authority to lower units of government should decrease the administrative requirements of State highway organizations. This effect is captured in the variable RLTOT, which should be associated with a negative coefficient estimate. Finally, a total Federal-aid term was included (AVTG) to evaluate the impacts of Federal highway grants on the performance of States' administrative and other higheay activities.

V.5 Empirical Results -- Parameter Estimates of the SRAM

As in the empirical analysis of the total expenditure model, lack of sufficient time series data precluded statistically reliable State by State estimation of the short run allocation model. Thus three separate pooled data regressions were performed,[1] corresponding to:

- the entire set of observations on the 48 States over 14 years (1957-1970).
- a subset of time series observations on the seven States exhibiting the lowest level of Interstate expenditures over and above minimum matching requirements, and
- the subset comprising observations on the 41 remaining States over the 14 year period 1957-1970.

As described in section V.2, estimation of the SRAM was performed for two alternative specifications of the individual structural (share) equations - a product form model, and an exponential form model.

---

[1] These data set stratifications are similar to the modelling strategy followed in chapter IV. The seven States with conspicuously low "excess" Interstate expenditures were Missouri, Montana, North Carolina, North Dakota, South Carolina, Vermont and Virginia.

The complete set of estimation results from the short run aallocation model are reproduced in Figures V.5.1 - V.5.8. In these figures, the results are displayed for each of the six expenditure shares.[1] In each share equation, the figures indicate the individual parameter estimates, standard errors and t-statistics <u>in that order</u>.

Figures V.5.1 and V.5.2 display the model parameters from the product form specification on the full pooled data set using OLS and GLS estimation respectively. The next four figures correspond to OLS and GLS estimation of the two data subsets of the SRAM in the product form specification. Finally, Figures V.5.7 and V.5.8 display the respective OLS and GLS estimations of the exponential form SRAM on the full pooled data set.

The empirical results from the short run allocation model are most easily interpreted in terms of elasticities and derivatives of the categorical expenditures with respect to the explanatory variables incorporated in our analysis. This will be our task in the next two sections of this chapter.

---

[1] The notation used in the figures to denote expenditure share equations is as follows: INT- Interstate construction, PRI - Primary System construction, SEC - Secondary System construction, NON - non-Federal Aid System construction, MNT- maintenance, and OTH - all other expenditures.

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: ORDINARY LEAST SQUARES

F-STAT: F(37,3323)=25.976 SEE= 1.037 RSQ= 0.200

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.36E 01	-0.14E 01	0.46E 00	-0.59E 00	-0.78E-01	0.98E 00	-0.27E-01
INT	0.15E 01	0.17E 00	0.17E 00	0.16E 00	0.28E-01	0.33E 00	0.22E 00
	-2.51	-8.49	2.72	-3.76	-2.73	2.93	-0.12

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	-0.42E 01	-0.12E 01	-0.83E-03	-0.40E 00	0.66E 00	0.13E 00
PRI	0.14E 01	0.16E 00	0.17E 00	0.16E 00	0.21E 00	0.33E 00
	-2.95	-7.48	-0.00	-2.55	3.07	0.38

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	-0.17E 01	-0.11E 01	-0.15E 00	-0.86E-01	0.26E 00	0.67E-02	0.45E 00	-0.58E-01
SEC	0.19E 01	0.13E 00	0.18E 00	0.32E 00	0.10E 00	0.42E-01	0.19E 00	0.34E 00
	-0.88	-7.87	-0.85	-0.27	2.49	0.16	2.35	-0.17

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	-0.97E 01	-0.77E 00	0.21E 00	-0.49E 00	-0.89E-01
NON	0.12E 01	0.17E 00	0.34E-01	0.66E-01	0.50E 00
	-7.91	-4.38	6.20	-7.42	-0.18

		SPOP	KSTK	PCMF	RLTOT	AVTG
		-0.86E 00	-0.14E 00	0.37E-01	-0.97E-01	0.21E 00
MNT		0.10E 00	0.93E-01	0.30E-01	0.34E-01	0.49E 00
		-8.54	-1.55	1.22	-2.88	0.43

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	-0.10E 02	-0.10E 01	0.94E 00	-0.75E 00	0.11E-01	0.54E 00
OTH	0.19E 01	0.15E 00	0.22E 00	0.19E 00	0.65E-01	0.51E 00
	-5.41	-6.78	4.23	-3.95	0.16	1.06

Figure V.5.1

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: GENERALIZED LEAST SQUARES

F-STAT: F(37,3323)=56.815 SEE= 0.997 RSQ= 0.354

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.70E 01	-0.15E 01	0.44E 00	-0.19E 00	-0.82E-01	0.12E 01	0.15E 00
INT	0.16E 01	0.24E 00	0.89E-01	0.19E 00	0.14E-01	0.25E 00	0.14E 00
	-4.52	-6.27	4.92	-1.03	-5.72	4.84	1.09

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	-0.58E 01	-0.63E 00	-0.16E 00	0.86E-01	0.71E 00	-0.92E-01
PRI	0.14E 01	0.16E 00	0.74E-01	0.13E 00	0.99E-01	0.16E 00
	-4.12	-4.01	-2.10	0.69	7.14	-0.57

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	0.27E 01	-0.54E 00	-0.24E 00	0.33E 00	0.31E 00	0.38E-01	0.31E 00	-0.11E 00
SEC	0.17E 01	0.69E-01	0.78E-01	0.14E 00	0.46E-01	0.18E-01	0.77E-01	0.81E-01
	1.56	-7.94	-3.13	2.31	6.74	2.07	3.97	-1.34

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	-0.48E 01	-0.85E 00	0.19E 00	-0.52E 00	0.23E 00
NON	0.12E 01	0.34E 00	0.60E-01	0.11E 00	0.36E 00
	-4.06	-2.48	3.21	-4.57	0.63

	SPOP	KSTK	PCMF	RLTOT	AVTG
	-0.90E 00	0.26E 00	0.78E-02	-0.71E-01	0.57E 00
MNT	0.23E 00	0.18E 00	0.26E-01	0.23E-01	0.37E 00
	-3.91	1.46	0.30	-3.10	1.51

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	-0.14E 02	0.23E 00	0.82E 00	-0.93E-01	-0.18E-02	-0.25E 00
OTH	0.17E 01	0.55E-01	0.85E-01	0.71E-01	0.22E-01	0.73E-01
	-8.02	4.18	9.66	-1.31	-0.79	-3.44

Figure V.5.2

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: ORDINARY LEAST SQUARES

F-STAT: F(37, 453)=12.449 SEE= 0.793 RSQ= 0.468

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.35E 01	-0.18E 01	0.48E-01	-0.20E 00	0.31E-01	0.81E 00	0.30E 00
INT	0.48E 01	0.34E 00	0.56E 00	0.31E 00	0.60E-01	0.79E 00	0.47E 00
	-0.74	-5.22	0.09	-0.64	0.52	1.03	0.64

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	-0.13E 01	-0.13E 01	0.58E 00	-0.10E 00	0.64E 00	0.73E-02
PRI	0.47E 01	0.33E 00	0.56E 00	0.31E 00	0.44E 00	0.77E 00
	-0.28	-4.13	1.04	-0.34	1.45	0.01

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	0.35E 01	-0.14E 01	0.14E 01	-0.28E 00	0.17E 01	-0.12E 00	-0.59E 00	-0.14E-01
SEC	0.54E 01	0.36E 00	0.64E 00	0.95E 00	0.77E 00	0.14E 00	0.79E 00	0.82E 00
	0.64	-3.99	2.18	-0.29	2 23	-0.86	-0.75	-0.02

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	0.34E 01	-0.12E 01	0.49E 00	-0.28E 00	-0.91E 00
NON	0.51E 01	0.56E 00	0.10E 00	0.15E 00	0.13E 01
	0.66	-2.12	4.84	-1.93	-0.72

		SPOP	KSTK	PCMF	RLTOT	AVTG
		-0.79E 00	0.50E-02	0.54E-01	-0.85E-01	0.18E-01
MNT		0.22E 00	0.13E 00	0.74E-01	0.76E-01	0.12E 01
		-3.68	0.03	0.73	-1.13	0.02

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	0.18E 01	-0.10E 01	0.70E-01	0.27E 00	-0.55E-01	0.75E-01
OTH	0.48E 01	0.29E 00	0.60E 00	0.40E 00	0.14E 00	0.12E 01
	0.38	-3.53	0.12	0.66	-0.38	0.06

Figure V.5.3

SHARE MODEL

ESTIMATION RESULTS

SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: GENERALIZED LEAST SQUARES

F-STAT: F(37, 453)=17.321 SEE= 1.039 RSQ= 0.550

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.94E 01	-0.16E 01	0.12E 00	0.13E 00	0.22E-01	0.81E 00	0.14E 00
INT	0.64E 01	0.29E 00	0.33E 00	0.23E 00	0.36E-01	0.50E 00	0.29E 00
	-1.48	-5.37	0.35	0.59	0.60	1.62	0.47

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	-0.31E 01	-0.80E 00	0.61E 00	0.19E 00	0.48E 00	-0.18E 00
PRI	0.62E 01	0.22E 00	0.26E 00	0.18E 00	0.21E 00	0.38E 00
	-0.50	-3.63	2.31	1.06	2.25	-0.49

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	0.80E 01	-0.10E 01	0.97E 00	-0.19E 00	0.13E 01	-0.24E-01	-0.32E 00	-0.73E-01
SEC	0.70E 01	0.19E 00	0.28E 00	0.41E 00	0.33E 00	0.60E-01	0.34E 00	0.32E 00
	1.15	-5.59	3.51	-0.46	3.94	-0.40	-0.94	-0.23

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	0.24E 01	-0.62E 00	0.36E 00	-0.35E 00	-0.13E 01
NON	0.66E 01	0.11E 01	0.18E 00	0.25E 00	0.13E 01
	0.36	-0.59	1.99	-1.38	-1.02

		SPOP	KSTK	PCMF	RLTOT	AVTG
		-0.69E 00	0.32E 00	0.12E 00	-0.58E-01	-0.62E-01
MNT		0.24E 00	0.18E 00	0.51E-01	0.48E-01	0.77E 00
		-2.84	1.78	2.42	-1.22	-0.08

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	0.97E 00	-0.32E 00	0.28E 00	0.45E 00	-0.94E-01	-0.22E 00
OTH	0.65E 01	0.15E 00	0.20E 00	0.16E 00	0.49E-01	0.43E 00
	0.15	-2.21	1.37	2.87	-1.92	-0.51

Figure V.5.4

SHARE MODEL

ESTIMATION RESULTS

SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: ORDINARY LEAST SQUARES

F-STAT: F(37,2833)=19.817 SEE= 1.058 RSQ= 0.183

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG	
	-0.34E 01	-0.12E 01	0.32E 00	-0.57E 00	-0.13E 00	0.94E 00	-0.15E 00	
INT	0.16E 01	0.20E 00	0.19E 00	0.18E 00	0.34E-01	0.37E 00	0.25E 00	
	-2.16	-5.80	1.71	-3.09	-3.92	2.53	-0.60	
	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG		
	-0.44E 01	-0.10E 01	-0.16E 00	-0.44E 00	0.68E 00	0.11E 00		
PRI	0.15E 01	0.18E 00	0.19E 00	0.18E 00	0.24E 00	0.37E 00		
	-2.88	-5.81	-0.85	-2.45	2.78	0.30		
	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	-0.23E 01	-0.94E 00	-0.44E 00	0.33E-01	0.25E 00	0.32E-01	0.56E 00	-0.93E-01
SEC	0.21E 01	0.15E 00	0.20E 00	0.34E 00	0.11E 00	0.46E-01	0.22E 00	0.38E 00
	-1.10	-6.30	-2.14	0.10	2.18	0.70	2.59	-0.24
	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG			
	-0.11E 02	-0.73E 00	0.18E 00	-0.45E 00	0.78E-01			
NON	0.13E 01	0.20E 00	0.36E-01	0.73E-01	0.56E 00			
	-8.24	-3.70	5.07	-6.17	0.14			
		SPOP	KSTK	PCMF	RLTOT	AVTG		
		-0.80E 00	-0.19E 00	0.23E-01	-0.56E-01	0.28E 00		
MNT		0.11E 00	0.10E 00	0.34E-01	0.37E-01	0.55E 00		
		-7.05	-1.82	0.69	-1.51	0.51		
	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG		
	-0.94E 01	-0.90E 00	0.72E 00	-0.77E 00	-0.96E-03	0.59E 00		
OTH	0.21E 01	0.17E 00	0.24E 00	0.21E 00	0.73E-01	0.56E 00		
	-4.46	-5.20	2.94	-3.59	-0.01	1.05		

Figure V.5.5

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: PRODUCT FORM MODEL

REGRESSION METHOD: GENERALIZED LEAST SQUARES

F-STAT: F(37,2833)=49.481 SEE= 1.000 RSQ= 0.359

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.79E 01	-0.11E 01	0.26E 00	-0.25E 00	-0.14E 00	0.11E 01	0.96E-01
INT	0.17E 01	0.22E 00	0.87E-01	0.18E 00	0.16E-01	0.25E 00	0.14E 00
	-4.71	-4.72	3.02	-1.37	-9.27	4.60	0.69

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	-0.70E 01	-0.53E 00	-0.30E 00	-0.53E-02	0.81E 00	-0.44E-01
PRI	0.15E 01	0.16E 00	0.84E-01	0.14E 00	0.11E 00	0.18E 00
	-4.72	-4.28	-3.62	-0.04	7.18	-0.25

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	0.25E 01	-0.51E 00	-0.39E 00	0.38E 00	0.32E 00	0.40E-01	0.30E 00	-0.48E-01
SEC	0.19E 01	0.72E-01	0.89E-01	0.15E 00	0.50E-01	0.20E-01	0.89E-01	0.93E-01
	1.33	-7.07	-4.39	2.48	6.54	2.02	3.35	-0.52

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	-0.47E 01	-0.71E 00	0.16E 00	-0.49E 00	0.48E 00
NON	0.12E 01	0.39E 00	0.66E-01	0.13E 00	0.45E 00
	-3.84	-1.82	2.51	-3.87	1.08

	SPOP	KSTK	PCMF	RLTOT	AVTG
	-0.64E 00	0.12E 00	-0.40E-01	-0.21E-01	0.63E 00
MNT	0.21E 00	0.17E 00	0.26E-01	0.23E-01	0.37E 00
	-3.05	0.74	-1.56	-0.92	1.69

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	-0.13E 02	0.21E 00	0.63E 00	-0.78E-01	-0.11E-01	-0.12E 00
OTH	0.19E 01	0.64E-01	0.90E-01	0.79E-01	0.24E-01	0.91E-01
	-6.98	3.21	6.99	-1.00	-0.47	-1.34

Figure V.5.6

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: EXPONENTIAL FORM MODEL
REGRESSION METHOD: ORDINARY LEAST SQUARES
F-STAT: F(37,3323)=23.745 SEE= 1.046 RSQ= 0.186

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.29E 00	-0.32E-06	0.88E 00	0.37E 00	-0.66E 01	0.48E-08	-0.10E-07
INT	0.20E 00	0.43E-07	0.32E 00	0.17E 00	0.11E 01	0.13E-07	0.16E-07
	-1.44	-7.47	2.72	2.14	-6.07	0.36	-0.63

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	0.13E 00	-0.35E-06	-0.59E 00	-0.59E-01	0.29E-07	-0.16E-08
PRI	0.20E 00	0.47E-07	0.32E 00	0.17E 00	0.23E-07	0.13E-07
	0.65	-7.35	-1.86	-0.34	1.27	-0.12

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	-0.27E-01	-0.37E-06	-0.12E 01	-0.16E 00	0.14E-04	-0.30E 01	0.24E-07	0.15E-08
SEC	0.35E 00	0.42E-07	0.33E 00	0.80E 00	0.79E-05	0.86E 00	0.28E-07	0.13E-07
	-0.08	-8.94	-3.73	-0.21	1.80	-3.54	0.86	0.11

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	-0.14E 01	-0.14E 01	0.33E 01	-0.55E 01	-0.95E-08
NON	0.20E 00	0.33E 00	0.81E 00	0.46E 00	0.13E-07
	-6.93	-4.22	4.01	-11.97	-0.72

		SPOP	KSTK	PCMF	RLTOT	AVTG
		-0.29E-06	-0.43E-01	-0.39E 00	-0.13E 01	-0.22E-08
MNT		0.24E-07	0.10E 00	0.19E 00	0.24E 00	0.13E-07
		-12.14	-0.42	-2.05	-5.50	-0.17

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	-0.41E 00	-0.33E-06	0.18E-03	-0.32E 00	0.74E 00	0.21E-08
OTH	0.20E 00	0.34E-07	0.81E-04	0.20E 00	0.47E 00	0.13E-07
	-2.09	-9.78	2.22	-1.61	1.59	0.16

Figure V.5.7

SHARE MODEL
ESTIMATION RESULTS
SPECIFICATION: EXPONENTIAL FORM MODEL
REGRESSION METHOD: GENERALIZED LEAST SQUARES

F-STAT: F(37,3323)=41.469 SEE= 1.003 RSQ= 0.285

	CONSTANT	SPOP	UFAC	KSTK	TOLPCT	AVIG	AVNIG
	-0.45E 00	-0.18E-06	0.90E 00	0.62E 00	-0.67E 01	0.27E-07	0.13E-07
INT	0.20E 00	0.46E-07	0.18E 00	0.21E 00	0.64E 00	0.12E-07	0.13E-07
	-2.28	-3.92	4.88	3.02	-10.49	2.34	1.04

	CONSTANT	SPOP	UFAC	KSTK	AVPG	AVIG
	0.59E 00	-0.13E-06	-0.72E 00	0.44E-01	0.46E-07	0.13E-07
PRI	0.21E 00	0.36E-07	0.15E 00	0.15E 00	0.14E-07	0.86E-08
	2.88	-3.65	-4.70	0.28	3.37	1.51

	CONSTANT	SPOP	UFAC	GINI	TSPMR	PCCRMT	AVSG	AVIG
	-0.57E 00	-0.97E-07	-0.10E 01	0.40E 00	0.16E-04	-0.23E 01	0.26E-07	0.62E-08
SEC	0.33E 00	0.14E-07	0.15E 00	0.36E 00	0.35E-05	0.35E 00	0.11E-07	0.27E-08
	-1.70	-7.04	-6.86	1.12	4.65	-6.56	2.45	2.29

	CONSTANT	UFAC	PCCRMT	RLTOT	AVIG
	-0.58E 00	-0.98E 00	0.15E 01	-0.53E 01	0.24E-07
NON	0.19E 00	0.64E 00	0.14E 01	0.81E 00	0.13E-07
	-3.05	-1.54	1.01	-6.56	1.78

		SPOP	KSTK	PCMF	RLTOT	AVTG
		-0.15E-06	0.22E 00	-0.39E 00	-0.12E 01	0.20E-07
MNT		0.41E-07	0.19E 00	0.15E 00	0.17E 00	0.12E-07
		-3.56	1.15	-2.53	-6.83	1.75

	CONSTANT	SPOP	PCY	KSTK	RLTOT	AVTG
	-0.14E 01	-0.24E-07	0.39E-03	-0.51E 00	0.46E 00	0.36E-08
OTH	0.19E 00	0.13E-07	0.31E-04	0.79E-01	0.16E 00	0.25E-08
	-7.35	-1.82	12.64	-6.46	2.83	1.44

Figure V.5.8

However, several properties of the actual regression results should be noted here. Our generalized least squares estimation technique significantly improved the efficiency of the parameter estimates. For example, comparing figures V.5.1 and V.5.2 the Standard Error of Estimate (as noted by SEE in the figures) decreased from 1.037 in the OLS estimation to 0.997 for GLS estimation. More importantly, 25 of the 37 parameters in the SRAM had higher t-statistics in the GLS estimation than in OLS estimation.

