

THE SHORT RUN RELATIONSHIP BETWEEN INVESTMENT
IN PUBLIC INFRASTRUCTURE AND THE FORMATION
OF PRIVATE CAPITAL

by

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In recent years, the condition of the nation's public infrastructure has become an issue of heightened concern. Several studies have concluded that the deterioration of roads, bridges, water and sewer facilities, and mass transit systems has reached alarming proportions and that massive public investment is needed to reverse this trend. These studies, though, do not take into account the impact of public infrastructure on the production decisions of private industry. The failure to consider this relationship is due primarily to the scarcity of empirical studies on this issue. Hence, the aim of this study is to fill this void in the economic literature by estimating the short run relationship between public capital outlay and net private investment.

The estimation of this relationship is based on an

export base model of a regional economy in which public capital enters the production process of the basic sector as an unpaid, exogenous input. The amount of public capital supplied to the basic sector is determined by the median voter of the region. The model is then closed by assuming that the median voter's income is dependent upon the wage bill of the basic sector which itself is affected by the amount of public capital supplied by the local governments in the region. This model generates the basic sector's demand equations for labor and net private investment as functions of output, relative input prices, and public investment.

These short run, input demand equations were estimated using two samples of SMSA's, growing and declining, for the period 1970 to 1978. Private and public capital were found to exhibit a relatively weak, substitutive relationship in growing regions (the estimated, short run, input demand elasticity with respect to public capital outlay is -0.224). The estimated, short run elasticity for declining regions is ten times smaller (i.e., -0.023). These findings suggest that private industry can substitute private capital for nonexistent or inadequate public infrastructure but that this ability is not great and differs between growing and declining regions.

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DEDICATION

This dissertation is dedicated in memory of Toby, my four-legged friend, who is greatly missed.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION.....	1
II.	PUBLIC INTERMEDIATE GOODS AND PUBLIC INFRASTRUCTURE.....	9
	Theory of Public Intermediate Goods.....	9
	Categories of Public Infrastructure.....	15
	Infrastructure and the Empirical Literature.....	20
	Implications for This Study.....	25
III.	A SIMPLE MODEL OF THE REGIONAL ECONOMY.....	27
	The Private Sector.....	30
	The Public Sector.....	36
	The Regional Labor Market.....	48
	The Complete Model of the Regional Economy.....	59
IV.	DERIVATION OF THE ESTIMATING EQUATIONS, THE DATA, AND PROBLEMS WITH THE EMPIRICAL ESTIMATION.....	73
	Derivation of the Estimating Equations..	73
	The Data and Problems with the Empirical Estimation.....	84
V.	EMPIRICAL ESTIMATION OF THE REGIONAL MODEL.....	98
	Estimation of the Short Run Input Demand Equations.....	98
	Estimation of the Public Expenditure Equations.....	136
VI.	THE EXISTENCE OF BUDGETARY TRADEOFFS.....	151
VII.	SUMMARY OF MAJOR FINDINGS, CONCLUDING ANALYSIS, AND SUGGESTIONS FOR FUTURE ANALYSES.....	165

APPENDIX

A.	CALCULATION OF SHORT RUN INPUT DEMAND ELASTICITIES.....	176
B.	SOURCES OF DATA AND METHODS OF CONSTRUCTING VARIABLES.....	178
	Private Sector Variables.....	178
	Public Sector Variables.....	180
C.	CORRECTION PROCEDURE FOR THE R^2 WHEN THE COMPUTER GENERATED INTERCEPT IS SUPPRESSED.....	184
D.	COMPUTATION OF EXPENDITURE ELASTICITIES....	188
E.	REGULARITY CONDITIONS.....	189
	BIBLIOGRAPHY.....	192

LIST OF TABLES

Table		Page
1.	Net Investment and Labor Demand Equations for Full Sample.....	99
2.	Summary of Estimates for Full Sample.....	101
3.	Classification of SMSA's.....	113
4.	Means of Component Variables Used to Compute SMSA Index Score.....	114
5.	Percentage Change in Net Private Investment and Gross Public Investment During the Period 1970-1978: Growth SMSA's.....	115
6.	Percentage Change in Net Private Investment and Gross Public Investment During the Period 1970-1978: Decline SMSA's.....	116
7.	Summary of Tests for Asymmetric Responses Between Growing and Declining Regions.....	119
8.	Net Investment and Labor Demand Equations for Sample of Growth SMSA's.....	123
9.	Summary of Estimates for Sample of Growth SMSA's.....	124
10.	Net Investment and Labor Demand Equations for Sample of Decline SMSA's.....	128
11.	Summary of Estimates for Sample of Decline SMSA's.....	130
12.	Public Expenditure Equations for Full Sample..	138
13.	Public Expenditure Equations for Sample of Growth SMSA's.....	143
14.	Public Expenditure Equations for Sample of Decline SMSA's.....	145
15.	Summary of Expenditure Elasticities.....	155

16.	Expenditure Elasticities with Respect to the Total Budget.....	160
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CHAPTER I

INTRODUCTION

In recent years, the condition of the nation's public infrastructure has become an issue of heightened concern. Several studies have concluded that the deterioration of roads, bridges, water and sewer facilities, and mass transit systems has reached alarming proportions and that massive public investment is needed to reverse this trend. Studies done by Choate (1982) and Associated General Contractors (1983), for example, estimated that \$3 trillion in public capital investment is required over the next two decades in order to ensure that the nation's public infrastructure is "adequate." Another study (Choate and Walter, 1981) estimated that it will cost \$40 billion to maintain New York City's infrastructure alone. A more modest estimate of the needed public investment (\$53 billion per year) was presented in a study by the Congressional Budget Office (1983).

This deterioration of the nation's public infrastructure may have serious consequences for regional economic development since one of the factors that may have a significant impact on regional growth is public investment. Neoclassical theory describes regional growth

as resulting from private capital and labor migrating in response to regional differences in input prices. Moreover, several studies have shown that private capital formation (and, hence, regional growth) has been adversely affected not only by increases in the cost of private capital but also by increases in energy prices, labor costs, and environmental regulations (e.g., Garofalo and Fogarty, 1984a; Eberts and Fogarty, 1984). Relatively little attention, though, has been paid to the potential impact of public investment on private capital formation.

Public infrastructure has several unique features. In particular, it may be both an intermediate and a final good. Residents of a region consume public infrastructure as a final good (e.g., taking a Sunday drive on publicly built and maintained roads). The same infrastructure, though, may be used as an intermediate good in the production process of private industry (e.g., a firm may use public roads to transport its good(s) to market). Public capital is not purchased "on the market," as are labor and private capital. Rather, a given amount of public capital is supplied to the private sector by the local governments in the region in return for a lump sum tax payment. Moreover, firms have no direct input into how much public capital is supplied to them. Thus, public infrastructure enters the production process of private industry as an "unpaid," fixed input and will have a direct impact on regional output as well as the

demand for private factors of production.

The amount of public capital supplied to private industry is determined by the the resident-voters of the region who consume public infrastructure as a final good. Yet, these voters may also be affected by the impact of public investment on the production decisions of private industry. For example, if public investment enhances the productivity of private capital and labor, then less inputs are required to produce a given level of output. Hence, public investment lowers the cost of producing a given level of output, which enables firms to lower the price of their output. The resulting increase in consumer demand will lead to an increase in production on the part of existing firms. Moreover, new firms may enter the region attracted by the productivity incentives offered by the local public infrastructure. In both cases, regional output will increase, putting upward pressure on wages and regional employment.

The resident-voters of the region may have a vested interest in this economic development because their income will be affected by this expansion of the private sector. This regional growth will result in additional wage income being generated by private industry. This will increase the total income of the region (through a multiplier effect) and, hence, increase the income of the resident-voters.

The link between public investment and regional income

may affect how the region's residents vote on public capital expenditure issues. For example, if public capital is a normal good, voters fully perceive the link between private industry and their income, and a majority of the voters will be residents of the region when the benefits of current public investment are realized, then the prospect of regional growth may induce voters to approve additional public capital expenditures. On the other hand, if this link is not perceived or a majority of the voters are elderly and/or highly mobile, then it is less likely that voters will approve additional public capital expenditures. In either case, the impact of public investment on the resident-voter's income is dependent upon the magnitude of the impact of public investment on regional, economic development.

The impact of deteriorating public infrastructure on regional growth depends upon the strength of this relationship between public investment and the production decisions of private industry. There have been very few empirical studies that have investigated this relationship. This is due mainly to the unavailability of private and public capital stock series. A few studies, though, have attempted to estimate this relationship. For example, Mera (1975), employing Japanese data, entered "social capital" in a regional production function and found it to have a significant impact on regional output, although the strength

of the effect varied depending on the type of social capital included in the regional production function. Another study (Hulten and Schwab, 1984) inferred the impact of public investment on regional growth from differences in regional total factor productivity since a measure of public infrastructure was not available. This study concluded that regional total factor productivity was not any different in regions in which the condition of public infrastructure was better than average than in regions with sub-standard public infrastructure. This study did not consider that public infrastructure may have an effect on firms' location decisions. A complete survey of the relevant studies on this issue is presented in the following chapter.

The purpose of this study is to fill this void by empirically estimating the impact of public investment on the formation of private capital, holding the level of regional output constant. This will give an indication of how public and private capital are technically related in the regional production function (i.e., how private industry reacts in the short run to scarce or inadequate public infrastructure). The long run impact of public investment (i.e., the effect on the demand for regional output and the impact on firms' location decisions) will not be directly considered by this study although its findings will allow for some speculation as to the magnitude of the long run effect. This study is made possible by the recent

construction of a regional private capital stock series. At this point, however, a regional public capital stock series is not yet available and a public capital outlay series is used instead. Thus, the short run impact of public infrastructure on private capital will be inferred from an estimation of the short run relationship between public capital outlay and net private investment.

Estimation of this short run relationship is based upon an export base model of a regional economy in which public capital enters the production process of the basic or export sector. The amount of public capital provided to the basic sector is determined by the decisive voter in the region, assumed to be the median voter. Public infrastructure is assumed to enter both the median voter's utility function and the aggregate production function of the basic sector. Unlike traditional median voter models, however, (e.g., Borcharding and Deacon, 1972; Bergstrom and Goodman, 1973; Pommerehne and Frey, 1976), the median voter's income is endogenous and is assumed to depend upon the wage income generated by the basic sector. Thus, the utility of the median voter will be affected by public investment in two ways. There will be a direct effect since the level of public capital directly enters the median voter's utility function (i.e., since public capital is directly consumed by the median voter as a final public good). There will also be an indirect effect since public capital may also be an

intermediate public good and enter the basic sector's aggregate production function as an "unpaid" input. An increase in public investment may result in a long run increase in the wage bill of the basic sector as basic sector wages and employment rises. Through a multiplier process, this will increase the median voter's income, although there may be a considerable time lag involved. The perception of the link between the private sector and the median voter's income and the discounting of future benefits from public investment will determine whether or not this public investment will induce the median voter to approve additional public capital expenditures.

It should be noted that although this study is primarily concerned with the short run microeconomic relationship between public and private investment, a macroeconomic model of a regional economy is used to develop the overall relationship between public infrastructure and the production decisions of private industry. Such a model is necessary in order to give some perspective to the findings of this study. These findings will provide just one piece to the overall puzzle of how public investment affects regional growth. The implications of these findings for the impact of declining public infrastructure on regional, economic development can only be analyzed in the context of a model that incorporates both the short and long run impacts of public investment on private industry.

The organization of this paper is as follows: Chapter II presents a brief discussion of the theoretical nature of public intermediate goods (of which public infrastructure is one type) and a survey of the relevant economic literature. The simple model of a regional economy outlined above is developed in greater detail in Chapter III. The estimating equations derived from this simple model are presented in Chapter IV along with a discussion of the data employed in the estimation of these equations and some of the estimation problems encountered. The findings of the empirical estimation of the short run relationship between public and private investment are then presented in Chapter V. Finally, some additional empirical findings are given in Chapter VI with a summary of the major findings of this study, concluding analysis, and suggestions for future research being presented in Chapter VII.

CHAPTER II

PUBLIC INTERMEDIATE GOODS AND PUBLIC INFRASTRUCTURE

Theory of Public Intermediate Goods

Public intermediate goods, of which public infrastructure is one type, are services provided by local governments that can enter the production process of private industry as well as the utility functions of the region's resident-voters. With respect to private industry, insight into how these local public goods might enter the production process can be gained by reviewing Meade's analysis of external economies and diseconomies (1952).

Meade's intention was to distinguish between two types of external economies (or diseconomies). The first type, called an "unpaid factor of production," is an input in the production process that is not "purchased on the market." Consider two industries, cohabitating a given region, apple-growing and bee-keeping. Since bees feed on apple blossoms, apples enter the production function for bee-keeping as follows:

$$(\text{Apple-growing}): X_1 = f_1(K_1, L_1)$$

$$(\text{Bee-keeping}): X_2 = f_2(K_2, L_2, X_1)$$

where K and L refer to private capital and labor and X_1 and

X_2 are apples and honey. Assuming the production function for apple-growing exhibits constant returns to scale, then a doubling of the amount of private capital and labor employed in apple-growing will exactly double the output of apples. But a doubling of the amount of private capital and labor used in bee-keeping will not double the output of honey unless the output of apples simultaneously doubles. Thus, there are constant returns to scale for both industries taken together but not for bee-keeping taken alone. Meade calls this a case of an unpaid factor because the apple-farmer cannot charge the bee-keeper for the bees' food.

A second type of external economy is a physical or social "atmosphere" affecting the production process. An example of atmosphere is rainfall. Rainfall is available to all farms in a region regardless of their number. Thus, if the amount of private capital and labor devoted to wheat farming is doubled, output of wheat would also double even if rainfall were to remain constant. This differs from the case of an unpaid input where a doubling of private capital, labor, and apple-blossoms was needed to double the output of honey. Thus, the main difference between these two types of externalities is that atmosphere is unaffected by changes in the industry's scale of operation. An unpaid input, on the other hand, is fixed in amount. Hence, as the number of firms in the industry increases, less of the unpaid input is available to each firm.

Meade's distinction between unpaid inputs and atmosphere can be used to classify public intermediate goods. For example, such public intermediate goods as basic technological knowledge, farm weather reports, and pollution control can be classified as atmosphere. These public goods augment the efficiency of existing factors of production and, hence, do not directly enter firms' production. That is, the i th firm's production function would have the form:

$$X_i = f[A(G)K_i, B(G)L_i]$$

Assuming constant returns to scale, a doubling of output would require a doubling of the effective inputs $A(G)K_i$ and $B(G)L_i$ (G being the total amount of the public intermediate good supplied by the local government). The flow of the services emanating from the public intermediate goods cannot be altered by the firm, firms cannot be excluded from using the services, and the full amount of the services is an input for all firms regardless of the firm's or industry's scale of operation. In other words, these are pure public inputs in the Samuelson sense (1954).

Meade's notion of an unpaid input can also be used to categorize certain other public intermediate goods. This type of public intermediate good directly enters the firm's production function. But because of congestion not all of this public good can be used by the firm (i.e., it must be shared with other firms). In this case, the i th firm's

production function would have the form:

$$X_i = f(K_i, L_i, g_i)$$

Again assuming constant returns to scale, a doubling of output would require a doubling of inputs including the firm's rationed amount (g_i) of the total amount of the public intermediate good supplied by the local governments (G) (one way g_i can be defined is the total amount of G supplied to private industry divided by the number of firms in the region who share this public good). An example of such a public intermediate good are publicly provided highways. The number of miles of highway is fixed (at least for a significant period of time). As the number of firms in a region increases, congestion effectively rations the total amount of highway services available to each firm. Equal use of this public good, thus, is impossible.