The signs of the parameter estimates proved to be generally consistent with the a priori hypotheses advanced in section V.4. For example, referring to the third share equation in Figure V.5.2, it was found that a State's Secondary System expenditures tend to decrease with population, urbanization and Interstate grant availability, and increase with the level income inequality, rural highway mileage and congestion levels, and Secondary System grant availability.[1] A full discussion of the implications of the entire set of SRAM parameter estimates will be deferred to the next section.

Finally, it should be noted that the product form specification of the SRAM provided somewhat more efficient parameter estimates than the exponential form specification. Comparing Figures V.5.2 and V.5.8, it may be seen that the F-statistics, Standard Error of Estimate, R-squared, and 24 of the 37 paramters' t-statistics

---

[1] These findings may be compared with our a priori hypotheses advanced in section V.4

were higher for the product form SRAM specification. For this reason, further analysis of the exponential form SRAM was abandoned.[1]

[1]Estimations of the exponentail form model were not performed on our two data subsets. Furthermore, the policy implications of the SRAM regression results found in the next two sections are all based on the findings from the product form model.

V.6 Evaluation of the Elasticities and Derivatives From the Short Run Allocation Model

The estimation results from the short run allocation model are not immediately interpretable in a direct or simple fashion. Our immediate concern is not with the estimation coefficients themselves but with how the model predicts changes in expenditure allocation with respect to the variables incorporated in the analysis. A convenient way to describe these changes is with derivatives and elasticities.

In our application, the derivative of an expenditure share with respect to a variable in the SRAM may be defined as:

$$\text{(25)} \qquad \frac{\partial s_j}{\partial X_k} = \frac{\partial \dfrac{\alpha_j}{\sum_i \alpha_i}}{\partial X_k} = \frac{\partial}{\partial X_k} \frac{f_j(Z,\varepsilon_j)}{\sum_i f_i(Z,\varepsilon_i)}$$

where s_j = expenditure share j

x_k = explanatory variable k

α_i = parameters of the utility function

f_i = structural (share) equation in the SRAM

The second and third terms of this equation follow directly from our derivation of the SRAM (c.f. equation 9). For our purposes here, the form of equation (25) has two important characteristics. First, it is clear that the derivatives are expressed as a function of the parameter estimates of the short run allocation model. And second, it may be seen that the variables included in any one share will have an effect on the derivatives (and elasticities) of all the shares in the SRAM.

Formally, this statement may be expressed as:

$$(26) \qquad \sum_{i=1}^{S} s_i \frac{\partial s_i}{\partial X_k} = 0 \quad \forall k$$

where S (=6) = number of shares in the SRAM

Equation (26) emphasizes the tradeoffs inherent in a State's resource allocation decision process. Given a fixed budget, the decision to increase expenditures on one activity must be compensated by a decrease in the resources devoted to at least one other highway function. For example if an increase in Interstate grants stimulates additional State expenditures on Interstate construction (as indicated by a positive derivative of the Interstate share with respect to Interstate grants), then expenditures on some other function(s) must decrease (as indicated, for example, by a negative derivative of the non-Federal-Aid System expenditure share with respect to Interstate grants).[1]

Appendix B develops a detailed derivation of the derivatives and elasticities of the short run allocation model. Our purpose here is to highlight the more significant policy implications of the SRAM. It should be remembered that at this point we are concerned only with allocation decisions.

---

[1]The same comments apply to the interpretation of the SRAM elasticities. The elasticities of the SRAM η are defined as

$$\eta = \frac{\partial s_j}{\partial X_k} \cdot \frac{X_k}{s_j}$$

from Figure V.6.1 that in the short run (i.e. fixed State budget), a one dollar increase in Interstate grant availability is associated with a $1.11 increase in total (State plus Federal) expenditures on that system. However, it is also apparent that the same one dollar increase in Interstate grants results in a decrease in expenditures devoted to all other categories except maintenance. Moreover, Figure v.6.1 indicates that Interstate grant increases effect a more significant reallocation of State resources than grants for the Primary and Secondary Systems. In particular, note that the derivative of Secondary System expenditures with respect to Secondary grants is only 1.04. If States matched Secondary grants dollar for dollar,[1] then we would expect to find a derivative of 2.0. It appears then that in the short run, States only minimally increase their own Secondary expenditures in response to increasing Secondary System grant availability.

To a lesser extent, the States' short run reaction to increases in Primary System grant availability is also characterized by less than a dollar for dollar matching response, as indicated by the derivative value of 1.72. Both these findings substantiate our earlier comments on the non-binding nature of ABC grants. In particular, since States have been expending more

---

[1]We have previously noted that Secondary (and Primary) grants are provided on a 50% Federal matching basis. In the Interstate grant program, the Federal government assumes 90% of project costs.

In the next section, we will intergrate the results of the SRAM with the total expenditure model to describe the impacts of Federal grants and other factors on both total State highway expenditures and interfunction allocation.

We begin our analysis of the SRAM with a presentation of the model derivatives. Figure V.6.1 displays the derivatives from the product form SRAM estimated (GLS) on the full 48 State/14 year data set. Each column represents a highway activity, and the row entries correspond to each of the explanatory variables in the SRAM.[1]

The most striking finding from this figure is that changes in the level of grants on a given Federal-Aid System affect not only the State's expenditures on that System, but significantly alter the expenditure shares of other Federal-Aid Systems and the remaining highway activities as well. For example, it is clear

[1]See Figure V.4.1 for a definition of the explanatory variables. The column headings are defined as INTERSTATE-Interstate System construction expenditures, PRIMARY-Federal-Aid Primary System construction expenditures, SECONDARY-Federal-Aid Secondary System construction expenditures, NONFASYST-non-Federal-Aid System construction expenditures, MAINT-maintenance expenditures, and OTHER-administrative and other miscellaneous expenditures.

FORTY-EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.105E 02	-0.753E 00	0.578E 00
UFAC	0.402E 08	-0.136E 08	-0.100E 08
PCY	-0.474E 04	-0.335E 04	-0.170E 04
GINI	-0.524E 07	-0.371E 07	0.167E 08
KSTK	-0.172E 08	0.808E 07	0.940E 06
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.287E 08	0.145E 08
RLTOT	0.661E 07	0.468E 07	0.237E 07
AVIG	0.111E 01	-0.374E 00	-0.197E 00
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

Figure V.6.1

FORTY-EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.105E 02	-0.753E 00	0.578E 00
UFAC	0.402E 08	-0.136E 08	-0.100E 08
PCY	-0.474E 04	-0.335E 04	-0.170E 04
GINI	-0.524E 07	-0.371E 07	0.167E 08
KSTK	-0.172E 08	0.808E 07	0.940E 06
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.287E 08	0.145E 08
RLTOT	0.661E 07	0.468E 07	0.237E 07
AVIG	0.111E 01	-0.374E 00	-0.197E 00
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

Figure V.6.1 (contd.)

than the minimal matching requirements for these Systems, they need not increase their own expenditures in order to satisfy the matching requirements of additional ABC aid. And, in fact, our results indicate that short run expenditure increases on the Primary and Secondary Systems do not match (dollar for dollar) increases in ABC grants.

Contrastingly, our SRAM results indicate that the short run state response to increasing Interstate aid is to increase their own expenditures by slightly more than the minimally required state matching share. Referring to figure v.6.1, the derivative of total (State plus Federal) Interstate expenditures with respect to Interstate grants is 1.11. Thus, for each dollar increase in Federal Interstate grant availability, we can expect (in the short run) an eleven cent increase in State resources devoted to Interstate construction.

In addition to the direct effect of Federal aid, (that is the effect of a Federal-Aid System grant on expenditures on the same System), Federal-aid also influences short run expenditures on other highway activities. To begin with, Figure V.6.1 indicates that each dollar increase in Interstate grant availability induces a 37 cent and 20 cent decrease in short run expenditures on the Primary and Secondary Systems respectively. Similarly, increases in Primary (or Secondary) System grants result in a decrease of States' resource allocation to the Interstate and

Secondary (or Primary) Systems. These "cross-derivatives"[1] are useful in suggesting the complementary and substitutive allocation characteristics manifest in States' highway expenditure behavior. For example, Figure V.6.1 indicates that (in the short run):

-- Interstate grant increases induce greater decreases in Primary System construction expenditures than in Secondary System expenditures (i.e. States view Interstate roads as a closer substitute for Primary System roads than Secondary System roads).

-- Primary System grant increases have tended to draw approximately equal resources from Secondary and Interstate System expenditures. ("cross-derivatives" equal to -.317 and -.286 respectively.)

-- Secondary System grant availability has had the least reallocational impact of any of the Federal Aid System grants. This is particularly true of the effect Secondary grants on Interstate System expenditures. From Figure V.6.1, it may be seen that each dollar increase in Federal-Aid Secondary System grant availability decreases States' Interstate expenditures by less than two cents.

---

[1] That is, the derivative of State expenditures on one activity with respect to Federal grants on another highway activity.

-- Interstate grant increases have tended to increase States' maintenance expenditures at the rate of approximately five cents per grant dollar. This is an interesting finding in light of the often expressed hypothesis that Federal aid availability has resulted in a decrease in States' expenditures on non-aided activites,[1] (e.g. maintenance). In fact, Interstate grants have tended to accelerate Interstate construction, which in turn has led to increasing maintenance requirements. Maintenance standards on the Interstate System are measurably higher than on other road types. This is because the Interstate System is designed for higher driving speeds and thus require maintenance of smooth roadways, wide rights-of-way and modern traffic service devices (signs, lighting).

Several other findings concerning States' short run expenditure behavior may be inferred from Figure V.6.1. In each of the paragraphs below, the model implications are followed by the relevant derivative from Figure V.6.1 in parentheses.

-- State maintenance expenditures increase with increasing levels of existing highway inventory, KSTK ($.138 \times 10^7$), the level of highway congestion, PCMF

---

[1] For example, see Maxwell, J.A., "Federal Grant Elasticity and Distortion", National Tax Journal, Volume XXII, Number 4 (December , 1969).

($.122 \times 10^7$) and the amount of Federal Interstate grants (.495).

-- The share of the States' budget devoted to the non-aided expenditure categories (non-Federal-Aid System construction, maintenance and "other") tends to decrease with increasing levels of any of the Federal Aid System grants.[1] This is particularly true of the change in administration, highway police and safety and other miscellaneous (i.e. "other") expenditures in response to increases in the grant availability on the Interstate (-.561), Primary (-.899) and Secondary (-.637) Systems.

-- Increasing levels of urbanization tend to increase State expenditures on the Interstate System ($.402 \times 10^8$) and decrease expenditures on the Primary ($-.136 \times 10^8$), Secondary (-1.00×10^8) and non Federal-Aid ($-.118 \times 10^8$) Systems. The explanation here is that the relatively large right of way requirements of the Interstate System, and the high price of urban (versus rural) land result in significantly higher Interstate

---

[1] The important exception of the effect of Interstate grants on maintenance expenditures has already been noted.

System costs in densely populated states. As might be expected, State expenditures on the rural-oriented road systems (the Secondary and non-Federal-Aid Systems) decrease with higher levels of urbanization.

-- State expenditures on maintenance and non-Federal-Aid System construction decrease with increasing levels of local participation in highway finance (derivatives equal $-.146 \times 10^8$ and $-.445 \times 10^7$ respectively.) These two activities are commonly delegated (to a greater or lesser degree) to county and municipal highway authorities. Thus to the extent that lower governmental agencies assume the financial responsibility for maintenance and local road construction, State expenditures on these activities decrease. By the same token, the resources "freed up" by the delegation of highway responsibility to lower governmental units result in increasing State expenditure levels on those functions under exclusive State control (as evidenced by the positive derivatives of expenditures on the Federal-Aid Systems with respect to RLTOT).

-- The SRAM results substantiate the hypothesis advanced in section V.4 that the degree of toll road financing (as measured by the variable TOLPCT) would negatively influence States Interstate expenditures. In fact, of all the expenditure categories in the SRAM, only the Interstate share had a negative derivative ($-.103\times10^9$) with respect to TOLPCT.

In summary, this section has explored short run State highway resource allocation behavior. The derivatives of the short run allocation model generally corroborated the hypotheses advanced in section V.4. Most notably, it was found that Primary and Secondary System grants do not induce a dollar for dollar matching response by the States in the short run. Here again we have drawn attention to the fact that although the ABC grant program is characterized by matching provisions, these provisions are not binding on States allocation behavior. Contrastingly, it was shown that the Interstate grant program has induced States to expend slightly more than the monomally required 10% State share, substantiating our earlier comments on the more binding nature of the Interstate grant program's matching provisions.

A more complete listing of the derivatives and elasticities derived from the short run allocation model is presented in Appendix C.[1]

---

[1]The empirical results in this section were discussed in terms of SRAM derivatives. The elasticities of the SRAM corroborate our general findings. In the next section where we investigate States' long run highway allocation behavior, our empirical results will be evaluated both in terms of model derivatives and elasticities.

V.7 Integration of the Results from the Total Expenditure Model and the Short Run Allocation Model: Long Run Responses

This section extends the analysis of the previous section by considering the derivatives and elasticities of expenditures on each of the six highway categories with respect to the variables employed in both the short run allocation model and the total expenditure model. We refer here to long run derivatives (or elasticities) since the analysis allows for the influence of each of the variables on short run allocation as well as total expenditure levels. For example, the results of the short run analysis in section V.6 indicated that the share of Interstate expenditures increases in response to increasing Interstate grant levels.[1] But we have also seen from our total expenditure model (Chapter IV) that Interstate grant increases have tended to increase States' total expenditure levels. Thus to measure the total effect of Interstate grants (or any other variable), we must apply the predicted shifts in (short run) allocation shares to the predicted change in (long run) total expenditures. In short, this section attempts to integrate our findings from the short run allocation model and the total expenditure model.

The two models of State highway expenditure behavior developed in this thesis take the form:

---

[1] More specifically, we have shown that Interstate grants have increased short run State Interstate expenditures. Given the fixed budget consumption of our short run analysis, it follows that the States' share of resources devoted to Interstate construction has increased.

<u>short run allocation model</u> (SRAM)

$$(27) \qquad s_j = \frac{E_j}{R} = \frac{f_j}{\sum_i f_i}$$

where s_j = share of expenditures devoted to category j

E_j = expenditures on category j

R = total (State & Federal) expenditures

f_j = structural equation in the SRAM

<u>total expenditure model</u> (TEM)

$$(28) \qquad R^o_{pc} = \beta_0 + \sum_m \beta_m X_m$$

where R^o = States per capita highway expenditures exclusive of Federal grants

X_m = TEM explanatory variables

β_m = TEM parameter estimates.

It may be noted that the dependent variable in the TEM (R^o_{pc}) is related to the form of the total expenditure term R in the short run allocation model. The former represents States' <u>own</u> per capita highway expenditures whereas the latter term is simply total highway expenditures (inclusive of Federal payments). Thus, by definition:

$$(29) \qquad R = SPOP \times (R^o_{pc} + F_{pc})$$

where SPOP = State population

F_{pc} = per capita Federal payments to the States.

Assuming that States ultimately expend all Federal grants made available, any differences between Federal highway payments F_{pc} and Federal highway grants can be attributed to short run, transient responses. In the long run, it can be assumed that Federal payments will eventually "settle down" to the rate of Federal grant availability.[1] Thus in a long run static situation:

(30) $$F_{pc} = G_{pc}$$

where G_{pc} = per capita Federal grant availability.

But per capita highway grants were included as an explanatory variable in the total expenditure model. Thus employing the conventions of equations (29) and (30) in equation (27), we can rewrite the total expenditure model as:

(31) $$R = \Big(\beta_0 + \underbrace{\sum \beta_m X_m}_{\text{exclusive of grant terms}} + (1+\beta_g)G_{pc} \Big) * SPOP$$

where R = total (inclusive of Federal grants) State highway expenditures

β_g = TEM parameter estimate of the Federal grant terms

G_{pc} = per capita Federal highway grants.

Equation (31) transforms our original TEM specification which served to predict States' own per capita highway expenditures, into a form which describes States total (inclusive of Federal grants) highway

---

[1] Particularly if Federal grant availability does not significantly change from year to year.

expenditures R. In fact, the definition of R in equation (31) is precisely the required form for interpretation of our allocation model.