The theoretical treatment of public intermediate goods in the economic literature has concentrated for the most part on this production relationship. The first two papers to explicitly deal with these types of public goods in a theoretical framework were Kaizuka (1965) and Sandmo (1972). These papers derived an equilibrium condition for the efficient provision of a pure public intermediate good that was the production analogue of Samuelson's pure public consumption good condition (1954). Assuming a fixed number of firms, this condition states that an efficient use of the

public intermediate good in production occurs when the sum of the values of the marginal product of the public intermediate good to all firms equals its marginal rate of transformation.

A series of four papers followed (Boadway, 1973; Henderson, 1974; Hillman, 1978; and McMillan, 1979), which all basically came to the same conclusions. First, the Samuelson-Kaizuka-Sandmo efficiency condition applies only to the case where the production function exhibits constant returns to scale in all inputs except the public good (i.e., where the public intermediate good is factor augmenting). Secondly, if the number of firms is allowed to vary and the production functions exhibit constant returns to scale in all inputs including the public good (i.e., unpaid input), the number of firms in the region should be as large as possible to take full advantage of the public intermediate good. Given this specification of the production function, firms will earn a rent according to the value of the marginal product of the public intermediate good. This rent will attract new firms to the region leading to the dissipation of this rent (assuming that the total amount of the public input, G , remains constant). Moreover, the smaller the firm, the larger is their ratio of public to private factors used by the firm, and, hence, the larger is the value of the marginal product of the private factors. Of course there are limits to this process such as

congestion, indivisibility of inputs, and legal barriers to entry.

A paper that has interesting implications for the long run impact of public investment on regional growth is Negishi (1973). Assuming the production function exhibits constant returns to scale in all inputs, including the public intermediate good, the firm will earn rents according to the value of the marginal product of the public input. Assuming further that this rent is imputed to the owners of private capital and that private capital and the public intermediate good exhibit a long run, complementary relationship, there will be a higher concentration of private capital in those industries that earn higher rents from the public input than other industries. Negishi concludes that if private capital and the public input are not perfect substitutes, then the productivity of the public input will be higher than the amount needed to satisfy the efficiency condition which will lead to a higher level of public expenditure assuming the local government seeks to maximize industrial profit.

Only two papers model the effects of public intermediate goods on the utility of the resident-voter. Pestieau (1976) assumed that the public intermediate good does not directly enter into the resident-voters' utility functions. But he did make the resident-voters' income dependent upon the profits of the firms who directly benefit

from the unpaid factor of production. The intent of this paper was to show whether under these conditions majority voting would lead to an optimal supply of the public intermediate good. The answer to this question is yes, if taxes are distributed equally among households, if the median voter consumes an average amount of each good, and if he/she owns an average share of each firm.

Kanemoto (1980) was the first to place the public intermediate good directly into the utility function of the resident-voter and the firms' production functions. Like Pestieau, the assumption was also made that the resident-voters' income was dependent upon the profits of the industry. The main emphasis of this paper, though, was on the production relationship. Kanemoto was able to show that, if the number of firms in the industry is fixed, the benefits accruing to firms from the public intermediate good are given by the value of the change in the industrial net output vector. An empirical estimation of these benefits, though, was not attempted.

Categories of Public Infrastructure

Public investment may be used as a policy tool by local governments for long run, regional development. Since public capital is one type of public intermediate good, it can enter the production process of private industry. In the long run, an increase in public investment may improve

the competitive position of the region in the national and international markets and may attract new firms to the region. Since all public infrastructure is not alike, insight into how public capital may affect private industry and regional growth can be gained by considering the different types of public capital.

One way public capital can be categorized is according to Meade's distinction between unpaid factors of production and atmosphere. Basically, this is what the public intermediate good literature has done. The services flowing from schools, hospitals, and parks and recreational facilities, for example, can be generally considered as atmosphere. These services are factor augmenting and, thus, have an impact on the effectiveness of the inputs employed by the private sector. Also, since these services do not directly enter the production process (in the same manner as private capital and labor), they have an indirect effect on regional economic activity. On the other hand, highways and bridges do enter directly into the production process since they are separate inputs from private capital and labor. In Meade's terminology, these would be called unpaid factors of production. Since they are fixed in amount, congestion effectively rations the services flowing from these public goods. Also, the firms who employ these inputs in their production process do not purchase these services on the market as they would private capital. Other types of

public infrastructure cannot easily be defined as either atmosphere or unpaid inputs. For example, water treatment facilities and sewer systems may both augment the effectiveness of the inputs employed by firms. On the other hand, both may also enter the production process as a separate input.

Hansen (1965), in a study of the determinants of local public investment, also divided public capital into two categories. Included in the category of "economic" overhead capital (EOC) are roads, gas and electricity supply, water supply, drainage and sewer systems, bridges, harbors and river transportation systems, irrigation systems, and market places. Local public infrastructure classified as EOC are "primarily oriented toward the support of directly productive activities or toward the movement of economic goods" (p. 151). On the other hand, "social" overhead capital (SOC) includes items that may affect regional productivity indirectly but are generally considered to satisfy "non-economic" demands. Such public capital includes schools, police and fire protection, public buildings, parks, and public housing. An additional distinction between EOC and SOC, according to Hansen, is that community residents are willing to leave their residences in order to take advantage of SOC located in other municipalities (e.g., parks, hospitals, schools). But, they prefer EOC to be located close to their residences

and places of employment (e.g., roads and gas, electricity, water, and sewer systems). Thus, as a municipality expands, the demand for EOC will be greater than that for SOC since SOC demands can be satisfied in other communities. Construction of SOC facilities, therefore, can be postponed in favor of EOC projects.

Mera (1975), in a comprehensive analysis of the contribution of public infrastructure to regional production, considered four classifications of "social capital": (1) social capital for the primary sector (i.e., agriculture, forestry, hunting, fishery, and marine culture); (2) social capital for the secondary sector (i.e., mining, construction, and manufacturing); (3) transportation and communication facilities; and (4) general welfare (i.e., health, education, and welfare, including housing). Mera's definition of social capital differs slightly from the traditional notion of public infrastructure in that he includes some types of private capital stock. "Social capital includes all capital improvements made by all levels of government and such portion of the stock of capital accumulated by the private sector that has definite social implications such as railroads, highways, hospitals, and educational and research institutions" (p. 107).

Following Meade, Mera treated social capital as a separate input in a regional production function but also realized that social capital may indirectly affect regional

productive activity by being an "allocator of private factors of production" (i.e., factor augmentation). Through an equilibrium model of regional growth, he found that in the U.S., the growth rate of regional output is equal to the growth rate of social capital. Thus, if social capital is to be used as a policy tool for increasing the growth of a region, then social capital must grow at a rate that equals the targeted growth rate for the region. He also discovered that regional growth rates are significantly affected by the growth of technology.

In an analysis of regional production functions in Japan, all four types of social capital were found to have a significant effect on regional output, although the strength of the effect varied depending on the type of social capital included in the production function. Furthermore, Mera was able to demonstrate the dual role of social capital, i.e., augmenting private factors of production. Using Japanese data, he was able to conclude that "high density development that is made possible by the provision of high density social capital helps to increase the productive efficiency of private capital and labor, and at the same time helps to save the quantity of social capital itself" (p. 230).

In this study, public capital is defined to include social capital provided only by local governments in a given region. This definition encompasses capital improvements on police and fire facilities, parks and recreation facilities,

highways, sewer systems and other forms of sanitation, hospitals, and health and welfare facilities. It will be assumed that this aggregate measure of public infrastructure satisfies Meade's definition of an unpaid input so that it can enter the production process of private industry as a separate input. This is a reasonable assumption to make since the services flowing from this aggregate measure is fixed in amount so that congestion will ration these services among firms. In addition, private industry is assumed to pay a lump sum amount for these services (e.g., property tax) rather than purchase these services at a per unit price as they do for private capital and labor.

Although this aggregate measure of public infrastructure is assumed to satisfy the definition of an unpaid input, it should be remembered that public capital may also affect the production process indirectly (i.e., through factor augmentation). Thus, the impact of public investment on the production process of private industry will encompass two effects: one resulting from public capital entering the production process as a separate input and another resulting from the "factor allocating" nature of public infrastructure.

Infrastructure and the Empirical Literature

Except for Mera (1975), there is a paucity in the economic literature concerning the effect of investment in

public infrastructure on private industry. Several studies have examined public investment but in different contexts. Peterson (1968) examined the determinants of local government, capital outlays in the context of a budgetary decision problem. Huckins (1983) focused on the demands for factors of production in the government sector and the degree of substitutability between these factors. Municipal services are produced from both capital and labor inputs. Huckins sought to determine how responsive municipal governments have been to factor price changes and technological change. His model combined a variant of the median voter model with a Nadiri and Rosen-type (1974) factor adjustment model to arrive at factor demand equations for capital and labor.

Using a sample consisting of 46 large municipalities over the period 1954 to 1979, Huckins found that these city governments appear to have been responsive to changes in relative input prices. Local governments appear to have responded to increases in the relative price of capital by employing more labor, and vice versa. In addition, the long run response was found to be greater than that of the short run. Analysis of the 46 cities individually over time produced much weaker evidence of cost minimizing behavior on the part of local governments.

Holcombe and Zardkoohi (1980) sought to explain, through a public choice approach, the division of the local

government budget between investment in public infrastructure and the output of public services that are contemporaneously consumed. If the stream of benefits produced by current investment extend beyond the lifetime of the average voter, then individuals will be biased against such public infrastructure since they will not be alive to realize all of the returns to public investment. Instead, voters will favor public expenditures that produce immediate benefits. Thus, the older the average voter, the more likely he/she will vote against investment in public infrastructure and in favor of public services that can be consumed at the current time (e.g., police and fire protection, parks and recreation).

State level data for 1972 were used to test this hypothesis. A regression of the ratio of capital to total outlays on a number of explanatory variables, which included the median age in each state, revealed that an increase in the median age results in a significant reduction in this ratio. Hence, given the level of total expenditures, it appears that the mix of public expenditures will be biased against investment in public infrastructure, at least at the state level.

Several studies have examined the optimal amount of public investment in what are referred to as "boomtowns." The term boomtown is used to describe relatively small communities that experience large jumps in population over a

five to twelve year period, after which the population settles to some lower equilibrium level. In most cases, boomtowns result from the sudden expansion of an existing production facility or the location of a new plant in or near the community. The industries most often the cause of boomtown expansion are power generation and mining. The problem facing local government officials concerns the timing of public investment. Should the community invest in public infrastructure to satisfy the peak of the boom and then suffer idle capital stock in future years or should the community invest to satisfy only the post-boom demand?

Cummings and Schulze (1978) constructed a model based on the idea that the optimal investment strategy is one where the marginal capital costs of excess capacities experienced during the post-boom period are equated with the marginal social costs attributable to deteriorated services from relatively lower per capita levels of public infrastructure during the construction phase of the expansion. The implication of this model for the timing of public investment is that the sooner the investment occurs, the more stable will be the construction period, with respect to periodic changes in the population.

Any model of an optimal investment strategy must account for the benefits of investment in public infrastructure. Cummings and Schulze posited that these benefits may be captured by a wage differential between

boomtowns and stable communities. In order to attract and retain labor in the boomtown, labor must be compensated for the difference in the "quality of life" relative to a stable community. This quality of living is proxied by the per capita level of public infrastructure in the boomtown. That is, during the construction phase, the existing infrastructure will not be able to provide the same quality of services as that found in a stable community (due to the increased population in the boomtown).

Cummings and Mehr (1977) attempted to find empirical evidence in support of the hypothesis that this wage differential can be (at least partly) explained by the differential in per capita infrastructure. Employing data from 28 towns in New Mexico and Colorado, the authors found that the greater is the differential in public infrastructure between boomtowns and stable communities, the smaller is the wage differential. It should be noted that this is very a tentative finding because of severe problems with the data employed in the analysis (e.g., public investment was used as a measure of public capital stock, the wage data was not city specific, and no account of private capital was taken).

Kiefer and Miller (1984) posited that during periods of rapid growth, local governments are subject to fiscal stress caused by the inflexibility of bureaucracy. The authors sought to quantify this stress by measuring the inadequacy

of public infrastructure to satisfy the demands of the population during boomtown growth. Because of bureaucratic inertia, the amount of public infrastructure supplied will not, at least in the short run, equal the amount demanded by the voters in the community. Taking this into account, the authors employed a dynamic budget adjustment model in order to explain per household public investment in boomtowns. The resulting equation explaining public investment was estimated using a pooled time series-cross section sample of fourteen Utah cities for the period 1971 through 1979. The results of that estimation suggest that in making the transition from a normal growth rate, assumed to be five percent, to boomtown conditions, assumed to be twenty percent, per household public infrastructure declines by about nine percent in spite of increased efforts on the part of local governments to raise additional revenue.

Implications for This Study

In light of the above literature review, it appears that this study is the first to examine the short run impact of investment in public infrastructure on private industry's investment decisions. Although Mera (1975) did include private capital in the regional production function, he was unable to estimate the elasticity of substitution between private and social capital. The model used in this study as foundation for this analysis is an extension of the basic

model used in the theoretical literature on public intermediate goods. Thus, the contribution of this study will be two-fold. First, it will provide a slightly different model for the analysis of the impact of public infrastructure on private industry by explicitly including both the consumption and production effects of public intermediate goods. Secondly, it will for the first time provide an estimate of the short run impact of public investment on the formation of private capital as well as the demand for labor. A formal development of this model is presented in the following chapter.

CHAPTER III

A SIMPLE MODEL OF THE REGIONAL ECONOMY

The impact of public investment on regional economic development is dependent upon three separate relationships. First, investment in public infrastructure may have a short run impact on the production decisions of private industry. That is, holding regional output constant, a change in the stock of public capital may have an impact on the demand for private capital and labor. For example, if a rise in the stock of public capital enhances the productivity of private capital, then less of this input would be required to produce a given level of output. Likewise, a reduction in net public investment may induce a rise in net private investment as private capital is substituted for nonexistent or inadequate public infrastructure. For example, a logging company may have to build its own roads if publicly provided roads are not available or a moving company may have to employ sturdier vehicles because of poorly maintained roads. This short run relationship depends upon the magnitude and sign of the elasticity of substitution between public capital and private capital and labor.

Public investment can also have a long run impact on firms' production decisions. For example, if public capital

enters into a short run, substitutive relationship with both private capital and labor, then net public investment will lower the variable cost of producing a given level of output as firms spend less on private capital and labor. This may enable firms to lower the price of its output which will result in a greater quantity demanded of the region's product. Hence, the competitive position of the region in the national and international markets may improve and regional output will rise. The extent of this effect depends not only on the elasticity of substitution but also on the elasticity of demand for the region's output. In addition, the increased profit earned by existing firms may attract new firms to the region. This will also increase regional output and put upward pressure on the demand for private factors of production.

Finally, public investment may have a feedback effect on the income of the resident-voters. The resulting growth of the private sector will result in additional wage income being generated by private industry. This will increase the total income of the region (through a multiplier process) and, hence, increase the income of the resident-voters. Depending upon the average age of the voters, their perception of this feedback effect, and the time lag involved, this additional income may induce voters to approve additional public capital expenditures.

The intent of this study is to estimate only the short

run impact of investment in public infrastructure on net private investment and labor demand. Yet, as was suggested in Chapter I, an overall model of the relationship between public investment and regional growth should be developed in order to give some perspective to the findings of this study. Such a model is developed in this chapter which incorporates the three relationships discussed above.

The model that will be used to investigate the short run relationship between investment in public infrastructure and the formation of private capital is a simple, export base model of a regional economy in which the level of public capital provided to private industry is determined by the median voter of the region. Since public infrastructure is a public intermediate good as well as a final consumption good, it is modeled as an argument of both the aggregate production function of the private sector and the median voter's utility function. Thus, public capital will have a direct impact on the utility of the median voter as well as upon private industry's demand for private capital and labor. The model also allows for a feedback effect from the private to the public sector. This is accomplished by assuming that the median voter's income is dependent upon the wage income generated by private industry which itself is affected by the level of public capital approved by the median voter. Hence, the median voter's demand for public capital will be influenced indirectly by the impact of

public infrastructure on the demand for private capital and labor.