Thus, rewriting equation (27), we get

(32) $E_j = s_j * R$

where s_j = a highway expenditure share as defined in the SRAM

and R = total State highway expenditures as defined by the transformation of the TEM represented by equation (30).

Finally, given the form of equation (32) we can define the long run derivatives of our expenditure categories E_j with respect to the explanatory variables X_k:

(33) $$\frac{\partial E_j}{\partial X_k} = s_j \frac{\partial R}{\partial X_k} + R \frac{\partial s_j}{\partial X_k}$$

The corresponding long run elasticity of E_j with respect to variable X_k, η_{E_j/X_k} is simply:

(34) $$\eta_{E_j/X_k} = \frac{\partial E_j}{\partial X_k}\frac{X_k}{E_j} = \frac{X_k}{E_j}\left(s_j \frac{\partial R}{\partial X_k} + R \frac{\partial s_j}{\partial X_k}\right)$$

$$= \frac{X_k}{E_j}\left(\frac{E_j}{R}\frac{\partial R}{\partial X_k} + R \frac{\partial s_j}{\partial X_k}\right) = \frac{X_k}{R}\frac{\partial R}{\partial X_k} + \frac{X_k}{s_j}\frac{\partial s_j}{\partial X_k}$$

$$= \eta_{R/X_k} + \eta_{s_j/X_k}$$

From the form of these equations, it is apparent that long run expenditures on a particular highway category E_j <u>increase</u> in response to a change in an explanatory variable X_k if:

- the share of expenditures devoted to category j increased by more than an attendant percentage decrease in total expenditures,
- total expentirues increase (in percentage terms) by more than an attendant decrease in the expenditure share devoted to highway category j, or
- both total expenditures and the share of expenditures devoted to category j increase.

Figure V.7.1[1] displays the long run derivatives derived from the two expenditure models. The interpretation of the derivatives of expenditures with respect to the Federal grant variables deserve particular attention since these results provide strong evidence on the substitution/stimulation impacts of the Federal-Aid Highway Program. It is apparent that of the three Federal grant programs evaluated in this thesis, only the Interstate grant program had the effect of increasing State expenditures by <u>more than the minimally required</u> State matching share. Specifically, our results indicate that each dollar increase in Interstate aid is associated with a \$1.57 increase in total Interstate expenditures, implying an increase in States' own Interstate expenditures by 57¢. In fact recalling

---

[1] The derivatives in this Figure were derived from the parameter estimates of the "SU11" specification of the total expenditure model (see Figure IV.6.1) and the GLS estimation of the SRAM (see Figure V.5.1).

FORTY-EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

VARIABLE	INTERSTATE	PRIMARY	SECONDARY
		SHARE	
SPOP	0.507E 01	0.103E 02	0.615E 01
UFAC	0.395E 08	-0.140E 08	-0.103E 08
PCY	0.147E 05	0.104E 05	0.526E 04
GINI	-0.460E 07	-0.325E 07	0.170E 08
KSTK	-0.686E 07	0.154E 08	0.464E 07
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.290E 08	0.147E 08
RLTOT	0.627E 07	0.444E 07	0.225E 07
AVIG	0.157E 01	-0.516E-01	-0.336E-01
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

Figure V.7.1

FORTY EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

VARIABLE	SHARE INTERSTATE	PRIMARY	SECONDARY
SPOP	0.507E 01	0.103E 02	0.615E 01
UFAC	0.395E 08	-0.140E 08	-0.103E 08
PCY	0.147E 05	0.104E 05	0.526E 04
GINI	-0.460E 07	-0.325E 07	0.170E 08
KSTK	-0.686E 07	0.154E 08	0.464E 07
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.290E 08	0.147E 08
RLTOT	0.627E 07	0.444E 07	0.225E 07
AVIG	0.157E 01	-0.516E-01	-0.336E-01
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

Figure V.7.1 (contd.)

the results of our total expenditure model analysis, and the short run allocation model analysis, our findings here are representative of a State response to increasing Interstate aid wherein States increase both their own total highway expenditures, and the share of those expenditures devoted to Interstate construction.

This behavior stands in contrast to the States' response to increasing Secondary System grant availability. Note from Figure V.7.1 that the derivative of Secondary System expenditures with respect to Secondary System grants is only 1.04. The implication here is that each additional Federal Secondary System grant dollar increases State expenditures by only four cents -- far less than the increase that would pertain if States were matching increasing Federal Aid on a dollar-for-dollar basis.[1]

In a similar fashion our results concerning the States' reaction to increasing Primary System aid suggest a less than a dollar-for-dollar expenditure matching response. The relevant derivative value here indicates that each dollar increase in Primary System aid induces only a 72¢ increase in States own expenditures on that System (derivative value equal to 1.72). These results reflect our findings from the empirical analysis of the total expenditure model (see section IV.6). That is, the increases in Primary and Secondary System expenditures in response to additions to grants on these

---

[1] We again note that over our analysis period, Primary and Secondary System grants were provided on a 50% Federal, 50% State matching basis.

FORTY EIGHT STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	INTERSTATE	PRIMARY	SECONDARY
		SHARE	
SPOP	0.330	0.943	1.117
UFAC	0.396	-0.198	-0.287
PCY	0.623	0.623	0.623
GINI	-0.029	-0.029	0.302
KSTK	-0.067	0.214	0.127
TSPMR	-0.031	-0.031	0.277
PCCRMT	-0.011	-0.011	0.026
PCMF	-0.001	-0.001	-0.001
TOLPCT	-0.059	0.023	0.023
RLTOT	0.028	0.028	0.028
AVIG	1.232	-0.057	-0.074
AVPG	-0.070	0.534	-0.176
AVSG	-0.002	-0.045	0.261

Figure V.7.2

FORTY EIGHT STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	NONFASYST	SHARE MAINT	OTHER
SPOP	1.662	0.497	1.987
UFAC	-0.890	-0.042	-0.042
PCY	0.623	0.623	1.440
GINI	-0.029	-0.029	-0.029
KSTK	0.127	0.387	0.034
TSPMR	-0.031	-0.031	-0.031
PCCRMT	0.183	-0.011	-0.011
PCMF	-0.001	0.007	-0.001
TOLPCT	0.023	0.023	0.023
RLTOT	-0.489	-0.043	0.026
AVIG	0.198	0.440	-0.146
AVPG	-0.130	-0.062	-0.226
AVSG	-0.026	0.001	-0.066

Figure V.7.2 (contd.)

Systems stem not from increases in States' own total expenditures,[1] but from increases in the share of a States' resources devoted to these Systems. Contrastingly, additional Interstate System aid has had the effect of increasing both the States' total expenditures, and the share of their expenditures devoted to Interstate construction.

The same general findings are evident from an examination of Figure V.7.2 showing the long run elasticities from the two expenditure models. It may be seen that a one percent increase in Interstate grants leads to a 1.23% increase in long run State Interstate expenditures. In other words, the fraction of total expenditures representing Federal grant decreases with increasing levels of Interstate aid. Conversely, the direct elasticities of Primary and Secondary expenditures with respct to grants for these Systems are less than one. These elasticities -- .53 for the Primary System and .26 for the Secondary System indicate that Federal grants comprise an increasingly larger fraction of total (State plus Federal) expenditures on these Systems. Thus, on the Primary and Secondary Systems, States' own expenditures have increased at approximately only one-half and one-fourth of the respective percentage

---

[1] In fact, we have shown that the States' response to ABC grants is characterized by expenditure substitution. That is each additional ABC grant dollar is associated with a decrease in States' own expenditures by one dollar.

rate increases in Federal aid (for these Systems).[1]

The elasticities (or derivatives) of categorical highway expenditures with respect to the other variables included in the expenditure models generally conform with expected State behavior. The indicated responses to each of these variables are summarized below.

Socio-Economic Characteristics

As expected, increasing levels of State population (SPOP) and per capita income (PCY) positively influence the expenditure levels on all the highway categories. Highway travel within a State increases with population and personal income. Therefore, we should expect higher levels of SPOP and PCY to increase the States' construction, maintenance and administrative expenditure requirements.[2] It should be kept in mind in interpreting the results that elasticities express percentage changes in the expenditure levels on each highway category. Thus for example, while the elasticity of maintenance expenditures with respect to population increases (.497) is

---

[1] Note that States' own Interstate expenditures have increased at a greater percentage rate than increases in Interstate aid. These findings are all the more significant when it is recalled that for several years in our analysis period, States own Interstate expenditures exceeded their ABC System expenditures (see Figure II.2.1) and the States' required matching share is lower on the Interstate than on the Primary or Secondary Systems.

[2] Moreover for a given gas tax rate, increasing highway travel provides States with higher levels of earmarked highway revenue.

greater than the corresponding elasticity for the Interstate System (.350), <u>in absolute terms</u> increases in Interstate expenditures (in response to changes SPOP) exceed those for highway maintenance.[1]

The measure of urbanization (UFAC) positively influenced Interstate System expenditures, reflecting the sharply increased cost of Interstate highway construction in urban areas. The elasticity of the remaining five shares with respect to UFAC were all negative, most notably for the "lower order" (Sconary and non-Federal Aid) Systems. GINI, the indicator of State income distribution had a positive elasticity only for Secondary System expenditures. This result reflects the fact that the rural States tend to have the greatest degree of income <u>in</u>equality, and thus commit relatively higher expenditure levels on the rural-oriented Secondary System.

<u>Highway System Characteristics</u>

Two measures of existing highway inventories (KSTK-depreciated highway capital expenditures and TSPMR - State <u>rural</u> highway mileage) and two indicators of highway congestion levels (PCCRMT--percent of heavily traveled rural mileage and PCMF--percent of heavily traveled total mileage) were incorporated in the analysis. As might be expected, increasing levels of highway inventories positively influenced maintenance and "other" (non-capital) expenditure levels. In fact only Interstate expenditures exhibited a negative elasticity

---

[1] As manifested by the corresponding <u>derivative</u> values (Figure V.7.1) of 5.07 for the Interstate category and 3.65 for the maintenance category.

with respect to KSTK. Secondary System expenditures exhibited a positive elasticity with repsect to rural highway mileage; again indicating the rural orientation of the Secondary System.

Although the measures of highway congestion did not prove particularly significant, the elasticities with respect to PCMF and PCCRMT indicate reasonable expenditure responses. In particular expenditures on the predominantly rural highway systems (Secondary and non-Federal Aid Sustems) exhibited a positive elasticity with respect to the level of rural highway congestion (PCCRMT). And maintenance expenditures were positively influenced by the general measure of State-wide congestion (PCMF).

Institutional Characteristics

The variable measuring the extent of local participation in highway finance (RLTOT) exhibited negative long run elasticities for the non-Federal Aid System and maintenance expenditure categories. Thus higher expenditure levels (presumably on highway maintenance and non-Federal Aid System construction) by counties and municipalities has the effect of "freeing up" (State) resources for the performance of exclusive State highway functions (Federal Aid System construction and administrative and other activities). The second indicator of State highway financing conventions--the extent of toll road financing (TOLPCT) did not appear to significantly influence the allocation of State resources. However, the results indicate that increasing use of toll roads has tended to decrease Interstate expenditures while increasing the level of expenditure on all other highway categories. As noted earlier, this finding stems from the common State practice of delegating Interstate System financing responsibility to quasi-public toll-financed Turnpike Authorities.

V.8 Summary

This chapter has presented an empirical analysis of the State highway allocation behavior in both a short run and long run context. The empirical model of short run highway allocation was derived from a utility maximization representation of State expenditure behavior. The model has the desirable property of explicitly accounting for State budget constraints and thus focuses on the inherent tradeoffs States must face in programming expenditures on alternative highway activities. A generalized least square estimation technique was developed to take proper statistical account of the joint interaction between States highway expenditure shares.

The short run analysis explored allocation behavior under the assumption that State budget levels were fixed. The results demonstrated the relative importance of the Interstate grant program in influencing States allocation decisions. The results from the short run allocation model were then integrated with the empirical findings of the total expenditure model (Chapter IV) to develop measures of States' long run highway allocation behavior. The results demonstrate that Federal grants for the Primary and Secondary Systems have not significantly increased States' own expenditures on these Systems. Specifically, it was shown that States have not had to increase their own expenditures on a dollar-for-dollar matching basis with increased Federal funding. This behavior contrasted with State responses to the Interstate grant program, where it was shown that increasing Federal aid has increased both total State expenditures and the share of the States' budgets devoted to Interstate construction.

It was also shown that increases in Federal grant availability have generally decreased State expenditures on non-aided activities. One exception of interest was the finding that Interstate grant increases have led to increases in States' maintenance expenditures, indicative of the relatively large maintenance requirements associated with that system.

The predicted expenditure responses to changes in the State socio-economic indicators, highway system characteristics and institutional characteristics generally corroborated our a priori hypotheses. The policy implications of our empirical findings will be explored in the next chapter.

CHAPTER VI

SUMMARY AND CONCLUSIONS

VI.1 Summary of the Thesis

This study has investigated the impacts of the Federal Aid Highway Program on State highway expenditures. Our concern throughout the conduct of the research has been to focus on this issue from a national policy perspective. In simplest terms, the motivation of the research was a consideration of the design of, and response to Federal and highway financing.

Our starting point was a review of the mechanics of State and Federal highway finance. Special attention was given to the unique aspects of the Federal Aid Highway Program (FAHP) and the attendant implications for empirical modelling. First, we took note of the widespread use of earmarked Trust Funds at both the Federal and State levels. This finding allowed us to restrict our modelling attention solely to the dynamics of State <u>highway</u> expenditure behavior.[1] Second, our review of the highway finance environment pointed out the significant differences between the structural characteristics of the various Federal highway grant programs--most notably between the Interstate and ABC highway grant programs. The modelling implications here were twofold.

---

[1] That is, unlike other State activities financed from general tax revenues, we have been able to "separate out" highway expenditure decisions from the overall State budgetary process. This modelling convention is discussed in detail in Chapter II.

First, it became apparent that the models of State expenditure behavior should explicitly account for the possibility of differing State responses to the availability of grants on the Interstate and ABC highway Systems.[1] And second, the existence of several distinct highway grant types suggested the importance of investigating the inherent tradeoffs States must face in programming expenditures on alternative highway activities. In other words, it was deemed important to trace the impact of the Federal Aid Highway Program on both the total level of States' highway expenditures and the allocation of State resources amongst Federally aided and non-Federally aided highway activites.[2]

Following the review of the Federal and State highway finance environment, we proceeded to develop a theory of State highway expenditure behavior. Our purpose here was to draw attention to the premise that State highway expenditure behavior depends not only on the level of available Federal grants-in-aid, but on the structural characteristics of the grant programs as well. Towards this end, Chapter III started out with a normative dis-

---

[1] This convention represents a departure from previous analytical analyses in this area. None of the studies cited in the literature review in Chapter I chose to evaluate the separate State expenditure responses to grants on the different Federal Aid Highway Systems. In section IV.6.1, we argue that failure to account for differing State responses to the Interstate vis-à-vis ABC highway grant programs obscures a fundamental characteristic of the Federal Aid Highway Program, and indeed yields misleading results.

[2] Here too, our modelling convention differs from previous empirical studies. As noted in Chapter I, the existing literature contain many examples of evaluations of States' total expenditure responses to grants or States' allocation behavior. This thesis has attempted to present an integrated treatment of the impacts of the FAHP on both dimensions of State expenditure behavior.

cussion of the considerations involved in designing a Federal highway grant program to achieve specific national objectives. A distinction was drawn between proposing changes to the existing structure of the FAHP because the initial justification for the Federal role in highway finance is no longer (or has never been) valid, or because the structure of the FAHP is not compatible with the accepted goals of the Federal role in highway finance. While the normative analysis was not conclusive,[1] the thesis does argue that the issues involved in the design of a Federal grant program are not simply a matter of political expediency. The adoption of a revenue sharing program (for example) will have significantly different allocational consequences than the provision of Federal aid on an open-ended categorical, matching grant basis. Thus the normative analysis stresses the importance in gaining a better understanding of the dynamics of State expenditure responses to alternative Federal aid grant structures.

Accordingly, the remainder of Chapter III was devoted to the development of a theory of State highway expenditure behavior. A typology of alternative grant types was introduced, and evaluated in terms of their impact in stimulating State expenditures on aided functions or in effecting a substitution response wherein States would reduce their own highway expenditures in response to

---

[1] The normative analysis is limited by the difficulty in ascertaining a unique, consensual national highway policy. Congressional debate is not normally conducted at an abstract (policy) level. Moreover, Federal highway objectives are not static.

increasing levels of Federal aid. Two modelling frameworks were introduced, one based on an extension of consumer allocation theory, and the other deriving from an application of a simple benefit/cost investment criterion. Although these two models ostensibly differed with respect to their underlying assumptions, in fact the conclusions drawn from both approaches were quite similar. That is, both analyses stressed the notion of price and income effects introduced by Federal grants, and proceeded to demonstrate how State expenditure responses differ according to the presence of one or both of these grant characteristics. The theoretical models were then used to investigate the historical grant and expenditure levels on the Interstate and ABC highway programs. The theoretical analyses suggested that for the Interstate program, Federal grants have stimulated State expenditures that would most likely not have been made in the absence of the grant program. This behavior was contrasted with the experience in the ABC program, where it was hypothesized that Federal grants have had a relatively insignificant impact in determining States' total expenditure levels.

The theoretical models were useful in suggesting both the appropriate framework for structuring the empirical models and the expected empirical results. Our purpose in the remainder of the thesis was to validate our theoretical hypotheses with econometric models. Two models were advanced, treating in turn the impacts of the FAHP on total State highway expenditures, and on the allocation of States' highway budgets. The total expenditure model (TEM) derived from a capacity utilization investment theory relating

States' highway investment levels to existing highway capital stocks, proxy measures of desired highway capital stocks, and the availability of Federal aid. The empirical results strongly corroborated the theoretical hypotheses regarding the differential impacts of the Interstate and ABC highway grant programs.

The empirical model dealing with the second dimension of State highway expenditure behavior--the short run allocation model (SRAM) was derived from a utility maximization representation of State decision making. The results demonstrated the differential impacts of the various grant programs on States' short run budget allocation amongst Federally aided and non-aided highway activities.

Finally, the empirical results from the short run allocation model were integrated with the findings of the total expenditure model to develop measures of the States' long run highway allocation behavior. These results were consistent with our a priori hypotheses of State highway expenditure behavior.

VI.2 Policy Implications of the Empirical Findings

As the main focus of this thesis was to explore the impacts of the FAHP on State expenditure behavior, we begin our discussion here with the policy implications of estimation results of the Federal grant terms included in the two expenditure models. We have shown that the Interstate grant program has effected more significant State expenditure responses than the ABC grant program. Specifically, we have traced the responses to Federal grants in terms of both States' total expenditure levels and short run State budget allocation amongst aided and non-aided highway activities. For the former dimension of State behavior, the empirical models have demonstrated that the Interstate programs have been associated with increases in total (State plus Federal) expenditures by more than the amount of increases in Federal Interstate aid. Thus we concluded that the Interstate grant program has had the effect of stimulating State highway expenditures.[1] This response pattern was contrasted with the ABC program, where the theoretical and empirical models have demonstrated that States have substituted their own highway expenditures for the receipt of increasing levels of Federal ABC aid.

Regarding the second dimension of State highway expenditure behavior, we have demonstrated that the various Federal grant programs have had a differential impact on States' allocation of their

---

[1] Furthermore, we have shown that the resulting increase in States' total highway expenditures derive mainly from increasing resource allocation to Interstate construction and maintenance activities (presumably in large measure in the Interstate system).

highway resources. Although all of the Federal highway grant programs considered in this thesis were shown to stimulate States' short run budget allocation to Federal-Aid System construction activities, our results indicate that short run impacts of Primary and Secondary System grants exhibit a less than dollar-for-dollar matching response by the State.[1] Contrastingly, the Interstate grant program was shown to increase States' short run Interstate expenditures by more than the minimally required matching share.

In fact, based on our <u>theoretical</u> analyses (see Chapter III), none of our empirical findings were unexpected. The empirical analyses served to validate our a priori hypotheses, and placed dimensions on the pattern of State responses to the FAHP. More importantly perhaps, the empirical research provides evidence which suggests policy recommendations for altering the present structure of the Federal-Aid Highway Program.

Specifically, with our clearer understanding of the dynamics of State expenditure responses to Federal aid, the fundamental issue of the objectives of the Federal Aid Highway Program is called into question. The imposition of Federal highway taxes and the pursuant distribution of categorical grants represents an explicit expression

---

[1] Since the matching ratio of ABC aid over our analyses period was 50% (except for the "public land States"; see Chapter II), our results indicate that even in the short run, States can "absorb" additional Federal aid without having to increase their own expenditures by the required State matching share. In Chapter II, we demonstrated that this response pattern could obtain only if States were histocially expending more than their minimally required matching share on the Federal-Aid Systems.

of Federal policy. In particular, the restrictions on the use of Federal funds for only certain types of facilities serves to identify those projects whose provision is deemed to be in the national interest. It may well be argued that guaranteeing a minimally acceptable provision of important transportation facilities or stimulating road construction necessary for interstate commerce are valid Federal objectives. But we have shown that for the ABC program, the former objective may not be appropriate, and the second objective is not being accomplished. In short, our results indicate that restructuring the Federal Aid Highway Program with a relaxation of the specificity of the categorical restrictions, and eliminating the built-in matching provisions would not significantly alter State expenditure levels. Since the ABC program has (over our analysis period) _effectively_ operated as a non-categorical block grant system, the detailed provisions (matching ratios, categorical restructions, etc.) of the FAHP are unnecessary and wasteful.

To be sure, the FAHP is characterized by other (non-allocational) consequences--ensuring adherence to Federal labor and contracting regulations, promoting the implementation of transportation planning and process guidelines, and guaranteeing that Federally-funded roads conform to certain safety standards. None of these "ancillary" impacts are tied to the particular _structure_ of the FAHP. They are merely conditions States must satisfy in order to be eligible for the receipt of Federal highway monies. Indeed, we are arguing that greater attention needs to be paid to exploiting these "ancillary" benefits in view of the failure of specific components of the FAHP to achieve significant allocational goals.

We have already noted (section II.2.viii) that the Federal Aid Highway Act of 1973 has incorporated several provisions designed to reduce the specificity of the FAHP, most notably in terms of increasing the allowable fund transfers between distinct Federal Aid Systems, and providing Urban System aid for transit as well as highway construction. The logical extension of the 1973 provisions would be to completely remove all categorical and matching provisions from those components of the FAHP where it is either not the intent or not a reasonable expectation (given projected State expenditure levels and Federal grant availability) for Federal grants to stimulate State expenditure levels.

As we noted in Chapter III, categorical matching grants are most appropriate in situations where the Federal government perceives a national interest in promoting investment on <u>specific</u> types of highway facilities. Thus we argue that the criteria to be considered in the design of the structure of the FAHP (specifically in terms of the provision of categorical aid) is the existence of identifiable investment needs[1] on specific highway facilities. The analyses

---

[1] The Interstate System was a case where States would not have heavily invested on this System in the absence of Federal <u>categorical</u> grants. Moreover, it may be argued that the Interstate System is characterized by significant "benefit spillovers" (see Chapter III) due to its value in enhancing <u>interstate</u> commerce and <u>national</u> defense. Thus, grants for the Interstate System may be viewed as a case where categorical aid was appropriate. Other

developed in this thesis suggest that categorical aid for broadly defined functional highway classes, for example the Federal Aid Primary System is not justified.

A related issue is the question of the advisability of the existing taxation scheme and distribution formulas characterizing the existing FAHP. We have shown that the gasoline excise tax is at best proportional (for journey to work travel) and at worst regressive (for vacation and business intercity travel). Moreover, the analyses in Chapter II suggests that the apportionment formulas currently in effect fail to accomplish a significant redistribution of income from wealthier to poorer States. While the FAHP's main objectives are not directly related to achieving more desirable income redistribution,[1] the generally recognized importance of transport systems in promoting economic growth and regional development suggests that more attention needs to be given to income distributive properties of FAHP apportionment formulas. In line with our conclusion that the numerous highway categorical matching

---

instances where categorical grants might be appropriate include high risk/new technology projects where categorical "demonstration" grants serve to overcome States' reluctance to invest in untested technology, or, more generally any instance where the Federal government perceives a national interest in accelerating expenditures on specific project types (e.g., TOPICS, and the "Priority Primary Routes" designated in the 1972 Highway Act).

[1] There are more efficient Federal policies to achieve significant income redistribution, for example direct transfer payments (Revenue Sharing) with income-based distribution formulas.

grants be consolidated into a block grant system, it is recommended that the Department of Transportation give consideration to a restructuring of the FAHP apportionment formulas.[1] Towards this end, the income and tax effort-based distribution formulas of the Federal government's General Revenue Sharing program merit particular importance.

The second aspect of income inequality inherent in the current FAHP--the gasoline excise tax--also deserves DOT's attention in developing future Federal highway policy. The issue here involves the income distribution characteristics, the revenue potential and the price distortion characteristics of alternative taxation schemes. While the gasoline tax possesses undesirable income distribution characteristics, it nonetheless represents an efficient and relatively stable revenue source,[2] and connotes a rough measure of equity.[3] In order to mitigate its perverse income distribution, DOT should consider supplementing the existing gasoline tax with an excise tax on automobiles where the tax rate would be progressively higher for larger engine vehicles. This scheme would have the

---

[1] Since the FAHP apportionment formulas are currently administered on a System-by-System basis, a grant consolidation program would require a change in apportionment policy in any event.

[2] In the sense that demand for gasoline/auto travel is price inelastic.

[3] In the sense that the tax burden on an individual is proportional to his usage of highway facilities.

merits of promoting progressive taxation and enhancing the Federal government's objective of reducing gasoline consumption.

VI.3 Limitations of the Empirical Approach and Directions for Further Research

The empirical analyses conducted in this thesis could be extended in several fruitful directions. First, more attention could be given to investigating the specifics of the variation in highway investment behavior between States. Data limitations precluded the possibility of applying our expenditure models (the short run allocation model and the total expenditure model) on a State-by-State basis. While we did take proper statistical account of interstate behavioral variation in the pooled data sample, more research is necessary to investigate causal factors underlying differences in State behavior. Along these lines, more attention could be given to political and institutional factors. Does a State's highway expenditure behavior change significantly after it has formed a multimodal Department of Transportation? Are there significant cultural and regional effects present--that is for example, do Southern States express a different outlook on the provision of public services that the New England States and is so, why?[1] Is there a difference in expenditure behavior that is attributable to differing State political organization, as for example between States where the Legislature exerts strong highway policy influence and States where the Executive branch (Governor)

[1] Some of these questions were examined in our highway expenditure models through the use of "dummy variables." None of these experiments produced conclusive results.

assumes a major role in highway policy formation?

These are all important questions that can only be addressed by adopting a more disaggregate analysis framework than the one applied in this thesis. The approach we did adopt reflected a focus on the highway investment issue from a national policy perspective.

A second area where future research would be fruitful involves exploring the validity of the assumptions underlying our empirical models. Our models have assumed States exhibit "rational economic behavior" in the sense that allocation and expenditure decisions are based on the desire to maximize States' perceived utility (or benefit). While this view of the motivations for State decision-making is quite general and non-restrictive, it would be instructive to conduct in-depth interviews with responsible State highway officials to validate our assumptions. Such interviews would be useful in both gaining further insight into the factors (variables) to be included in future model development and checking the reasonableness of our empirical results.[1]

Finally, our modelling approach could be extended in a forecasting environment to assess the impacts of future Federal policy alternatives. Along these lines, the policy recommendations expressed earlier in this chapter (grant consolidation and an alteration

---

[1] The Federal Highway Administration has reviewed the major empirical results developed in this research, and has indicated general agreement with our findings based on their own in-house analyses.

in the taxation and grant distribution characteristics of the FAHP) as well as other alternative program variants could be evaluated against baseline predictions of the consequences of continuing the existing FAHP.

Advisory Commission on Intergovernmental Relations, STATE-LOCAL FINANCES: SIGNIFICANT FEATURES AND SUGGESTED LEGISLATION, 1972 Edition

Advisory Commission on Intergovernmental Relations, SPECIAL REVENUE SHARING: AN ANALYSIS OF THE ADMINISTRATION'S GRANT CONSOLIDATION PROPOSALS, December, 1971

Advisory Commission on Intergovernmental Relations, IMPACT OF FEDERAL PROGRAMS ON LOCAL GOVERNMENT, ORGANIZATION AND PLANNING, 1962

Ainsworth, K.G., "Comments on Monypenny's Federal Grants-in -Aid to State Governments: A Political Analysis," National Tax Journal, Volume XIII, Number 3 (September, 1960)

Balestra, P., and M. Nerlove, "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, Volume 34, Number 3

Barr, J.L. and O.A. Davis, "An Elementary Political and Economic Theory of Expenditure of Local Governments," Southern Economic Journal, Volume 34, Number 1 (October, 1966)

Birkhead, Guthrie S., METROPOLITAN ISSUES: SOCIAL, GOVERNMENTAL, FISCAL, Brookings Institution Reprint Number 61, Washington, D.C., 1962

Bishop, George A., "Stimulative Versus Substitutive Effects of State School Aid in New England," National Tax Journal, Volume XVII, Number 2 (June, 1964)

Break, George F., INTERGOVERNMENTAL FISCAL RELATIONS IN THE UNITED STATES, The Brookings Institution, (Studies of Government Finance), Washington, D.C., 1967

Burch, P., HIGHWAY REVENUE AND EXPENDITURE POLICY IN THE UNITED STATES, Rutgers University Press, New Brunswick, New Jersey, 1962

Dearing, C.I., and W. Owen, NATIONAL TRANSPORTATION POLICY, The Brookings Institution, Washington D.C., 1949

DeGarmo, E. Paul, ENGINEERING ECONOMY, The MacMillan Company,New York, New York, 1960

Dorfman, Robert, PRICES AND MARKETS, Foundations of Modern Economics Series, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1967

Dresch, S.P., "An 'Alternative' View of the Nixon Revenue Sharing Program," National Tax Journal, Volume XXIV, Number 2 (June, 1971)

Due, John F. and A.F. Friedlaender, GOVERNMENT FINANCE: ECONOMICS OF THE PUBLIC SECTOR, Richard D. Irwin Inc., Homewood, Illinois, Fifth Edition, 1973

Faddeev, D.K. and V.N. Faddeeva, COMPUTATIONAL METHODS OF LINEAR ALGEBRA, W. H. Freeman Inc., San Francisco, California, 1963

Ferman, Gerald, OUTPUT ANALYSIS: THE DISTRIBUTION OF GRANTS-IN-AID 1957-1967, Working Paper Number 10, Denter for the Study of Federalism, Temple University, Philadelphia, Pennsylvania, 1974

Findakly, H.K., A DECISION MODEL FOR INVESTMENT ALTERNATIVES IN HIGHWAY SYSTEMS, Unpublished ScD Thesis, Department of Civil Engineering, Massachsuetts of Technology, September, 1972

Friedlaender, A. F., THE INTERSTATE HIGHWAY SYSTEM, North Holland Publishing Co., Amsterdam, 1965

Friedlaender, A.F., "The Federal Highway Program as a Public Works Tool," in Ando, A. et al, STUDIES IN ECONOMIC STABILIZATION, The Brookings Institution, Washington, D.C., 1968

Gabler, L.R., and J.I. Brest, "Interstate Variations in Per Capita Highway Expenditures," National Tax Journal, Volume XX, Number 1 (March, 1967)

Gallamore, Robert E., (Reprint of) Testimony Before the Subcomittee on Roads of the Senate Public Works Committee, February 15, 1973

Gramlich, E.M., "Alternative Federal Policies for Stimulating State and Local Expenditures: A Comparison of Their Effects," National Tax Journal, Volume XXI, Number 1 (June 1968)

Haskell, M.A., "Notes and Memoranda: Federal Grants in Aid-Their Influence on State and Local Expenditures," Canadian Journal of Economics and Political Science, Volume XXX, Number 4 (November, 1964)

Haveman, R.H., and J. Margolis (editors) PUBLIC EXPENDIUTRES AND POLICY ANALYSIS, Markham Publishing Company, Chicago, Illinois, 1970

Henderson, J.M. and R. E. Quandt, MICROECONOMIC THEORY: A MATHEMATICAL APPROACH, McGraw-Hill Book Co., 1958

Highway Research Board, HIGHWAY FINANCING: 10 REPORTS, Highway Research Record Number 20, 1963

Jack Faucett Associates Inc., CAPITAL STOCK MEASURES FOR TRANSPORTATION, Report Number JACKFAU-71-04-1, Volumes I, II, and III, Chevy Chase, Maryland, June, 1972

Johnson, D.W. and C.M. Mohan, "Revenue Sharing and the Supply of Public Goods," National Tax Journal, Volume XXIV, Number 2 (June, 1971)

Kuh, Edwin, CAPITAL STOCK GROWTH: A MICROECONOMETRIC APPROACH, North Holland Publishing Co., Amsterdam, 1971

Kurnow, Ernest, "Determinants of State and Local Expenditures Reconsidered," National Tax Journal, Volume XVI, Number 3 (September, 1963)

McFarland, W.F., ECONOMIC EFFICIENCY IN HIGHWAY EXPENDITURES, Unpublished PhD Thesis, Tulane University, New Orleans, Louisiana, 1970

McMahon, W.W. and C.M. Sprenkle, "A Theory of Earmarking," National Tax Journal, Volume XXIII, Number 3 (September, 1970)

Maxwell, J.A., "Federal Grant Elasticity and Distortion," National Tax Journal, Volume XXII, Number 4 (December, 1969)

Maxwell, J.A., FINANCING STATE AND LOCAL GOVERNMENTS, The Brookings Institute, Washington, D.C., 1969

Miller, Edward, "The Economics of Matching Grants: The ABC Highway Program," National Tax Journal, Volume XXVII, Number 2 (June, 1974)

Miller, Edward, "Short Run Responses to Changes in the Availability of Federal Funds," Unpublished Department of Transportation Paper (TPI-10), 1972

Miller, Edward, "Effects of Federal Grants in Aid on Local Expenditures," Unpublished Department of Transportation Paper (TPI-10), 1972

Miller, Edward, "The Effects of the Revenue Sharing Pass Through in Large Urban Areas," Unpublished Department of Transportation Paper (TPI-10) 1972

Miller, Edward, "Impacts of the ABC Program on Highway Investment," Unpublished Department of Transportation Paper (TPI-10) 1972

Miller, Edward, "Differences in Returns by Road System," Unpublished Department of Transportation Paper (TPI-10) 1972

Mogulof, M.B., "Regional Planning, Clearance, and Evaluation: A Look at the A-95 Process," American Institute of Planners Journal, Volume 37, Number 6 (November, 1971)

Monypenny, P., "Federal Grants-in-Aid to State Governments: A Political Analysis," National Tax Journal, Volume XIII, Number 1 (March, 1960)

Musgrave, R.A. and P.B. Musgrave, PUBLIC FINANCE IN THEORY AND PRACTICE, McGraw-Hill Book Co., 1973

Musgrave, R.A. (editor), ESSAYS IN FISCAL FEDERALISM, The Brookings Institution, Washington, D.C., 1965

Neuman, Lance, A TIME STAGED STRATEGIC APPROACH TO TRANSPORTATION SYSTEM PLANNING, Unpublished SM Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, 1972

Oates, W.E., "The Dual Impact of Federal Aid on State and Local Government Expenditures: A Comment," National Tax Journal, Volume XXI, Number 4 (November, 1968)

O'Brien, T., "Grants-in-Aid:Some Further Answers," National Tax Journal, Volume XXIV, Number 1 (March 1971)

Osman, Jack W., "The Dual Impact of Federal Aid on State and Local Government Expenditure," National Tax Journal, Volume XIX, Number 4 (December, 1966)

Osman, Jack W., "On the Use of Intergovernmental Aid as an Expenditure Determinant," National Tax Journal, Volume XXI, Number 4 (December, 1968)

Pecknold, Wayne M., EVOLUTION OF TRANSPORT SYSTEMS: AN ANALYSIS OF TIME STAGED INVESTMENT STRATEGIES UNDER UNCERTAINTY, Unpublished PhD Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, 1970

Quandt, Richard E. and K.H. Young, "Cross-Sectional Travel Demand Models: Estimates and Tests," Journal of Regional Science, Volume IX, Number 2 (1969)

Roth, G.J., A SELF FINANCING ROAD SYSTEM, Institute for Economic Affairs, London, 1966

Sacks, Seymour and R. Harris, "The Determination of State and Local Government Expenditure and Intergovernmental Flow of Funds," National Tax Journal, Volume XVII, Number 1 (March, 1964)

Scott, A.D., "The Evaluation of Federal Grants," Economica, Volume XIX, Number, 76 (November, 1952)

Smerk, George M., URBAN TRANSPORTATION; THE FEDERAL ROLE, Indiana University Press, Bloomington, Indiana, 1965

Smith, A.H., "State Payments to Lcoal Governments in Wisconsin," National Tax Journal, Volume XV, Number 3 (September, 1962)

Smith, D.L., "The Response of State and Local Governments to Federal Grants," National Tax Journal, Volume XXI, Number 3 (September, 1968)

Stanford Research Institute, BENEFIT/COST ANALYSIS OF HIGHWAY IMPROVEMENT PROJECTS, SRI Project MU-7362, Stanford, California, December, 1969

Stockfisch, J.A., "Fees and Service Cahrges as a Source of City Revenues," National Tax Journal, Volume XIII, Number 2 (June, 1970)

Strotz, R.H., "The Empirical Implications of a Utility Tree, Econometrica, Volume 25, Number 2

Teeples, R.K., "A Model of a Matching Grant-in-Aid Program With External Tax Effects," National Tax Journal, Volume XXII, Number 4 (December, 1969)

Theil, Henri, OPTIMAL DECISION RULES FOR GOVERNMENT AND INDUSTRY, North Holland Publishing Co., Amsterdam, 1964

Theil, Henri and A.S. Goldberger, "On Pure and Mixed Statistical Estimation in Economics," International Economic Review, Volume 2, Number 1 (January, 1961)

U.S. Bureau of the Census, 1967 CENSUS OF TRANSPORTATION, Volume 1, National Travel Survey, Washington, D.C., July, 1970

U.S. Bureau of the Census, GOVERNMENTAL FINANCES IN 1953-1954 (Yearly editions to 1969-1970), Washington, D.C.