A detailed description of this model is provided in this chapter. First, the short run, production relationship between public capital and private capital and labor is developed. This is followed by a discussion of the median voter model. Third, the link between the median voter's income and the private sector is developed in a discussion of the regional labor market. Finally, the complete model of the regional economy is specified and several interesting features of this model, such as the feedback from private to public capital, the median voter's perception of the income effect, and the nature of regional growth, are discussed.

The Private Sector

Consider a regional economy that is divided into basic and non-basic sectors. The basic sector produces goods for sale on a national, and possibly international, market (e.g., manufacturing industry) and the non-basic sector produces goods and services for local consumption (e.g., service industry). Although public capital may be employed by both the basic and non-basic sectors, for the purpose of this study it will be assumed that, of the two, the basic sector is the dominant user of public investment. Let the production function of the i th or representative firm in the basic sector be given by:

$$(1) \quad Q_{it} = e^t f(K_{it}, L_{it}, g_{it})$$

where Q_{it} = output in period t

e^t = parameter that captures the effect of shifts in the production function over time due to technological change

K_{it} = private capital stock in period t

L_{it} = stock of labor in period t

g_{it} = stock of public capital in period t

Public infrastructure (g) is provided to the basic sector by the local governments of the region and is assumed to enter the i th firm's production function as an exogenous, unpaid factor in the Meade sense. In spite of this assumption, public capital may also have an atmospheric or factor augmenting impact on private capital and labor. Unfortunately, the estimating procedure employed in this study does not allow for a separation of these two impacts.

The full amount of public capital provided by the local governments in the region (G) does not enter the i th firm's production function because of congestion. The firm must share the given level of G not only with other firms in the basic sector but also with the residents of the region. The amount of public infrastructure employed by the i th firm in period t , g_{it} , can be related to G by a function of the form $g_{it} = N_t^{-\gamma} G_t$ where N_t is the number of users of public capital in the region and γ reflects the degree of congestion. Since both firms and the residents of the

region use G and since firms employ workers in the region, the total population of the region can be used as proxy for all users of public capital. If $\gamma = 1$, then public capital takes on the characteristics of a pure private factor of production. In other words, N units of the public good must be produced if the i th firm is to obtain one unit of the good. On the other hand, if $\gamma = 0$, then public capital is a pure public factor in the Samuelson sense. Hence, an increase in the number of users has no effect on the quantity of G the i th firm can employ. Intermediate values of γ imply quasi-publicness or quasi-privateness in production. This congestion parameter has been empirically estimated only with respect to consumption and not production. Most studies (e.g., Bergstrom and Goodman, 1973; Borcherting and Deacon, 1972) have not found this parameter to differ significantly from one. This implies that with respect to consumption, local public goods have the same characteristics as private consumption goods (i.e., subject to the same kind of congestion effects). This study will be the first to estimate this congestion parameter with respect to private industry.

The i th firm is assumed to minimize costs, given a level of output. The cost of public capital to the firm is assumed to be lump sum in nature and, thus, not dependent upon the quantity of public capital employed by the firm. The firm does not purchase public capital on the market at a

per unit price as it does private capital. Rather, public capital is provided to the firm by the local government in return for a lump sum tax payment (e.g., property tax). Furthermore, the firm has no direct control over how much public capital is provided for its use. It is true that some public capital services are provided on a per unit basis (e.g., water and sewer treatment). But, in light of the aggregate measure of public capital employed in this study (which does not include water treatment), the assumption of a lump sum cost is not unrealistic. The relevant objective function to be minimized, then, is simply:

$$(2) \underset{[K,L]}{M_{it}} = w_t L_{it} + v_t K_{it} + T_{it} - \lambda_1 [Q_{it} - e^{tf}(K_{it}, L_{it}, g_{it})]$$

where w_t = prevailing wage rate in the basic sector

v_t = price of private capital determined on the national market

T_{it} = lump sum tax payment

λ_1 = lagrange multiplier

An argument can be made, though, that the lump sum tax payment is not independent of the use of public capital by private industry. Presumably, an increase in the amount of public capital provided to the basic sector will, in the long run, lead to a rise in basic sector output as firms enter the region attracted by the productivity incentive

offered by public capital. This in turn may lead to a rise in basic sector profits which may be capitalized into industrial property values. If this is the case, then the lump sum, property tax payment will rise, *ceteris paribus*. Although this effect may indeed occur, it is a long run effect and should not affect the firm's short run cost minimization problem. Furthermore, it is difficult to believe that firms will take into account the long run capitalization of profits into property values when making short run production decisions. Thus, the only short run variable costs of production the firm should be concerned about are due to private capital and labor.

The amount of public capital provided to the firm is determined through the political process in which the firm has no direct input, although the firm's preferences may be conveyed through lobbying efforts directed at voters or government officials. Since the firm has no direct control over the amount of public capital supplied to it, private capital and labor are the only decision variables in this cost minimization problem. Minimization of (2) yields the firm's short run demand equations for private capital and labor:

$$(3) \quad \begin{aligned} L^D_{it} &= L_i(w_t, v_t, Q_{it}, g_{it}, t) \\ K^D_{it} &= K_i(w_t, v_t, Q_{it}, g_{it}, t) \end{aligned}$$

If all firms in the basic sector employ the same production

technology, then aggregation leads to the following industry, short run, input demand equations for private capital and labor:

$$(4) \quad \begin{aligned} L^D_t &= L(w_t, v_t, Q_t, g_t, t) \\ K^D_t &= K(w_t, v_t, Q_t, g_t, t) \end{aligned}$$

Thus, the short run, basic sector demand for private capital and labor depends upon the amount of public capital provided by the local governments in the region, input prices, and the level of industrial output.

Theoretically, the short run relationship between public and private capital and public capital and labor can be either complementary or substitutive. A substitutive relationship would indicate that public investment enhances the productivity of private capital and labor. Thus, less of these inputs would be required to produce a given level of output. A complementary relationship, on the other hand, would indicate that public capital reduces the productivity of private capital and labor. Hence, more of these inputs would be required to produce the same level of output. The true nature of this short run relationship is not a priori obvious. Yet, if the aggregate production function for the basic sector is "well behaved," of the three pairs of inputs, at least two must exhibit a substitutive relationship (Allen, 1964). Past empirical studies (using three input, regional production functions and an aggregate

measure of basic sector labor) have verified that private capital and labor are indeed substitutes (e.g., see Garofalo and Fogarty, 1984 and Malhotra and Garofalo, 1984). Thus, in the short run, either public and private capital and/or public capital and labor should be substitutes. It is the intent of this study to determine the sign and magnitude of the short run impact of public capital on private capital through the estimation of the short run, private capital and labor demand equations.

The Public Sector

The most widely used specification of the local political process is the median voter model. Originally proposed by Bowen (1943) and elaborated upon by Downs (1957), the median voter model describes the link between taxpayer votes and local expenditure levels. The model posits that political competition will lead to the election of a local government whose platform is identical to the preferences of the median voter. Assuming that resident-voters are well informed about the costs and benefits of local government services, have single peaked preferences, and are "sincere" voters (i.e., vote their preferences and not strategically), elected government officials will be those who propose to bring the median voter's marginal taxprice in line with his/her marginal benefit. Thus, the quantity of a local public good supplied will be equal to

the quantity demanded by the median voter.

The Empirical Heritage of the Median Voter Model

The empirical heritage of the median voter model is quite extensive. Early empirical studies posited that the pivotal median voter lives in the median valued house and receives the median income in the community. By including median income and a measure of median taxprice (along with other demographic variables) in a regression analysis of the demand for local expenditures, these studies were able to explain local expenditures with a high degree of significance. In particular, these studies found the income and taxprice elasticities to be significantly positive and negative, respectively (e.g., see Barr and Davis, 1966; Borcharding and Deacon, 1972; Bergstrom and Goodman, 1973; Pommerehne and Frey, 1976; Pommerehne, 1978; Pommerehne and Schneider, 1978).

Other studies employed somewhat different models but obtained similar results. For example, Lovell (1978), in an examination of school expenditure levels in Connecticut, was able to verify the median voter hypothesis through the use of a model which was based on an explicit specification of the household utility function. Inman (1978), elaborating upon the theory developed by Bergstrom and Goodman, analyzed school expenditure levels in 58 Long Island school

districts. He found that for at least three-fourths of those districts, school expenditure levels corresponded to that preferred by the homeowner with the median town income. For the remaining districts (in which the median voter hypothesis was rejected) the average bias from the level of expenditure preferred by the median voter was at most 20 percent.

More recent empirical studies have also validated the median voter hypothesis. For example, Holcombe (1980) analyzed data generated from Michigan school referenda in 1973. He found that the average (approved) millage rates did not differ significantly from his computed, median voter's most preferred rate. Gramlich and Rubinfeld (1982) used micro level data (from a 1978 University of Michigan survey of 2000 households in Michigan) to again validate the median voter hypothesis. For example, in the Detroit area, they found that 2/3 of the voters indicated they wanted no change in the level of public spending indicating that the median voter also favored no change.

In spite of this impressive empirical heritage, the manner in which past studies have sought to validate the median voter hypothesis may be severely flawed. Romer and Rosenthal (1979), in an article that is highly critical of past empirical work, suggest that most studies commit at least one, if not both, of the following fallacies. First, although most studies show that local expenditures can be

significantly explained by median income and median taxprice, they cannot prove whether actual spending is at the level desired by the median voter or is at some multiple of that desired level. Romer and Rosenthal call this problem a "multiple fallacy." Second, most studies fail to test the median voter model against alternative models. For example, if any fractile is substituted for the median, would the same empirical results be obtained? This problem is called a "fractile fallacy." Romer and Rosenthal contend that in light of these fallacies, it cannot be concluded from past empirical studies that the political process can be summarized by the median voter model. They suggest that local expenditures depend upon not only voter preferences but also upon the structure of political institutions. Some support for their hypothesis is provided in a later study (Romer and Rosenthal, 1982) in which they analyze Oregon school district referenda data from 1970 to 1977. In this study they contrast the median voter model with a "setter" model in which voters are given a choice between an expenditure level proposed by an agenda setter (e.g., school board) and a reversion level of expenditures (which occurs if the setter's proposal is not approved by the voters). Their theory predicts that under the median voter model, the reversion should have no effect on the outcome of the referendum process. Their empirical analysis indicated that the addition of reversion variables to a

standard, median voter demand equation increased significantly the explanatory power of the model, thus validating their prediction.

Another potential problem with the empirical validation of the median voter hypothesis is that failure to consider the Tiebout mechanism (Tiebout, 1956) may lead to a biased estimate of the effect of median income on local expenditure levels. The Tiebout process is a behavioral method which sorts individuals into communities according to their desired level of local public goods (G) (i.e., each community contains only individuals with the same optimal values of G). Goldstein and Pauly (1981) show that the median voter procedure for estimating the demand for G will tend to overestimate the impact of median income. Operationally, this bias is due to the fact that median voter samples are usually not drawn from some segment of the population defined by values of the exogenous variables. Most median voter studies employ a random sample of communities rather than a random sample of individuals (i.e., they group observations according to the dependent variable (G) rather than the independent variable, median income). Maddala (1977) shows how grouping by the dependent variable can lead to biased estimates and Goldstein and Pauly show that the sign of this bias is positive. The implication of this finding is that unbiased estimates can be achieved by using individual households as units of

observation. But, if impediments to mobility are large (i.e., the Tiebout process is imperfect) then the median voter model is likely to come closer to providing an unbiased estimate of the impact of median income on local expenditure levels.

The influence of private industry on local expenditure decisions is ignored by the standard median voter model. Presumably, private industry is excluded from this model of the political process because "firms" cannot vote. Yet, realistically, private industry does influence local government decision making. Downs (1957) contends that local governments are apt to be more attentive to private industry than voters when formulating policy. This is because private industry is much more likely to be an "influencer" than are voters. Firms are concerned with only a few policies which will have a direct impact on their production process (e.g., investment in public infrastructure) while voters are concerned with a wide range of policies. Thus, because information gathering is costly, voters are not likely to fully perceive how a few specific policies will affect them. Firms, on the other hand, can absorb not only the high cost of information gathering but also the cost associated with persuading local government officials in their favor. Hence, "government is bound to be more attentive to producers than consumers when it creates policy . . . even though government formulates policy so as

to maximize votes . . ." (p. 255).

Downs' theory appears to invalidate the prediction of the median voter model. If private industry can apply a high degree of pressure on the local decision making process (e.g., through direct lobbying of government officials, campaign contributions, or requests as prominent "citizens" of the community), then the amount of public output supplied may not be the amount desired by the median voter. On the other hand, the median voter model may still be applicable if the effect of private industry pressure is on the mix of public output rather than on the total amount of local public output provided. That is, the median voter's desired total local budget prevails yet the mix of that budget may be biased in favor of private industry (e.g., bias in favor of capital outlay and against welfare expenditures). There has been no empirical or theoretical work to date that has examined the effect of industry pressure on the median voter hypothesis.

In this study, it will be assumed that the level of public infrastructure is determined by the pivotal median voter in the region. Since the primary aim of this study is to estimate the relationship between private and public investment and not the demand for public services, the shortcomings of the model discussed above should not affect the findings of this study. As Deacon (1977a) suggests, "the median voter model might be best characterized as a

framework for examining aggregate responses rather than as a vehicle for estimating the demands of any particular individual" (pp. 379-380). The effect of pressure exerted on the local political process by private industry, though, will be included in an expanded version of this basic model in Chapter IV.

The Formal Median Voter Model

A formalization of the median voter model can be accomplished by assuming that the utility function of the median voter is given by the following:

$$(5) \quad U_{it} = e^t U_i(X_{it}, g_t)$$

where e^t = parameter that captures the effects of shifts in the utility function over time due changes in preferences

X_{it} = a vector of private consumption goods

g_t = quantity of public capital consumed by the median voter

The median voter does consume other public services but it serves our purpose in describing the basic model to consider only public capital. The tradeoff between different categories of public expenditure, though, will be examined in Chapter VI. Of the total amount of public capital supplied (G_t), the amount that is consumed by the median voter (g_t) can be defined by the function $g_t = N_t^{-\phi} G_t$. Thus, if $\phi = 0$, then public capital is a

pure public good in the Samuelson sense. If $\phi = 1$, then public capital is a pure private good. Finally, intermediate values of ϕ imply quasi-publicness or quasi-privateness in consumption. As was the case in the private sector, ϕ is a congestion parameter. If public capital is a pure public good, then it can be simultaneously consumed by all residents of the region. On the other hand, if public capital is a pure private good, then N units of the good must be produced if the average citizen is to receive one unit of the good.

Theoretically, γ and ϕ do not necessarily have to take on the same value. Although a particular public capital good may give rise to the same amount of congestion with respect to the private and public sector, how this congestion affects the production process of the basic sector and the utility of the median voter may differ. Consider a congested highway. Although this may have a large effect on the productivity of private capital and labor (e.g., a logging truck transporting felled trees to the mill), it may have only a minor effect on the utility of the median voter who, say, is out for a leisurly afternoon drive on the same highway. Thus, the perception of the true value of the congestion parameter may differ between the private and public sector.