U.S. Bureau of the Census, STATE GOVERNMENT FINANCES IN 1950 (Yearly edition to 1970), Washington, D.C.

U.S. Bureau of Public Roads, HIGHWAY STATISTICS 1950 (Yearly editions to 1970), Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

U.S. Department of Transportation, Office of the Assistant Secretary For Policy and International Affairs, 1972 NATIONAL TRANSPORTATION REPORT, Washington, D.C., 1972

U.S. Department of Transportation, NATIONWIDE PERSONAL TRANSPORTATION STUDY: HOME-TO-WORK TRIPS AND TRAVEL, Volume 8, Washington D.C., August, 1973

U.S. Department of Transportation, ALLOCATION OF HIGHWAY COST RESPONSIBILITY AND TAX PAYMENTS, Washington, D.C., 1969

U.S. Federal Highway Administration, FINANCIAL BACKGROUND FOR THE 1972 HIGHWAY NEEDS STUDY, Unpublished Report C-1, Washington, D.C., 1972

U.S. Federal Highway Administration, HIGHWAY FINANCE MANUAL, Washington, D.C., 1972

Urban Mass Transportation Administration, CAPITAL GRANTS FOR URBAN MASS TRANSPORTATION: INFORMATION FOR APPLICANTS, Washington, D.C., June, 1972

Wells, John D. et al, ECONOMIC CHARACTERISTICS OF THE URBAN PUBLIC TRANSPORTATION INDUSTRY, Institute for Denfense Analyses, Arlington, Virginia, February, 1972

Wilde, J.A., "Grants-in-Aid: The Analytics of Design and Response," National Tax Journal, Volume XXIV, Number 2 (June, 1971)

Wilde, J.A., "The Expenditure Effects of Grant-in-Aid Programs," National Tax Journal, Volume XXI, Number 3 (November, 1968)

Winch, D.M., THE ECONOMICS OF HIGHWAY PLANNING, University of Toronto Press, Toronto, Ontario, 1963

Young, K.H., "The Synthesis of Time Series and Cross-Section Analyses: Demand for Air Transportation Service," Journal of the American Statistical Association, Volume 67, Number 339

______, "The Public Finance Aspects of the Transportation Sector, A Staff Paper Prepared by the Office of Policy and Plan Development, U.S. Department of Transportation, Washington, D.C., May, 1971

______, FINANCING STATE AND LOCAL GOVERNMENTS, Proceedings of the Monetary Conference, Nantucket Island, Massachusetts, June 14-16, 1970

______,Sales Management's SURVERY OF BUYING POWER, (Yearly editions 1950-1970), Bill Brothers Publications, New York, New York

Biographical Summary

Dr. Sherman was born in New York City on June 22, 1948. He pursued undergraduate studies at the Massachusetts Institute of Technology, receiving a Bachelor of Science degreee in Aeronautical and Astronautical Engineering in February, 1971. Dr. Sherman received a Master of Science degree in Transportation Systems Analysis from M.I.T. in June, 1971. His S.M. thesis was entitled "The Airport Access Problem: A Case Study Approach." Dr. Sherman remained at M.I.T. for his doctoral research, concentrating in the field of transportation economics. He submitted his Ph.D. dissertation entitled "The Impacts of the Federal Aid HIghway Program on State and LOcal Highway Expenditures," in January, 1975.

Dr. Sherman's research interests include a wide range of topics relating to transport economics. He is currently employed as a Senior Research Associate for Charles River Associates, Inc., where he is conducting research on Federal energy and environmental policy alternatives, and developing imporved methods for predicting urban travel demand patterns. He has worked as a consultant to the government of Venezuela, assisting in the development of capital budgeting procedures. Dr. Sherman has also consulted to the U. S. Department of Transportation in a variety of areas including developing procedures for assessing urban mobility, and assisting in the design of the National Transportation Study.

Appendix A

Estimated Parameter Values of the Long Run Revenue Policy Model

This appendix presents a complete listing of the regression runs performed on the total expenditure model (TEM). In the figures that follow, each regression run is described by a four character model number, $l_1 l_2 n_1 n_2$ where:

l_1 = { S - grant terms stratified by type (Interstate and non-Interstate; T - single grant term

l_2 = { U - undeflated data set; D - price deflated data set

n_1 = { 1 - 48 State/14 year pooled data sample; 2 - 7 State/14 year pooled data sample; 3 - 41 State/14 year pooled data sample

n_2 = 1,2,..., - model specification number

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU11

GENERALIZED LEAST SQUARES

F-STAT: F(9,6621) = 258.86 SEE = 5.37 RSQ = 0.779

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	9.96	-0.650E-06	9.468	-0.601	0.018	0.605
STANDARD ERROR	5.58	0.732E-07	1.124	0.031	0.001	0.124
T-STATISTIC	1.78	8.74	8.41	19.53	17.94	4.88

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.319	0.457	-1.146	0.619
STANDARD ERROR	0.036	0.069	0.091	0.043
T-STATISTIC	8.86	6.62	12.55	14.39

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU12

GENERALIZED LEAST SQUARES

F-STAT: F(10,661) = 238.10 SEE = 5.32 RSQ = 0.782

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	8.98	-0.597E-06	10.639	-0.599	0.017	0.613
STANDARD ERROR	5.55	0.796E-07	1.206	0.030	0.001	0.123
T-STATISTIC	1.62	7.51	8.82	19.61	17.26	4.97

	RLTOT	TOLPCT	AVNIGP	AVIGP	BIPTCX
ESTIMATE VALUE	-0.298	0.355	-1.123	0.608	0.088
STANDARD ERROR	0.037	0.088	0.097	0.043	0.055
T-STATISTIC	8.05	4.02	11.61	14.14	1.58

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU13

GENERALIZED LEAST SQUARES

F-STAT: F(10,661) = 236.17   SEE = 5.34   RSQ = 0.781

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	6.73	-0.649E-06	9.872	-0.587	0.018	0.656
STANDARD ERROR	5.70	0.728E-07	1.139	0.031	0.001	0.125
T-STATISTIC	1.18	8.91	8.66	18.83	17.98	5.24

	RLTOT	TOLPCT	AVNIGP	AVIGP	GPOP
ESTIMATE VALUE	-0.333	0.407	-1.146	0.607	-0.402
STANDARD ERROR	0.036	0.072	0.091	0.043	0.172
T-STATISTIC	9.12	5.68	12.61	14.08	2.34

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU14

GENERALIZED LEAST SQUARES

F-STAT: F(11,660) = 223.92 SEE = 5.07 RSQ = 0.803

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	25.48	-0.608E-06	12.852	-0.652	0.016	0.820
STANDARD ERROR	6.06	0.758E-07	1.193	0.031	0.001	0.120
T-STATISTIC	4.20	8.02	10.76	21.05	15.51	6.82

	RLTOT	TOLPCT	AVNIGP	AVIGP	BIPTCX	GPOP
ESTIMATE VALUE	-0.247	0.284	-1.179	0.530	0.059	-0.508
STANDARD ERROR	0.037	0.086	0.093	0.042	0.053	0.164
T-STATISTIC	6.68	3.29	12.71	12.62	1.12	3.10

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU15

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 247.95   SEE = 5.47   RSQ = 0.771

	CONSTANT	MEC	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	7.93	-0.153E-05	9.315	-0.602	0.018	0.659
STANDARD ERROR	5.67	0.204E-06	1.130	0.031	0.001	0.126
T-STATISTIC	1.40	7.49	8.24	19.17	17.62	17.62

	PLTCT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.324	0.401	-1.119	0.621
STANDARD ERROR	0.037	0.071	0.093	0.044
T-STATISTIC	5.23	8.84	5.68	12.03

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU16

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 250.79   SEE = 5.44   RSQ = 0.773

	CONSTANT	VMI	KSIK	UFAC	PCY	GINI
ESTIMATE VALUE	10.01	-0.137E-03	9.360	-0.600	0.018	0.606
STANDARD ERROR	5.66	0.173E-04	1.128	0.031	0.001	0.126
T-STATISTIC	1.77	7.91	8.30	19.16	17.73	4.81

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.330	0.410	-1.135	0.620
STANDARD ERROR	0.036	0.070	0.093	0.043
T-STATISTIC	9.07	5.83	12.22	14.25

ESTIMATION RESULTS

TOTAL EXPE NDITURE MODEL

MODEL NO. SU21

GENERALIZED LEAST SQUARES

F-STAT: F(9, 88) = 21.76 SEE = 6.57 RSQ = 0.690

	CONSTANT	SPOP	KSTK	UFAC	PCY	GINI
ESTIMATE VALUE	97.82	-0.668E-06	0.209	-1.340	0.006	-0.542
STANDARD ERROR	8.94	0.737E-06	0.307	0.227	0.002	0.114
T-STATISTIC	10.95	0.91	0.68	5.90	3.66	4.74

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.127	2.772	-0.310	0.657
STANDARD ERROR	0.090	0.492	0.161	0.061
T-STATISTIC	1.41	5.64	1.92	10.75

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU22

GENERALIZED LEAST SQUARES

F-STAT: F(10, 87) = 15.24   SEE = 6.11   RSQ = 0.697

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	73.58	-0.178E-05	0.166	-0.616	0.003	-0.416
STANDARD ERROR	9.02	0.865E-06	0.133	0.147	0.002	0.194
T-STATISTIC	8.16	2.05	1.24	4.19	1.41	2.14

	RLTOT	TOLPCT	AVNIGP	AVIGP	BIPTCX
ESTIMATE VALUE	-0.032	1.400	-0.379	0.571	0.484
STANDARD ERROR	0.090	0.490	0.208	0.091	0.491
T-STATISTIC	0.91	2.86	1.82	6.26	0.99

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU31

GENERALIZED LEAST SQUARES

F-STAT: F(0,564) = 241.31 SEE = 5.14 RSQ = 0.794

	CONSTANT	SPOP	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	16.15	-0.478E-06	8.274	-0.637	0.018	0.693
STANDARD ERROR	5.55	0.724E-07	1.032	0.034	0.001	0.122
T-STATISTIC	2.91	6.60	8.02	18.50	17.32	5.67

	RLTOT	TOLPCT	AVNIGP	AVIGP
ESTIMATE VALUE	-0.524	0.368	-0.856	0.439
STANDARD ERROR	0.041	0.071	0.114	0.057
T-STATISTIC	12.75	5.21	7.51	7.68

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SU32

GENERALIZED LEAST SQUARES

F-STAT: F(10,563) = 223.20 SEE = 5.08 RSQ = 0.799

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	16.24	-0.508E-06	10.050	-0.631	0.018	0.683
STANDARD ERROR	5.48	0.783E-07	1.125	0.034	0.001	0.121
T-STATISTIC	2.96	6.49	8.93	18.53	16.99	5.65

	RLTOT	TCLPCT	AVNIGP	AVIGP	BIPTCX
ESTIMATE VALUE	-0.534	0.393	-0.919	0.415	-0.052
STANDARD ERROR	0.043	0.086	0.120	0.057	0.056
T-STATISTIC	12.32	4.55	7.64	7.30	0.93

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU11

GENERALIZED LEAST SQUARES

F-STAT: F(8,663) = 214.96 SEE = 6.02 RSQ = 0.722

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	24.12	-0.454E-06	13.640	-0.454	0.014	0.307
STANDARD ERROR	6.17	0.807E-07	1.655	0.033	0.001	0.138
T-STATISTIC	3.90	5.62	8.24	13.69	13.01	2.21

	RLTOT	TOLPCT	AVTGP
ESTIMATE VALUE	-0.488	0.482	0.038
STANDARD ERROR	0.038	0.078	0.032
T-STATISTIC	12.84	6.14	1.17

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU12

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 206.44 SEE = 5.85 RSQ = 0.737

	CONSTANT	SPOP	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	20.84	-0.314E-06	16.553	-0.458	0.013	0.337
STANDARD ERROR	6.04	0.844E-07	1.814	0.032	0.001	0.135
T-STATISTIC	3.45	3.72	9.13	14.07	12.29	2.50

	RLTOT	TOLPCT	AVTGP	BIPTCX
ESTIMATE VALUE	-0.418	0.178	0.039	0.259
STANDARD ERROR	0.039	0.098	0.035	0.056
T-STATISTIC	13.62	1.83	1.11	4.40

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU13

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 199.56 SEE = 5.93 RSQ = 0.731

	CONSTANT	SPOP	KSTK	UFAC	PCY	GINI
ESTIMATE VALUE	19.96	-0.455E-06	16.177	-0.461	0.015	0.355
STANDARD ERROR	6.23	0.795E-07	1.756	0.033	0.001	0.138
T-STATISTIC	3.19	5.72	9.21	12.96	13.30	2.57

	RLTOT	TOLPCT	AVTGP	GPOP
ESTIMATE VALUE	-0.502	0.388	-0.004	-0.543
STANDARD ERROR	0.038	0.081	0.033	0.191
T-STATISTIC	13.18	4.80	0.11	2.85

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU14

GENERALIZED LEAST SQUARES

F-STAT: F(10,661) = 173.72   SEE = 5.78   RSQ = 0.743

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	36.41	-0.322E-06	11.084	-0.534	0.012	0.618
STANDARD ERROR	6.90	0.835E-07	1.411	0.034	0.001	0.136
T-STATISTIC	5.27	3.86	7.85	15.66	10.74	4.53

	RLTOT	TOLPCT	AVTGP	BIPTCX	GPOP
ESTIMATE VALUE	-0.374	0.178	0.080	0.252	-0.554
STANDARD ERROR	0.041	0.098	0.032	0.058	0.186
T-STATISTIC	9.16	1.81	2.52	4.33	2.98

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. IU21

GENERALIZED LEAST SQUARES

F-STAT: F(8, 89) = 15.39 SEE = 7.61 RSQ = 0.580

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	99.12	0.317E-05	2.680	-1.331	0.001	-0.647
STANDARD ERROR	11.25	0.116E-05	0.611	0.216	0.002	0.208
T-STATISTIC	8.81	2.74	4.38	6.06	0.42	3.10

	RLTOT	TOLPCT	AVTGP
ESTIMATE VALUE	-0.260	1.641	0.725
STANDARD ERROR	0.090	0.189	0.101
T-STATISTIC	2.90	8.67	7.15

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU22

GENERALIZED LEAST SQUARES

F-STAT: F(9, 88) = 16.56 SEE = 7.15 RSQ = 0.629

	CONSTANT	SPOP	KSTK	UEAC	PCY	GINI
ESTIMATE VALUE	101.40	0.716E-06	0.255	-1.720	0.006	-0.416
STANDARD ERROR	9.79	0.938E-06	0.135	0.241	0.002	0.218
T-STATISTIC	10.35	0.76	1.88	7.12	2.85	1.91

	RLTOT	TOLPCT	AVTGP	BIPTCX
ESTIMATE VALUE	-0.304	3.290	0.583	0.085
STANDARD ERROR	0.088	0.546	0.089	0.096
T-STATISTIC	3.45	6.03	6.49	0.89

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU31

GENERALIZED LEAST SQUARES

F-STAT: F(8,565) = 243.48 SEE = 5.37 RSQ = 0.775

	CONSTANT	SPOP	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	28.27	-0.357E-06	9.880	-0.528	0.015	0.458
STANDARD ERROR	5.60	0.739E-07	1.182	0.034	0.001	0.125
T-STATISTIC	5.05	4.82	8.36	15.79	14.68	3.66