The median voter's demand function for public infrastructure is found by maximizing the utility function

given by (5) subject to an income constraint. Hence, the relevant objective function to be maximized is simply:

$$(6) \quad \underset{[X,g]}{R_{it}} = e^{tU_i(X_{it}, g_t)} - \lambda_2[y_{it} - P_t^X X_{it} - \tau_{it} P_t^G G_t]$$

where y_{it} = median voter's disposable income

P_t^G = vector of private consumption good prices

τ_{it} = median voter's tax share of the cost of public capital

P_t^G = unit cost of public capital

λ_2 = lagrange multiplier

If the expression $N_t^\phi g_t$ is substituted for G_t , the median voter's budget constraint becomes:

$$(7) \quad y_{it} = P_t^X X_{it} + \tau_{it} P_t^G N_t^\phi g_t$$

First order conditions yield the median voter's demand equation for public capital:

$$(8) \quad g_{it} = g_i(P_t^X, \tau_{it}, P_t^G, N_t, y_{it}, t)$$

Before proceeding further, a complicating factor should be introduced. State and federal aid to the region may significantly affect the median voter's demand for public capital. Summarizing the theoretical results of Bradford and Oates (1971), a lump sum grant to a region will have the same impact on local public good demand as if each resident of the region received an individual grant proportional to

his/her local tax share. This is known as the income effect in the intergovernmental aid literature. If the grant to the region is a matching grant, then there may also be a price effect. That is, a matching grant will reduce the per unit tax price to each resident of the region by the fraction of the unit cost of the local public good financed by the grantor.

The importance of federal grants earmarked for public capital projects at the local level has increased dramatically over the past thirty years (the following discussion is based on a 1980 Department of Commerce study of public investment in the U.S.). In 1957, federal capital grants represented ten percent of total state and local public capital outlay. By 1977, they increased to about forty percent. The most significant category of federal capital aid has been the federal highway program which accounted for more than thirty percent of all federal capital grants during the 1957 to 1977 period. In addition to highways, sewer systems and airports were the second and third most significant categories of federal aid. In 1977, capital grants in these three categories were equivalent to 74, 65, and 49 percent, respectively, of all state and local capital outlays in these areas. The predominant type of federal capital grant is the closed-ended matching categorical grant. The recipient of such a grant must match dollars at a certain rate but there is a limit on the amount

of aid available on these terms. In addition, aid is confined to a specific category of expenditure.

Although federal capital aid is dominated by matching grants, total intergovernmental aid (from both the state and federal level) contains both matching and lump sum grants. Moreover, for the purpose of this study, it will be assumed that the effective impact of intergovernmental aid on the median voter is as if such aid is dominated by lump sum grants. A strong argument can be made in support of this assumption. Perkins (1977) noted that if the binding aid ceilings that exist on matching grants were restrictive enough, the price effect would be negligible. Borcharding (1971), asserted that most conditional and matching grants are not open-ended (as noted above, the major federal capital grants are indeed closed-ended). "In point of fact, most (local governmental) units spend in excess of that which they are eligible for in matching grants. Thus, the effects of most conditional grants are no different from unconditional aid, i.e., they are purely inframarginal." Finally, data on intergovernmental aid is highly aggregated. Thus, a decomposition into aid per local government function is impossible, which would be necessary if the model is to take into account the separate price and income effects.

In light of the above discussion, assume that state and federal lump sum grants are distributed such that the median voter's share is proportional to his/her tax share of public

capital. That is, the median voter receives an individual lump sum grant equal to $\tau_{it}(S_t + F_t)$ where S_t and F_t are, respectively, state and federal grants. In addition, the median voter's state and federal tax liability must be subtracted from his/her gross income in order to derive median disposable income. Thus, the median voter's demand equation for public capital becomes:

$$(9) \quad g_{it} = g_i(p_t^X, \tau_{it}, p_t^G, N_t, Y_{it}^D)$$

where $Y_{it}^D = Y(\text{gross})_{it} + \tau_{it}(S_t + F_t) - t_{it}^s - t_{it}^f$
 t_{it}^s = median voter's state tax liability
 t_{it}^f = median voter's federal tax liability

The Regional Labor Market

This simple model of a regional economy can be closed by assuming that the median voter's disposable income is dependent upon the wage income generated in the basic sector. This will allow for a feedback effect from the private to the public sector with respect to the approved level of public capital. Before this link can be formally made, though, a discussion of how the wage rate and level of basic sector employment are determined in the regional labor market is warranted.

Competing Theories of Regional Wage and Employment Determination

In the economic literature, there are two main

competing theories that seek to explain how the equilibrium wage rate and level of employment are determined in a regional labor market. The first theory contends that the regional wage rate is determined primarily by demand side factors. An extreme version of this theory, suggested originally by Borts and Stein (1964) and elaborated upon by Muth (1968, 1983), posits that the long run, regional labor demand curve is perfectly elastic. The assumptions of the model that generates this result are (1) the basic industry sells only one output on a national or worldwide market; (2) output emanating from any given region is so small that the product demand curve facing firms in the region is perfectly elastic; (3) the price of private capital is fixed (for analagous reasons); (4) private capital is highly mobile; and (5) firms in the basic sector employ production functions that are linearly homogenous in labor and private capital. If the regional labor supply curve is upward sloping (in order for equilibrium to be determinant), wages are completely demand determined, where labor demand is a function of the price of output and private capital. Under these conditions, changes in labor supply would affect only population and employment.

This extreme version of the demand side theory does not necessarily imply that the short run, labor demand curve is also horizontal (i.e., even a constant returns to scale production function can give rise to diminishing marginal

productivity). Thus, regional wages can be affected by changes in labor supply in the short run. Also, if any of the above assumptions are violated or if local products are relatively unique, sold in geographically limited markets, or if local natural resources are a significant input into the production process, then the long run, labor demand curve will not be perfectly elastic. The proponents of this theory, though, contend that demand side factors will still have a dominant role in determining regional wages.

Several studies have found evidence that supports this demand side hypothesis. In a study concerned with determining why cities grow at different rates, Muth (1968) found that for a sample of 25 SMSA's during the 1950's, changes in employment had little effect on regional wage rates. Wages were affected more by increases in the demand for a region's exportable good rather than by increases in the number of people migrating into the region. Eberts and Stone (1985) were also able to validate the demand side hypothesis by examining regional wage differentials for a sample of SMSA's between 1974 and 1983. They found that skill-adjusted wage differentials (obtained by averaging the wage residuals in each year that resulted from the estimation of a wage equation reflecting primarily demand side factors, i.e., human capital variables) were positively (and significantly) correlated with the percentage change in employment. All of the SMSA's with increases in the wage

differential of 5 percent or more experienced higher than average rates of employment growth between 1974 and 1983.

Most studies of regional wage differentials, though, have allowed a dominant role for labor supply in determining regional wages (e.g., Scully, 1969; Bellante, 1979; Sahling and Smith, 1983; Johnson, 1983). This second, more traditional view of regional wage determination posits that long run, equilibrium wages are determined primarily by supply side factors (via migration) and that changes in labor demand has its largest impact on employment. Some of the factors that might affect wages via migration are the local cost of living, environmental amenities important to workers, local taxes, and unions. An extreme version of this theory (Johnson, 1983) argues that if there are no differences in the assessments by individuals of the nonpecuniary attributes associated with residence in different regions or if such attributes are not important, and if transaction costs of migration are zero, then the long run, labor supply curve is perfectly elastic. Assuming that the long run, labor demand curve is downward sloping (i.e., at least one of the assumptions underlying the Borts and Stein hypothesis is violated), long run equilibrium wages are completely supply determined with changes in labor demand affecting only the level of employment. But, as long as individuals' assessments of different regions vary and there are transaction costs to migration, the labor supply

curve will be upward sloping and changes in labor demand will also have an effect on regional wages. Proponents of the supply side theory, though, contend that the labor supply curve is still highly elastic.

A Simple Model of the Impact of Public Investment on Basic Sector Wages and Employment

The supply-side theory outlined above can be made more explicit by analyzing the impact of an increase in public capital on equilibrium wages and employment in a simple regional model. Consider a two region model (A and B) where region A can be partitioned into a basic sector (which produces a single export good that is sold on a national market) and a non-basic sector (which produces goods and services for domestic consumption). Assume that, for simplicity's sake, region B consists of only one sector. Moreover, assume that the production process employed by the basic sector in region A uses a locally unique resource, public capital, in addition to labor and private capital (Johnson, 1984, shows how this assumption leads to a finite elastic, long run labor demand curve). Furthermore, assume that wages are initially equalized across both regions and sectors, public capital is employed as an input in the production process of only the basic sector of region A, and firms seek to minimize the cost of production. Finally, assume that the short run, labor demand curve is negatively

sloped and the short run, labor supply curve is positively sloped in all regions and sectors.