	RLTOT	TOLPCT	AVTGP
ESTIMATE VALUE	-0.643	0.391	0.013
STANDARD ERROR	0.040	0.074	0.028
T-STATISTIC	16.17	5.30	0.45

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TU32

GENERALIZED LEAST SQUARES

F-STAT: F(9,564) = 218.85   SEE = 5.34   RSQ = 0.777

	CONSTANT	SPOP	KSIK	UEAC	PCY	GINI
ESTIMATE VALUE	26.46	-0.322E-06	10.556	-0.529	0.015	0.482
STANDARD ERROR	5.61	0.788E-07	1.239	0.034	0.001	0.124
T-STATISTIC	4.72	4.08	8.52	15.80	14.19	3.88

	BLTOT	TOLPCT	AVTGP	BIPTCX
ESTIMATE VALUE	-0.617	0.315	0.018	0.068
STANDARD ERROR	0.044	0.090	0.032	0.057
T-STATISTIC	14.00	3.49	0.56	1.20

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD11

GENERALIZED LEAST SQUARES

F-STAT: F(9,6621) = 248.72   SEE = 6.92   RSQ = 0.772

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	12.12	-0.857E-06	8.028	-0.738	0.022	0.771
STANDARD ERROR	7.16	0.943E-07	1.050	0.040	0.001	0.159
T-STATISTIC	1.69	9.09	7.65	18.66	17.52	4.84

	RLTOT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.430	0.598	-1.103	0.642
STANDARD ERROR	0.046	0.089	0.092	0.045
T-STATISTIC	9.27	6.75	14.43	12.03

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD12

GENERALIZED LEAST SQUARES

F-STAT: F(10,6611) = 235.83 SEE = 6.77 RSQ = 0.781

	CONSTANT	SPOP	DEEKSIK	UEAC	DEEPCY	GINI
ESTIMATE VALUE	11.33	-0.791E-06	11.286	-0.730	0.022	0.750
STANDARD ERROR	7.04	0.101E-06	1.247	0.039	0.001	0.156
T-STATISTIC	1.61	7.81	9.05	18.81	16.95	4.80

	RLTOT	TOLPCT	DEFNIG	DEFIG	BIPTCX
ESTIMATE VALUE	-0.395	0.421	-1.123	0.606	0.118
STANDARD ERROR	0.047	0.112	0.096	0.044	0.071
T-STATISTIC	8.40	3.75	11.60	13.70	1.67

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD13

GENERALIZED LEAST SQUARES

F-STAT: F(10,6611) = 233.26 SEE = 6.80 RSQ = 0.779

	CONSTANT	SPOP	DEFKSIK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	8.32	-0.861E-06	10.389	-0.715	0.023	0.808
STANDARD ERROR	7.26	0.927E-07	1.167	0.040	0.001	0.129
T-STATISTIC	1.15	9.28	8.90	18.03	17.74	5.07

	RLTOT	TOLPCT	DEFNIG	DEFIG	GPOP
ESTIMATE VALUE	-0.442	0.494	-1.148	0.607	-0.530
STANDARD ERROR	0.046	0.091	0.091	0.044	0.218
T-STATISTIC	9.54	5.39	12.59	13.67	2.43

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD14

GENERALIZED LEAST SQUARES

F-STAT: F(11,660) = 222.67 SEE = 6.44 RSQ = 0.802

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	33.23	-0.796E-06	13.677	-0.801	0.020	1.040
STANDARD ERROR	7.64	0.963E-07	1.220	0.039	0.001	0.153
T-STATISTIC	4.34	8.27	11.21	20.44	15.03	6.81

	RLTOT	TOLPCT	DEFNIG	DEFIG	BIPTCX	GPOP
ESTIMATE VALUE	-0.323	0.327	-1.167	0.520	0.087	-0.619
STANDARD ERROR	0.047	0.110	0.092	0.043	0.067	0.207
T-STATISTIC	6.88	2.97	12.65	12.04	1.30	2.99

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD21

GENERALIZED LEAST SQUARES

F-STAT: F(9, 88) = 28.00 SEE = 7.50 RSQ = 0.741

	CONSTANT	SPOP	DEFKSIK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	121.10	-0.623E-06	0.776	-1.783	0.010	-0.679
STANDARD ERROR	9.36	0.879E-06	0.368	0.236	0.002	0.099
T-STATISTIC	12.93	0.71	2.10	7.56	4.97	6.87

	RLTOT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.185	3.590	-0.295	0.666
STANDARD ERROR	0.101	0.502	0.132	0.058
T-STATISTIC	1.83	7.15	2.24	11.50

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD22

GENERALIZED LEAST SQUARES

F-STAT: F(10, 87) = 17.73 SEE = 7.45 RSQ = 0.771

	CONSTANT	SPOP	DEFKSTK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	87.41	-0.179E-05	0.056	-0.859	0.005	-0.419
STANDARD ERROR	10.94	0.106E-05	0.165	0.176	0.002	0.231
T-STATISTIC	7.99	1.68	0.34	4.88	2.07	1.82

	RLTOT	TOLPCT	DEFNIG	DEFIG	BIPTCX
ESTIMATE VALUE	0.092	1.789	-0.433	0.624	0.492
STANDARD ERROR	0.109	0.456	0.206	0.087	0.549
T-STATISTIC	0.84	3.76	2.10	7.17	0.90

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD31

GENERALIZED LEAST SQUARES

F-STAT: F(9,5641) = 236.03 SEE = 6.60 RSQ = 0.790

	CONSTANT	SPOP	DEFKSIK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	19.62	-0.648E-06	8.696	-0.778	0.023	0.869
STANDARD ERROR	7.10	0.928E-07	1.065	0.044	0.001	0.157
T-STATISTIC	2.76	6.98	8.16	17.64	17.01	5.55

	RLTCT	TOLPCT	DEFNIG	DEFIG
ESTIMATE VALUE	-0.686	0.444	-0.867	0.440
STANDARD ERROR	0.053	0.091	0.116	0.060
T-STATISTIC	12.99	4.87	7.48	7.33

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. SD32

GENERALIZED LEAST SQUARES

F-STAT: F(10,5631) = 216.52 SEE = 6.55 RSQ = 0.794

	CONSTANT	SPOP	DEFKSIK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	19.59	-0.676E-06	10.153	-0.771	0.023	0.861
STANDARD ERROR	7.04	0.101E-06	1.152	0.044	0.001	0.155
T-STATISTIC	2.78	6.72	8.81	17.60	16.57	5.55

	RLTOT	TOLPCT	DEFNIG	DEFIG	BIPTCX
ESTIMATE VALUE	-0.697	0.468	-0.908	0.415	-0.053
STANDARD ERROR	0.056	0.111	0.122	0.060	0.072
T-STATISTIC	12.44	4.21	7.44	6.94	0.73

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD11

GENERALIZED LEAST SQUARES

F-STAT: F(8,6631) = 215.33   SEE = 7.63   RSQ = 0.722

	CONSTANT	SPOP	DEFKSIK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	30.59	-0.620E-06	14.757	-0.551	0.018	0.359
STANDARD ERROR	7.81	0.102E-06	1.711	0.042	0.001	0.175
T-STATISTIC	3.92	6.06	8.62	13.11	12.92	2.04

	RLTOT	TOLPCT	DEFTG
ESTIMATE VALUE	-0.638	0.576	0.017
STANDARD ERROR	0.048	0.100	0.033
T-STATISTIC	13.27	5.76	0.52

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD12

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 203.36 SEE = 7.46 RSQ = 0.734

	CONSTANT	SPOP	DEFKSIK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	25.83	-0.441E-06	16.012	-0.561	0.017	0.427
STANDARD ERROR	7.68	0.108E-06	1.784	0.041	0.001	0.172
T-STATISTIC	3.36	4.08	8.97	13.55	12.17	2.48

	RLTOT	TOLPCT	DEFTG	BIPTCX
ESTIMATE VALUE	-0.551	0.222	0.044	0.331
STANDARD ERROR	0.050	0.124	0.035	0.076
T-STATISTIC	10.98	1.79	1.27	4.38

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD13

GENERALIZED LEAST SQUARES

F-STAT: F(9,662) = 195.76   SEE = 7.57   RSQ = 0.727

	CONSTANT	SPOP	DEFKSTK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	24.98	-0.622E-06	15.419	-0.529	0.019	0.447
STANDARD ERROR	7.98	0.102E-06	1.712	0.042	0.001	0.176
T-STATISTIC	3.13	6.12	9.00	12.49	13.19	2.54

	RLTOT	TOLPCT	DEFTG	GPOP
ESTIMATE VALUE	-0.657	0.496	0.004	-0.659
STANDARD ERROR	0.048	0.103	0.032	0.243
T-STATISTIC	13.57	4.81	0.13	2.72

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD14

GENERALIZED LEAST SQUARES

F-STAT: F(10,661) = 173.92 SEE = 7.33 RSQ = 0.743

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	45.66	-0.453E-06	11.785	-0.655	0.015	0.791
STANDARD ERROR	8.71	0.106E-06	1.437	0.043	0.002	0.173
T-STATISTIC	5.24	4.27	8.20	15.13	10.61	4.58

	RLTOT	TOLPCT	DEFTG	BIPTCX	GPOP
ESTIMATE VALUE	-0.489	0.212	0.067	0.315	-0.736
STANDARD ERROR	0.052	0.124	0.032	0.074	0.236
T-STATISTIC	9.44	1.71	2.08	4.24	3.12

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD21

GENERALIZED LEAST SQUARES

F-STAT: F(8, 89) = 12.77 SEE = 9.99 RSQ = 0.535

	CONSTANT	SPOP	DEFKSTK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	94.63	0.224E-05	2.180	-1.097	0.003	-0.619
STANDARD ERROR	13.92	0.141E-05	0.671	0.250	0.002	0.271
T-STATISTIC	6.80	1.58	3.25	4.40	1.07	2.28

	RLTOT	TOLPCT	DEFTG
ESTIMATE VALUE	-0.286	1.322	0.563
STANDARD ERROR	0.116	0.129	0.094
T-STATISTIC	2.45	10.25	6.00

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD22

GENERALIZED LEAST SQUARES

F-STAT: F(9, 881) = 16.56   SEE = 8.92   RSQ = 0.629

	CONSTANT	SPOP	DEFKSIK	UEAC	DEFPCY	GINI
ESTIMATE VALUE	107.32	0.109E-05	0.372	-1.870	0.009	-0.381
STANDARD ERROR	11.80	0.117E-05	0.140	0.275	0.002	0.278
T-STATISTIC	9.10	0.93	2.66	6.81	3.50	1.37

	RLTOT	TOLPCT	DEFTG	BIPTCX
ESTIMATE VALUE	-0.368	3.578	0.580	0.057
STANDARD ERROR	0.110	0.657	0.086	0.127
T-STATISTIC	3.36	5.45	6.76	0.45

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD31

GENERALIZED LEAST SQUARES

F-STAT: F(8,565) = 239.00 SEE = 6.88 RSQ = 0.772

	CONSTANT	SPOP	DEEKSTK	UEAC	DEEPCY	GINI
ESTIMATE VALUE	34.84	-0.498E-06	10.351	-0.643	0.019	0.574
STANDARD ERROR	7.15	0.948E-07	1.217	0.043	0.001	0.160
T-STATISTIC	4.87	5.25	8.51	15.00	14.41	3.59

	RLTOT	TOLPCT	DEFTG
ESTIMATE VALUE	-0.834	0.479	0.001
STANDARD ERROR	0.058	0.095	0.029
T-STATISTIC	16.40	5.05	0.04

ESTIMATION RESULTS

TOTAL EXPENDITURE MODEL

MODEL NO. TD32

GENERALIZED LEAST SQUARES

F-STAT: F(9,564) = 215.82 SEE = 6.83 RSQ = 0.775

	CONSTANT	SPOP	DEFKSTK	UFAC	DEFPCY	GINI
ESTIMATE VALUE	32.15	-0.455E-06	11.340	-0.641	0.019	0.612
STANDARD ERROR	7.14	0.101E-06	1.290	0.043	0.001	0.159
T-STATISTIC	4.50	4.50	8.79	15.00	13.93	3.86

	RLTOT	TOLPCT	DEFTG	BIPTCX
ESTIMATE VALUE	-0.801	0.382	0.002	0.082
STANDARD ERROR	0.056	0.115	0.032	0.073
T-STATISTIC	14.21	3.31	0.05	1.12

Appendix B

Derivation of Derivatives and Elasticities from the Expenditure Models

This appendix sets forth the derivation of derivatives and elasticities from the long run revenue policy model, and the short run allocation model. Moreover, it will be shown how the results from these two models can be combined to indicate the total change- on both revenue and allocation- resulting from changes in the level of the explanatory variables.

The short run allocation model takes the form

$$(1) \qquad S_j = \frac{E_j}{R} = \frac{f_j}{\sum f_i}$$

where S_j = share of expenditure devoted to category j

E_j = expenditures on category j

$R = \sum_i E_i$ = total expenditures (State and Federal funds)

$f_j = f_j(X) = \prod_{k \epsilon j} X_k^{\hat{\alpha}jk}$ or $\Pi e^{\hat{\alpha}jk} X_k$

We wish to derive the form of both the derivative of E_j with respect to X_k, $\frac{\partial E_j}{\partial X_k}$, and the elasticity of E_j with respect to X_k, η_{E_j/X_k}

From (1) we get

$$(2) \qquad E_j = R \frac{f_j}{\sum_i f_i} = R(X) \frac{f_j(X)}{\sum_i f_i(X)}$$

But R(X) is related to the estimated form of the long run revenue policy model.

The long run revenue policy model takes the form:

$$(3) \qquad R_{own,pc} = \beta_o + \sum_m \hat{R}_m X_m$$

where $R_{own,pc}$ = total per capita expenditures from states own sources (i.e. exclusive of Federal payments to the States, F).

$\hat{\beta}_m$ = estimated coefficients

Thus, $R_{own,pc}$ in (3) is related to R in (2) by:

$$(4) \qquad R = SPOP *(R_{own,pc} + F_{pc})$$

where SPOP = state population

F_{pc} = Federal highway payments per capita

Assuming a long run static solution[1] whereby

$$(5) \qquad F_{pc} = G_{pc}$$ where G_{pc} = per capita highway <u>grants</u>,

---

1. Assuming that the states ultimately expend all Federal grants made available, differences between G_{pc} and F_{pc} can be attributed to short run, transient responses. In the long run, it can be assumed that Federal payments will eventually "settle down" to the rate of Federal grant availability.

the long run revenue policy model can be rewritten as:

$$(6) \qquad R = \left(\beta_o + \hat{\beta}_m X_m + (1 + \hat{\beta}_g)\, G_{pc}\right) \ {*}SPOP$$

Returning to equation (2) we can now define the derivative of E_j with respect to X_k as:

$$(7) \qquad \frac{\partial E_j}{\partial X_k} = S_j \frac{\partial R}{\partial X_k} + R \frac{\partial s_j}{\partial X_k}$$

The corresponding elasticity is simply:

$$(8) \qquad \eta_{Ej/X_k} = \frac{\partial E_j}{\partial X_k} \frac{X_k}{E_j} = \frac{X_k}{E_j} \left\{S_j \frac{\partial R}{\partial X_k} + R \frac{\partial S_j}{\partial X_k}\right\}$$

$$= \frac{X_k}{E_j} \left(\frac{E_j}{R} \frac{\partial R}{\partial X_k} + R \frac{\partial S_j}{\partial X_k}\right) = \frac{X_k}{R} \frac{\partial R}{\partial X_k} + \frac{X_k}{S_j} \frac{\partial S_j}{\partial X_k}$$

$$= \eta_{R/X_k} + \eta_{S_j/X_k}$$

The Product Form Model

In this case, the specification of each share takes the form:

$$(9) \qquad s_j = \frac{\prod_{k \varepsilon j} X_k^{\hat{\alpha}_{jk}}}{\sum_i \prod_{l \varepsilon i} X_l^{\hat{\alpha}_{il}}} = \frac{n}{d}$$

where: n = share numerator

d = share denominator

$\hat{\alpha}_{jk}$ = estimated share model coefficients

Assume variable X_p appears in the share numerator and one or more of the f_i in the share denominator. The derivative of the numerator with respect to X_p takes the form:

$$(10) \qquad \frac{\partial n}{\partial X_p} = \hat{\alpha}_{jp} X_p^{\hat{\alpha}_{jp} - 1} \prod_{\substack{k \varepsilon j \\ k \neq p}} X_k^{\hat{\alpha}_{jk}} = \frac{\hat{\alpha}_{jp}}{X_p} n$$

By the same reasoning, the derivative of the share denominator with respect to X_p is:

(11) $$\frac{\partial d}{\partial X_p} = \sum_i \frac{\hat{\alpha}_{ip}}{X_p} f_i$$

Using these results, we can now derive:

(12) $$\frac{\partial s_j}{\partial X_p} = \frac{d \frac{\partial n}{\partial X_p} - n \frac{\partial d}{\partial X_p}}{d^2}$$

$$= \hat{\alpha}_{jp} \cdot d \cdot n - n \sum_i \frac{\hat{\alpha}_{ip}}{X_p} f_i$$

$$= s_j (1 - s_j) \frac{\hat{\alpha}_{jp}}{X_p} - s_j \sum_{i \neq j} \frac{\hat{\alpha}_{ip}}{X_p} s_i$$

Returning to equation (7), the derivative of expenditures on category j with respect to variable X_p is:

(13) $$\frac{\partial E_j}{\partial X_p} = s_j \frac{\partial R}{\partial X_p} + \frac{R}{X_p} \{s_j (1 - s_j) \hat{\alpha}_{jp} - s_j \sum_{i \neq j} \hat{\alpha}_{ip} s_i\}$$

But from (6),[1]

[1]If the variable in question X_p = SPOP, then $\frac{\partial R}{\partial SPOP} = \hat{\beta}_o +$ $2 \hat{\beta}_o$ SPOP

$$(14) \qquad \frac{\partial E_j}{\partial X_p} = \hat{\beta}_p \text{ SPOP}$$

Thus, we can now state the final form of the derivative of E_j with respect to variable X_p:

$$(15) \qquad \frac{\partial E_j}{\partial X_p} = s_j \hat{\beta}_p \text{ SPOP} + \frac{R}{X_p} \{ s_j (1 - s_j) \hat{\alpha}_{jp} - s_j \sum_{i \neq j} \hat{\alpha}_{ip} s_i \}$$

The corresponding elasticity for the product form model is simply:

$$(16) \qquad \eta_{E_j/X_p} = \frac{\hat{\beta}_p X_p \text{ SPOP}}{R} + (1-s_j) \hat{\alpha}_{jp} - \sum_{i \neq j} \hat{\alpha}_{ip} s_i$$

Special Cases: The Product Form Model

In the derivation of the derivatives and elasticities of the expenditure models, on the preceding pages, it was assumed that the explanatory variables X enter into the allocation model as given in equation (9). In the actual estimated form of the models, there were two exceptions to this specification.

The first concerns the highway grant variables, which enter several of the expenditure shares as either specific grant types (e.g. Interstate, Primary, Secondary) or as aggregates across grant categories (e.g. total non-Interstate grants, total grants). We are interested in deriving the derivatives and elasticities of expenditures with respect to each of the categorical grant types. Since the derivation in this instance follows the same reasoning as in the preceding section, the results are presented without a detailed derivation.

Let $G_I \equiv$ Interstate grants

$G_P \equiv$ Primary grants

$G_S \equiv$ Secondary grants

$G_{NI} \equiv G_P + G_S =$ non-Interstate grants

$G_T \equiv$ Total Grants

From equation (6), it is clear that:

$$\text{(17)} \qquad \frac{\partial R}{\partial G_g} = (1 + \hat{\beta}_g)\ \text{SPOP}, \quad \text{for } g = I, P, S$$

Using this result in equation (7), the derivatives of expenditures with respect to grant terms take the form:

$$\text{(18)} \qquad \frac{\partial E_j}{\partial G_g} = s_j \cdot (1 + \hat{\beta}_g) \cdot \text{SPOP} + R\, \{ s_j \cdot (1 - s_j) \cdot \left(\frac{\hat{\alpha}_{jg}}{G_g} + \frac{\delta_I}{G_{NI}} \hat{\alpha}_{jNI} + \frac{\hat{\alpha}_{jT}}{G_T} \right) - s_j \sum_{i \neq j} \left(\frac{\hat{\alpha}_{ig}}{G_g} + \frac{\delta_I}{G_{NI}} \hat{\alpha}_{iNI} + \frac{\hat{\alpha}_{iT}}{G_T} \right) s_i \}$$

for $g = I, P, S$

and $\delta_I = \begin{cases} 0 \text{ if } g=I \\ 1 \text{ if } g= P \text{ or } S \end{cases}$

The corresponding derivatives follow directly from equation (18):

$$(19) \qquad \eta_{E_j/G_g} = \frac{(1 + \hat{\beta}_g)\, G_g \text{ SPOP}}{R} + (1 - s_j) \cdot$$

$$\left(\hat{\alpha}_{jg} + \delta_I \frac{G_g}{G_{NI}} \hat{\alpha}_{jNI} + \frac{G_g}{G_T} \hat{\alpha}_{jT} \right) -$$

$$\sum_{i \neq j} \left(\hat{\alpha}_{ig} + \delta_I \frac{G_g}{G_{NI}} \hat{\alpha}_{iNI} + \frac{G_g}{G_T} \hat{\alpha}_{iT} \right) s_i$$

The second exception to the general derivation of elasticities and derivatives concerns the population variable, SPOP. This variable appears in several of the expenditure shares in both direct form, and as the denominator of the variable measuring capital *per capita* (KSTK). In this case, we can rewrite equation (9) as:

$$(20) \qquad s_j = \frac{\text{SPOP}^{\hat{\alpha}_{j\text{SPOP}}} \left(\frac{\text{CAPTL}}{\text{SPOP}} \right)^{\hat{\alpha}_{j\text{KSTK}}} X_1^{\hat{\alpha}_{jk}} \cdots X_k^{\hat{\alpha}_{jk}}}{\sum_i \text{SPOP}^{\hat{\alpha}_{i\text{SPOP}}} \left(\frac{\text{CAPTL}}{\text{SPOP}} \right)^{\hat{\alpha}_{i\text{KSTK}}} X_1^{\hat{\alpha}_{i1}} \cdots X_k^{\hat{\alpha}_{ik}}}$$

where: CAPTL = highway capital stocks

The derivative and elasticity of share s_j with respect to SPOP can be written respectively as:

(21) $$\frac{\partial s_j}{\partial SPOP} = \frac{(\hat{\alpha}_{jSPOP} - \hat{\alpha}_{jKSTK})}{SPOP} s_j (1 - s_j) - s_j \cdot \sum_{i \neq j} \left(\frac{\hat{\alpha}_{iSPOP} - \hat{\alpha}_{iKSTK}}{SPOP} \right)$$

(22) $$\eta_{s_j/SPOP} = (1 - s_j)(\hat{\alpha}_{jSPOP} - \hat{\alpha}_{jKSTK}) - \sum_{i \neq j} s_i \cdot (\hat{\alpha}_{iSPOP} - \hat{\alpha}_{iKSTK})$$

As noted in the footnote on page , the derivative of total expenditures, R with respect to population is:

(23) $$\frac{\partial R}{\partial SPOP} = \hat{\beta}_o + 2\beta_{SPOP}\, SPOP$$

Thus we can now state the form of the derivative and elasticity of E_j with respect to SPOP:

(24) $$\frac{\partial E_j}{\partial SPOP} = s_j (\hat{\beta}_o + 2\hat{\beta}_{SPOP}\, SPOP) + \frac{R\, s_j}{SPOP} \{(\hat{\alpha}_{jSPOP} - \hat{\alpha}_{jKSTK})(1 - s_j) - \sum_{i \neq j} (\hat{\alpha}_{iSPOP} - \hat{\alpha}_{iKSTK}) \cdot s_i\}$$

(25) $$\eta_{E_j/SPOP} = \frac{SPOP}{R}(\hat{\beta}_o + 2\hat{\beta}_{SPOP}) + (\hat{\alpha}_{jSPOP} - \hat{\alpha}_{jKSTK})(1 - s_j) - \sum_{i \neq j}(\hat{\alpha}_{iSPOP} - \hat{\alpha}_{iKSTK}) \cdot s_i$$

The Exponential Form Model

The derivatives and elasticities from the exponential form allocation model differ from the previously presented results of the product form model. In this case, each share is specified as:

(26) $$s_j = \frac{\prod_{k \varepsilon j} e^{\hat{\alpha}_{jk} X_k}}{\sum_i \prod_{l \varepsilon i} e^{\hat{\alpha}_{il} X_l}}$$

Following the same reasoning as expressed in equations (10) through (12), the derivative of expenditure share j with respect to a particular variable X_p is given by:

(27) $$\frac{\partial s_j}{\partial X_p} = \hat{\alpha}_{jp} s_j (1 - s_j) - s_j \sum_{i \neq j} \hat{\alpha}_{ip} s_i$$

The corresponding elasticity is simply:

(28) $$\eta_{s_j/X_p} = \hat{\alpha}_{jp} X_p (1 - s_j) - X_p \sum_{i \neq j} \hat{\alpha}_{jp} s_i$$

Substituting these results in equations (7) and (8), we get the derivative and elasticity of E_j with respect to X_p for the exponential form allocation model:

$$(29) \qquad \frac{\partial E_j}{\partial X_p} = s_j \hat{\beta}_p \, SPOP + R\{\hat{\alpha}_{jp} s_j (1 - s_j) - s_j \sum_{i \neq j} \hat{\alpha}_{ip} s_i\}$$

$$(30) \qquad \eta_{E_j/X_p} = \frac{\hat{\beta}_p X_p \, SPOP}{R} + \hat{\alpha}_{jp} X_p (1 - s_j) - X_p \sum_{i \neq j} \hat{\alpha}_{ip} s_i$$

Special Cases: The Exponential Form Model

As in the product type allocation model, the general form of the derivatives and elasticities for the exponential form allocation model do not apply in the case of the population variable and the highway grant terms. The derivatives and elasticities from the exponential model, for these special cases are presented below.[1]

$$(31) \qquad \frac{\partial E_j}{\partial G_g} = (1 + \hat{\beta}_g) \, SPOP + R \{ s_j (1 - s_j) (\hat{\alpha}_{jg} + \delta_I \hat{\alpha}_{jNI} + \hat{\alpha}_{jT}) - s_j \sum_{i \neq j} (\hat{\alpha}_{ig} + \delta_I \hat{\alpha}_{iNI} + \hat{\alpha}_{iT}) \}$$

[1] The notation used here is identical to the definitions given in the section "Special Cases: The Product Form Model."

(32)
$$\eta_{E_j/G_g} = \frac{(1+\hat{\beta}_g)\ G_g\ SPOP}{R} + G_g\ \{(1-s_j)\ (\hat{\alpha}_{jg} + \delta_I\ \hat{\alpha}_{jNI} + \hat{\alpha}_{jT}) - \sum_{i \neq j} (\hat{\alpha}_{ig} + \delta_I\ \hat{\alpha}_{iNI} + \hat{\alpha}_{iT})\ s_i\ \}$$

for $g = I, P, S$

and $\delta_I = \begin{cases} 0 \text{ if } g=I \\ 1 \text{ if } g\neq I \end{cases}$

(33)
$$\frac{\partial E_j}{\partial SPOP} = s_j\ (\hat{\beta}_o + 2\hat{\beta}_{SPOP}\ SPOP) + R \cdot KSTK \cdot s_j \cdot \{(1-s_j)\ (\hat{\alpha}_{jSPOP} - \frac{\hat{\alpha}_{jKSTK}}{SPOP}) - \sum_{i \neq j} (\hat{\alpha}_{iSPOP} - \frac{\hat{\alpha}_{iKSTK}}{SPOP})\ s_i\ \}$$

(34)
$$\eta_{E_j/SPOP} = \frac{SPOP}{R}\ (\hat{\beta}_o + 2\hat{\beta}_{SPOP}\ SPOP) + KSTK\ \{(1-s_j)\ (\hat{\alpha}_{jSPOP}\ SPOP - \hat{\alpha}_{jKSTK}) - \sum_{i \neq j} (\hat{\alpha}_{iSPOP}\ SPOP - \hat{\alpha}_{iKSTK})\ s_i\ \}$$

Appendix C

Derivatives and Elasticities from the Two Expenditure Models

This appendix contains the derived elasticities and derivatives from the expenditure models described in Chapters IV and V. On the pages that follow, the tables are titled "Short Run" or "Long Run" Elasticities (or Derivatives). The short run measures pertain to the short run expenditure model (SRAM), where by definition the States' budgets are fixed. The long run elasticities and derivatives reflect the empirical analysis integrating the results of the SRAM and TEM, and thus describe States' long run expenditure responses to Federal grants (*inter alia*) where budget levels can change.

The derivatives and elasticites are presented for both the product form and exponential form of the SRAM (see Chapter V.).

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.682	0.069	0.105
UFAC	0.402	0.192	-0.280
PCY	-0.201	-0.201	-0.201
GINI	-0.033	-0.033	0.298
KSTK	-0.169	0.112	0.026
TSPMR	-0.031	-0.031	0.277
PCCRMT	-0.011	-0.011	0.026
PCMF	-0.001	-0.001	-0.001
TOLPCT	-0.059	0.023	0.023
RLTOT	0.029	0.029	0.029
AVIG	0.873	-0.416	-0.433
AVPG	-0.070	0.534	-0.176
AVSG	-0.002	-0.045	0.261

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	0.650	-0.515	0.975
UFAC	-0.884	-0.036	-0.036
PCY	-0.201	-0.201	0.616
GINI	-0.033	-0.033	-0.033
KSTK	0.026	0.285	-0.068
TSPMR	-0.031	-0.031	-0.031
PCCRMT	0.183	-0.011	-0.011
PCMF	-0.001	0.007	-0.001
TOLPCT	0.023	0.023	0.023
RLTOT	-0.488	-0.041	0.028
AVIG	-0.161	0.082	-0.505
AVPG	-0.130	-0.062	-0.226
AVSG	-0.026	0.001	-0.066

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.573	0.126	0.085
UFAC	-0.128	0.366	0.726
PCY	-0.049	-0.049	-0.049
GINI	0.022	0.022	-0.168
KSTK	-0.077	-0.021	-0.211
TSPMR	-0.150	-0.150	1.150
PCCRMT	-0.014	-0.014	-0.038
PCMF	-0.021	-0.021	-0.021
TOLPCT	0.015	-0.006	-0.006
RLTOT	0.189	0.189	0.189
AVIG	0.774	-0.217	-0.759
AVPG	-0.016	0.379	-0.105
AVSG	0.084	0.035	-0.282

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

VARIABLE	SHARE NONFASYST	MAINT	OTHER
SPOP	1.122	0.114	0.347
UFAC	-0.867	-0.245	-0.245
PCY	-0.049	-0.049	0.232
GINI	0.022	0.022	0.022
KSTK	-0.211	0.110	0.238
TSPMR	-0.150	-0.150	-0.150
PCCRMT	0.348	-0.014	-0.014
PCMF	-0.021	0.103	-0.021
TOLPCT	-0.006	-0.006	-0.006
RLTOT	-0.161	0.131	-0.750
AVIG	-0.962	-0.076	-0.186
AVPG	-0.375	-0.117	-0.149
AVSG	-0.115	0.028	0.010

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.406	-0.117	-0.102
UFAC	0.314	-0.254	-0.339
PCY	-0.162	-0.162	-0.162
GINI	-0.037	-0.037	0.343
KSTK	-0.174	0.070	0.075
TSPMR	-0.032	-0.032	0.292
PCCRMT	-0.010	-0.010	0.030
PCMF	0.005	0.005	0.005
TOLPCT	-0.104	0.041	0.041
RLTOT	0.024	0.024	0.024
AVIG	0.781	-0.397	-0.401
AVPG	-0.124	0.617	-0.193
AVSG	0.112	-0.157	0.140

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

VARIABLE	NONFASYST	MAINT	OTHER
		SHARE	
SPOP	0.406	-0.361	0.690
UFAC	-0.663	0.050	0.050
PCY	-0.162	-0.162	0.465
GINI	-0.037	-0.037	-0.037
KSTK	0.075	0.200	-0.003
TSPMR	-0.032	-0.032	-0.032
PCCRMT	0.155	-0.010	-0.010
PCMF	0.005	-0.035	0.005
TOLPCT	0.041	0.041	0.041
RLTOT	-0.472	0.003	0.012
AVIG	-0.006	0.102	-0.441
AVPG	-0.096	-0.066	-0.217
AVSG	0.221	0.338	-0.253

PRODUCT FORM SPECIFICATION OF THE SRAM

FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

SHARE

VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-.105E 02	-.753E 00	0.578E 00
UFAC	0.402E08	-0.136E08	-0.100E 08
PCY	-0.474E 04	-0.335E 04	-0.170E 04
GINI	-0.524E 07	-0.371E 07	0.167E 08
KSTK	-0.172E 08	0.808E 07	0.940E 06
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.287E 08	0.145E 08
RLTOT	0.661E 07	0.468E 07	0.237E 07
AVIG	0.111E 01	-0.374E 00	-0.197E 00
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

	SHARE		
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	0.134E 01	-0.378E 01	0.131E 02
JFAC	-0.118E 08	-0.169E 07	-0.310E 07
PCY	-0.633E 03	-0.226E 04	0.127E 05
GINI	-0.701E 06	-0.250E 07	-0.458E 07
KSTK	0.351E 06	0.138E 08	-0.601E 07
TSPMR	-0.296E 02	-0.106E 03	-0.193E 03
PCCRMT	0.379E 08	-0.821E 07	-0.150E 08
PCMF	-0.531E 05	0.122E 07	-0.347E 06
TOLPCT	0.541E 07	0.193E 08	0.354E 08
RLTOT	-0.146E 08	-0.445E 07	0.543E 07
AVIG	-0.273E-01	0.495E-01	-0.561E 00
AVPG	-0.791E-01	-0.135E 00	-0.899E 00
AVSG	-0.390E-01	0.774E-02	-0.637E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

VARIABLE	SHARE INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.930E 01	0.150E 01	0.553E 00
UFAC	-0.114E 08	0.238E 08	0.259E 08
PCY	-0.888E 03	-0.649E 03	-0.356E 03
GINI	0.231E 07	0.169E 07	-0.710E 07
KSTK	-0.481E 07	-0.957E 06	-0.529E 07
TSPMR	-0.870E 03	-0.636E 03	0.268E 04
PCCRMT	-0.412E 08	-0.301E 08	-0.448E 08
PCMF	-0.102E 08	-0.746E 07	-0.409E 07
TOLPCT	0.526E 08	-0.155E 08	-0.851E 07
RLTOT	0.365E 08	0.267E 08	0.146E 08
AVIG	0.957E 00	-0.196E 00	-0.376E 00
AVPG	-0.679E-01	0.118E 01	-0.179E 00
AVSG	0.645E 00	0.194E 00	-0.866E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

VARIABLE	SHARE NONFASYST	SHARE MAINT	SHARE OTHER
SPOP	0.293E 01	0.109E 01	0.340E 01
UFAC	-0.124E 08	-0.129E 08	-0.132E 08
PCY	-0.143E 03	-0.524E 03	0.255E 04
GINI	0.371E 06	0.136E 07	0.139E 07
KSTK	-0.213E 07	0.407E 07	0.899E 07
TSPMR	-0.140E 03	-0.514E 03	-0.526E 03
PCORMT	0.165E 09	-0.243E 08	-0.249E 08
PCMF	-0.164E 07	0.295E 08	-0.617E 07
TOLPCT	-0.342E 07	-0.125E 08	-0.128E 08
RLTOT	-0.500E 07	0.149E 08	-0.874E 08
AVIG	-0.191E 00	-0.552E-01	-0.139E 00
AVPG	-0.257E 00	-0.295E 00	-0.384E 00
AVSG	-0.142E 00	0.126E 00	0.465E-01

PRODUCT FORM SPECIFICATION OF THE SRAM

FORTY ONE STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

SHARE

VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.799E 00	-0.252E 01	0.972E 01
UFAC	-0.865E 07	0.232E 07	0.468E 07
PCY	-0.509E 03	-0.181E 04	0.104E 05
GINI	-0.799E 06	-0.284E 07	-0.571E 07
KSTK	0.106E 07	0.997E 07	-0.306E 06
TSPMR	-0.300E 02	-0.106E 03	-0.214E 03
PCCRMT	0.293E 08	-0.666E 07	-0.134E 08
PCMF	0.243E 06	-0.586E 07	0.174E 07
TOLPCT	0.864E 07	0.307E 08	0.618E 08
RLTOT	-0.139E 08	0.266E 06	0.254E 07
AVIG	-0.908E-03	0.594E-01	-0.517E 00
AVPG	-0.566E-01	-0.133E 00	-0.915E 00
AVSG	-0.644E-02	0.398E-01	-0.556E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

VARIABLE	NONFASYST	MAINT	OTHER
	SHARE		
SPOP	0.799E 00	-0.252E 01	0.972E 01
UFAC	-0.865E 07	0.232E 07	0.468E 07
PCY	-0.509E 03	-0.181E 04	0.104E 05
GINI	-0.799E 06	-0.284E 07	-0.571E 07
KSTK	0.106E 07	0.997E 07	-0.306E 06
TSPMR	-0.300E 02	-0.106E 03	-0.214E 03
PCCRMT	0.293E 08	-0.666E 07	-0.134E 08
PCMF	0.243E 06	-0.586E 07	0.174E 07
TOLPCT	0.864E 07	0.307E 08	0.618E 08
RLTOT	-0.139E 08	0.266E 06	0.254E 07
AVIG	-0.908E-03	0.594E-01	-0.517E 00
AVPG	-0.566E-01	-0.138E 00	-0.915E 00
AVSG	-0.644E-02	0.398E-01	-0.556E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.330	0.943	1.117
UFAC	0.396	-0.198	-0.287
PCY	0.623	0.623	0.623
GINI	-0.029	-0.029	0.302
KSTK	-0.067	0.214	0.127
TSPMR	-0.031	-0.031	0.277
PCCRMT	-0.011	-0.011	0.026
PCMF	-0.001	-0.001	-0.001
TOLPCT	-0.059	0.023	0.023
RLTOT	0.028	0.028	0.028
AVIG	1.232	-0.057	-0.074
AVPG	-0.070	0.534	-0.176
AVSG	-0.002	-0.045	0.261

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	1.662	0.497	1.987
UFAC	-0.890	-0.042	-0.042
PCY	0.623	0.623	1.440
GINI	-0.029	-0.029	-0.029
KSTK	0.127	0.387	0.034
TSPMR	-0.031	-0.031	-0.031
PCCRMT	0.183	-0.011	-0.011
PCMF	-0.001	0.007	-0.001
TOLPCT	0.023	0.023	0.023
RLTOT	-0.489	-0.043	0.026
AVIG	0.198	0.440	-0.146
AVPG	-0.130	-0.062	-0.226
AVSG	-0.026	0.001	-0.066

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	SHARE		
	INTERSTATE	PRIMARY	SECONDARY
SPOP	1.326	2.026	1.985
UFAC	-0.139	0.355	0.715
PCY	0.188	0.188	0.188
GINI	0.018	0.018	-0.172
KSTK	-0.075	-0.019	-0.209
TSPMR	-0.150	-0.150	1.150
PCCRMT	-0.014	-0.014	-0.038
PCMF	-0.021	-0.021	-0.021
TOLPCT	0.016	-0.006	-0.006
RLTOT	0.189	0.189	0.189
AVIG	1.159	0.168	-0.374
AVPG	0.031	0.425	-0.058
AVSG	0.110	0.061	-0.256

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	NONFASYST	MAINT	OTHER
		SHARE	
SPOP	3.021	2.014	2.247
UFAC	-0.878	-0.256	-0.256
PCY	0.188	0.188	0.468
GINI	0.018	0.018	0.018
KSTK	-0.209	0.113	0.240
TSPMR	-0.150	-0.150	-0.150
PCCRMT	0.348	-0.014	-0.014
PCMF	-0.021	0.103	-0.021
TOLPCT	-0.006	-0.006	-0.006
RLTOT	-0.162	0.131	-0.750
AVIG	-0.576	0.310	0.200
AVPG	-0.328	-0.071	-0.103
AVSG	-0.089	0.054	0.036

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	SHARE INTERSTATE	PRIMARY	SECONDARY
SPOP	0.754	1.042	1.057
UFAC	0.307	-0.261	-0.346
PCY	0.690	0.690	0.690
GINI	-0.033	-0.033	0.348
KSTK	-0.086	0.157	0.162
TSPMR	-0.032	-0.032	0.292
PCCRMT	-0.010	-0.010	0.030
PCMF	0.005	0.005	0.005
TOLPCT	-0.104	0.041	0.041
RLTOT	0.021	0.021	0.021
AVIG	1.098	-0.080	-0.084
AVPG	-0.115	0.626	-0.184
AVSG	0.115	-0.154	0.144

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

LONG RUN MODEL ELASTICITIES

VARIABLE	SHARE: NONFASYST	MAINT	OTHER
SPOP	1.565	0.799	1.850
UFAC	-0.670	0.043	0.043
PCY	0.690	0.690	1.318
GINI	-0.033	-0.033	-0.033
KSTK	0.162	0.287	0.084
TSPMR	-0.032	-0.032	-0.032
PCCRMT	0.155	-0.010	-0.010
PCMF	0.005	-0.035	0.005
TOLPCT	0.041	0.041	0.041
RLTOT	-0.475	-0.000	0.009
AVIG	0.312	0.419	-0.124
AVPG	-0.087	-0.057	-0.208
AVSG	0.224	0.341	-0.249

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

	SHARE		
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.507E 01	0.103E 02	0.615E 01
UFAC	0.395E 08	-0.140E 08	-0.103E 08
PCY	0.147E 05	0.104E 05	0.526E 04
GINI	-0.460E 07	-0.325E 07	0.170E 08
KSTK	-0.686E 07	0.154E 08	0.464E 07
TSPMR	-0.221E 03	-0.157E 03	0.707E 03
PCCRMT	-0.172E 08	-0.122E 08	0.147E 08
PCMF	-0.398E 06	-0.281E 06	-0.142E 06
TOLPCT	-0.103E 09	0.290E 08	0.147E 08
RLTOT	0.627E 07	0.444E 07	0.225E 07
AVIG	0.157E 01	-0.516E-01	-0.336E-01
AVPG	-0.317E 00	0.172E 01	-0.286E 00
AVSG	-0.170E-01	-0.354E 00	0.104E 01

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

VARIABLE	NONFASYST	SHARE MAINT	OTHER
SPOP	0.342E 01	0.365E 01	0.267E 02
UFAC	-0.119E 08	-0.201E 07	-0.368E 07
PCY	0.196E 04	0.701E 04	0.297E 05
GINI	-0.614E 06	-0.219E 07	-0.402E 07
KSTK	0.173E 07	0.188E 08	0.302E 07
TSPMR	-0.296E 02	-0.106E 03	-0.193E 03
PCCRMT	0.379E 08	-0.821E 07	-0.150E 08
PCMF	-0.531E 05	0.122E 07	-0.347E 06
TOLPCT	0.548E 07	0.196E 08	0.358E 08
RLTOT	-0.147E 08	-0.461E 07	0.513E 07
AVIG	0.336E-01	0.267E 00	-0.162E 00
AVPG	-0.791E-01	-0.135E 00	-0.899E 00
AVSG	-0.390E-01	0.774E-02	-0.637E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

LONG RUN MODEL DERIVATIVES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.215E 02	0.240E 02	0.129E 02
UFAC	-0.124E 08	0.231E 08	0.255E 08
PCY	0.342E 04	0.250E 04	0.137E 04
GIN.	0.191E 07	0.140E 07	-0.726E 07
KSTK	-0.466E 07	-0.846E 06	-0.523E 07
TSPMR	-0.870E 03	-0.636E 03	0.268E 04
PCCRMT	-0.412E 08	-0.301E 08	-0.448E 08
PCMF	-0.102E 08	-0.746E 07	-0.409E 07
TOLPCT	0.546E 08	-0.140E 08	-0.770E 07
RLTOT	0.364E 08	0.266E 08	0.146E 08
AVIG	0.143E 01	0.152E 00	-0.185E 00
AVPG	0.130E 00	0.132E 01	-0.996E-01
AVSG	0.843E 00	0.339E 00	-0.787E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
SEVEN STATE SAMPLE

LONG RUN MODEL DERIVATIVES

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	0.789E 01	0.193E 02	0.220E 02
UFAC	-0.126E 08	-0.135E 08	-0.138E 08
PCY	0.551E 03	0.202E 04	0.516E 04
GINI	0.308E 06	0.113E 07	0.116E 07
KSTK	-0.210E 07	0.416E 07	0.908E 07
TSPMR	-0.140E 03	-0.514E 03	-0.526E 03
PCCRMT	0.165E 09	-0.243E 08	-0.249E 08
PCMF	-0.164E 07	0.295E 08	-0.617E 07
TOLPCT	-0.309E 07	-0.113E 08	-0.116E 08
RLTOT	-0.502E 07	0.149E 08	-0.875E 08
AVIG	-0.115E 00	0.226E 00	0.149E 00
AVPG	-0.225E 00	-0.178E 00	-0.264E 00
AVSG	-0.110E 00	0.243E 00	0.166E 00

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

LONG RUN MODEL DERIVATIVES

	SHARE		
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.115E 02	0.112E 02	0.566E 01
UFAC	0.311E 08	-0.186E 08	-0.123E 08
PCY	0.168E 05	0.118E 05	0.589E 04
GINI	-0.540E 07	-0.380E 07	0.202E 08
KSTK	-0.944E 07	0.121E 08	0.622E 07
TSPMR	-0.233E 03	-0.164E 03	0.748E 03
PCCRMT	-0.145E 08	-0.102E 08	0.156E 08
PCMF	0.189E 07	0.133E 07	0.661E 06
TOLPCT	-0.172E 09	0.475E 08	0.237E 08
RLTOT	0.479E 07	0.337E 07	0.168E 07
AVIG	0.140E 01	-0.719E-01	-0.374E-01
AVPG	-0.526E 00	0.202E 01	-0.295E 00
AVSG	-0.137E 00	-0.318E 00	0.106E 01

PRODUCT FORM SPECIFICATION OF THE SRAM
FORTY ONE STATE SAMPLE

LONG RUN MODEL DERIVATIVES

VARIABLE	SHARE NONFASYST	MAINT	OTHER
SPOP	0.308E 01	0.558E 01	0.260E 02
UFAC	-0.874E 07	0.199E 07	0.400E 07
PCY	0.216E 04	0.768E 04	0.295E 05
GINI	-0.696E 06	-0.247E 07	-0.498E 07
KSTK	0.229E 07	0.143E 08	0.848E 07
TSPMR	-0.300E 02	-0.106E 03	-0.214E 03
PCCRMT	0.293E 08	-0.666E 07	-0.134E 08
PCMF	0.243E 06	-0.586E 07	0.174E 07
TOLPCT	0.870E 07	0.309E 08	0.622E 08
RLTOT	-0.140E 08	-0.993E 04	0.198E 07
AVIG	0.511E-01	0.244E 00	-0.145E 00
AVPG	-0.514E-01	-0.120E 00	-0.878E 00
AVSG	-0.123E-02	0.583E-01	-0.519E 00

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

	SHARE		
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.469	-0.018	0.087
UFAC	0.554	-0.415	-0.579
PCY	-0.242	-0.242	-0.242
GINI	-0.015	-0.015	0.138
KSTK	0.314	-0.026	-0.051
TSPMR	-0.014	-0.014	0.121
PCCRMT	0.007	0.007	-0.082
PCMF	0.008	0.008	0.008
TOLPCT	-0.164	0.064	0.064
RLTOT	0.065	0.065	0.065
AVIG	0.554	-0.108	-0.435
AVPG	-0.057	0.379	-0.229
AVSG	0.012	-0.058	0.081

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	0.308	-0.157	0.554
UFAC	-0.569	0.017	0.017
PCY	-0.242	-0.242	0.740
GINI	-0.015	-0.015	-0.015
KSTK	-0.051	0.077	-0.351
TSPMR	-0.014	-0.014	-0.014
PCCRMT	0.063	0.007	0.007
PCMF	0.008	-0.054	0.008
TOLPCT	0.064	0.064	0.064
RLTOT	-1.345	-0.248	0.188
AVIG	0.404	0.230	-0.555
AVPG	0.086	0.038	-0.182
AVSG	0.071	0.051	-0.039

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

	SHARE		
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	-0.721E 01	-0.191E 00	0.477E 00
UFAC	0.553E 08	-0.293E 08	-0.207E 08
PCY	-0.570E 04	-0.403E 04	-0.204E 04
GINI	-0.243E 07	-0.172E 07	0.776E 07
KSTK	0.319E 08	-0.187E 07	-0.188E 07
TSPMR	-0.968E 02	-0.685E 02	0.309E 03
PCCRMT	0.106E 08	0.747E 07	-0.453E 08
PCMF	0.315E 07	0.223E 07	0.113E 07
TOLPCT	-0.236E 09	0.795E 08	0.401E 08
RLTOT	0.145E 08	0.103E 08	0.522E 07
AVIG	0.704E 00	-0.971E-01	-0.198E 00
AVPG	-0.258E 00	0.122E 01	-0.372E 00
AVSG	0.136E 00	-0.456E 00	0.322E 00

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

SHORT RUN MODEL DERIVATIVES

VARIABLE	NONFASYST	MAINT	OTHER
		SHARE	
SPOP	0.633E 00	-0.115E 01	0.744E 01
UFAC	-0.760E 07	0.825E 06	0.151E 07
PCY	-0.761E 03	-0.272E 04	0.152E 05
GINI	-0.325E 06	-0.116E 07	-0.212E 07
KSTK	-0.700E 06	0.373E 07	-0.312E 08
TSPMR	-0.129E 02	-0.462E 02	-0.846E 02
PCCRMT	0.130E 08	0.504E 07	0.922E 07
PCMF	0.421E 06	-0.968E 07	0.275E 07
TOLPCT	0.150E 08	0.535E 08	0.979E 08
RLTOT	-0.404E 08	-0.266E 08	0.369E 08
AVIG	0.686E-01	0.139E 00	-0.617E 00
AVPG	0.524E-01	0.817E-01	-0.723E 00
AVSG	0.105E 00	0.270E 00	-0.377E 00

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL ELASTICITIES

		SHARE	
VARIABLE	INTERSTATE	PRIMARY	SECONDARY
SPOP	0.543	0.994	1.098
UFAC	0.547	-0.421	-0.586
PCY	0.583	0.583	0.583
GINI	-0.011	-0.011	0.142
KSTK	0.415	0.076	0.050
TSPMR	-0.014	-0.014	0.121
PCCRMT	0.007	0.007	-0.082
PCMF	0.008	0.008	0.008
TOLPCT	-0.163	0.064	0.064
RLTOT	0.063	0.063	0.063
AVIG	0.913	0.251	-0.076
AVPG	-0.057	0.379	-0.229
AVSG	0.012	-0.058	0.081

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL **ELASTICITIES**

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	1.320	0.855	1.565
UFAC	-0.576	0.011	0.011
PCY	0.533	0.583	1.564
GINI	-0.011	-0.011	-0.011
KSTK	0.050	0.179	-0.250
TSPMR	-0.014	-0.014	-0.014
PCCRMT	0.063	0.007	0.007
PCMF	0.008	-0.054	0.008
TOLPCT	0.064	0.064	0.064
RLTCT	-1.346	-0.250	0.187
AVIG	0.762	0.589	-0.196
AVPG	0.086	0.038	-0.182
AVSG	0.071	0.051	-0.039

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

VARIABLE	SHARE INTERSTATE	PRIMARY	SECONDARY
SPOP	0.836E 01	0.108E 02	0.605E 01
UFAC	0.547E 08	-0.298E 08	-0.210E 08
PCY	0.137E 05	0.972E 04	0.492E 04
GINI	-0.178E 07	-0.126E 07	0.799E 07
KSTK	0.423E 08	0.545E 07	0.183E 07
TSPMR	-0.968E 02	-0.685E 02	0.309E 03
PCCRMT	0.106E 08	0.747E 07	-0.453E 08
PCMF	0.315E 07	0.223E 07	0.113E 07
TOLPCT	-0.285E 09	0.797E 08	0.403E 08
RLTOT	0.142E 08	0.101E 08	0.510E 07
AVIG	0.116E 01	0.226E 00	-0.347E-01
AVPG	-0.258E 00	0.122E 01	-0.372E 00
AVSG	0.136E 00	-0.456E 00	0.322E 00

EXPONENTIAL FORM SPECIFICATION OF THE SRAM
FORTY EIGHT STATE SAMPLE

LONG RUN MODEL DERIVATIVES

		SHARE	
VARIABLE	NONFASYST	MAINT	OTHER
SPOP	0.271E 01	0.628E 01	0.211E 02
UFAC	-0.769E 07	0.512E 06	0.938E 06
PCY	0.184E 04	0.656E 04	0.322E 05
GINI	-0.238E 06	-0.851E 06	-0.156E 07
KSTK	0.681E 06	0.867E 07	-0.222E 08
TSPMR	-0.129E 02	-0.462E 02	-0.846E 02
PCCRMT	0.130E 08	0.504E 07	0.922E 07
PCMF	0.421E 06	-0.968E 07	0.275E 07
TOLPCT	0.150E 08	0.537E 08	0.984E 08
RLTOT	-0.404E 08	-0.268E 08	0.366E 08
AVIG	0.129E 00	0.357E 00	-0.218E 00
AVPG	0.524E-01	0.817E-01	-0.723E 00
AVSG	0.105E 00	0.270E 00	-0.377E 00