Suppose now that the stock of public capital (G) is increased in region A. Given a fixed level of output, the demand for labor may either rise or fall depending upon the short run production relationship between labor and public capital. That is, labor and public capital may be either short run complements or substitutes. A complementary relationship would suggest that an increase in public capital will increase the equilibrium wage rate and level of employment in the basic sector as the labor demand curve shifts outwards along the labor supply curve. On the other hand, if labor and public capital are substitutes, then the the initial impact of an increase in public capital will be a reduction in the equilibrium wage rate and employment level.

There may also be several long run responses to this higher level of public capital provided in region A. First, the additional public capital stock may induce new firms to enter the region attracted by the productivity incentives offered by the local public infrastructure. If this occurs, then the demand for labor in the basic sector will rise in response to the increase in basic sector output. If labor and public capital are short run complements, then this rise in labor demand will further increase employment and the wage rate in the basic sector. If labor and public capital

are short run substitutes, then the level of employment and wage rate will rise if the increase in labor demand more than offsets the initial fall in labor demand (due to the short run substitution of public capital for labor). A priori, it seems more likely that the basic sector wage rate will increase, especially if the expansion of the basic sector is large.

Secondly, the increase in the stock of public capital may improve the competitive position of the region on the national market by reducing the variable cost of producing a given level of output. This would occur if public infrastructure and private capital and labor exhibit a substitutive relationship (i.e., an increase in public capital would enhance the productivity of both private capital and labor, requiring less of both inputs to produce the same level of output). This would enable firms to reduce the price of their output, resulting in an increase in the output of the basic sector as firms respond to the higher quantity demanded at this lower price. This increase in output will then put upward pressure on labor demand and the basic sector wage rate. *→ Job demand*

Thirdly, if the basic sector wage rate does increase, then there will be a reduction in the supply of labor to region A's non-basic sector as workers enter the basic sector labor force seeking higher wages. This intra-

regional migration will increase the wage paid in the non-basic sector (as the labor supply curve shifts upwards along the labor demand curve) and increase labor supply in the basic sector.

Finally, inter-regional migration may result as workers in region B migrate to region A in search of higher wages. This will increase the supply of labor to both the basic and non-basic sectors of region A and increase the wage paid in region B. Assuming labor is completely mobile, labor supply would continue to adjust until wages were equalized once again across regions and across both sectors in region A. The potential long run impact of this public investment is a higher employment level and wage rate (as compared to the initial long run equilibrium) in the basic sector of region A and a higher wage but lower employment level in the non-basic sector of region A and in region B (if the additional wage income derived from the basic sector were taken into account, then conceivably the demand for the output of the non-basic sector would rise, increasing labor demand and, hence, employment in the non-basic sector of region A).

In actuality, though, equalization of wages is not likely to occur. Labor is not completely mobile since certain costs must be incurred when moving from one region to another (although intra-regional migration may be relatively costless). Also, productivities may differ between regions and especially between sectors (e.g.,

manufacturing versus service industries). Furthermore, Johnson (1984) points out that workers' perception of the nonpecuniary attributes of regions may differ thus requiring compensating variations in wages in order to entice labor to migrate to "unattractive" regions. These observations, together with the simple model outlined above suggest that the long run, labor supply curve for the basic sector is highly elastic but still positively sloped. Hence, an increase in public investment can lead to a long run increase in the basic sector wage rate and employment level.

This simple model of a regional labor market can be used to establish a link between the private and public sector. Assume that total regional income is some multiple of the income earned in the basic sector (i.e., total wage bill). Given that the median voter's income is some function of total regional income, an increase in the basic sector payroll will increase the income of the median voter. Thus, the median voter's income is endogenously determined. An increase in public capital can increase the income of the median voter which may induce the median voter to approve additional capital outlay (assuming public capital is a normal public good), although this is a long run effect.

A Formal Model of the Basic Sector Labor Market

A formalization of the basic sector labor market can be

achieved through the specification of the short run, labor demand and supply functions. The short run demand for labor in period t (assuming cost minimization) is given by equation (4). That is:

$$(10) \quad L^D_t = L^D(v_t, w_t, Q_t, g_t, t)$$

where v_t is the price of private capital, w_t is the nominal wage rate, Q_t is output, and g_t is the stock of public capital employed by the basic sector, and t captures shifts in the underlying production function over time. v_t , Q_t , and g_t determine the position of this labor demand curve in w - L space while the quantity of labor demanded is assumed to be inversely related to the nominal wage rate. The supply of labor to the basic sector can be given by the following equation:

$$(11) \quad L^S_t = L^S(w_t, \Theta_t, N_t)$$

where N_t is regional population and Θ_t is a vector of non-pecuniary attributes of the region which may affect workers' migration decision. This vector, which determines the position of the labor supply curve in w - L space along with regional population, might include such factors as weather conditions, quality of local schools, and proximity to oceans and mountains. This short run, labor supply curve is assumed to be positively sloped in w - L space.

The basic sector labor market can then be summarized by

the following set of equations:

$$\begin{aligned}
 (12) \quad & L_t^D = L^D(v_t, w_t, Q_t, g_t, t) \\
 & L_t^S = L^S(w_t, \theta_t, N_t) \\
 & L_t^D = L_t^S
 \end{aligned}$$

This model allows for the simultaneous determination of the equilibrium wage rate and level of employment in the basic sector. Identification of the labor demand and supply equations can be shown through the rank condition which is a necessary and sufficient condition for identification (Maddala, 1977). Examination of the reduced form equations (derived from the structural labor demand and supply equations) shows that public capital can have an impact on both the equilibrium wage rate and level of employment:

$$\begin{aligned}
 (13) \quad & L_t = L(v_t, Q_t, g_t, \theta_t, N_t, t) \\
 & w_t = w(v_t, Q_t, g_t, \theta_t, N_t, t)
 \end{aligned}$$

The simple model outlined above suggests that this impact can be positive in nature. Hence, investment in public infrastructure can result in an increase in the basic sector's total wage bill.

As suggested earlier, a link between the private and public sector can be established by making the income of the median voter dependent upon the payroll of the basic sector. In particular, assume that the median voter's income is equal to some function of total regional income, which

itself is some multiple of the wage income generated by the basic sector. That is,

$$\begin{aligned}
 (14) \quad Y^D_{it} &= Y(Y^T_t) \\
 Y^T_t &= \psi Y^B_t \\
 Y^B_t &= w_t L_t
 \end{aligned}$$

where Y^T_t is total regional income, Y^B_t is the income generated by the basic sector, and ψ is the basic sector multiplier. The income generated by the basic sector is simply equal to the aggregate wage bill ($w_t L_t$) where w_t and L_t are determined by the reduced form equations (13). Thus, assuming that public capital has a positive impact on the aggregate wage bill of the basic sector, the income of the median voter will be increased which may induce the median voter to approve additional public capital outlay, given that public capital is a normal public good.

The Complete Model of the Regional Economy

The simple model of the regional economy developed in this chapter can be summarized by the following set of equations:

- (1) Short run demand for private capital by the basic sector:

$$(15) \quad K^D_t = K^D(v_t, w_t, Q_t, g_t, t)$$

- (2) Short run demand for labor and the basic sector labor market:

$$\begin{aligned}
 L_t^D &= L^D(v_t, w_t, Q_t, g_t, t) \\
 (16) \quad L_t^S &= L^S(w_t, \Theta_t, N_t) \\
 L_t^D &= L_t^S
 \end{aligned}$$

(3) Median voter demand equation for public capital:

$$(17) \quad g_{it} = g_i(p_t^X, \tau_{it}, p_t^G, N_t, Y_{it}^D, t)$$

(4) Link between the basic and public sector:

$$(18) \quad Y_{it}^D = Y^D(\psi w_t L_t)$$

The Bi-directional Nature of the Relationship Between Public and Private Capital

There are several interesting features of this simple model of the regional economy. First, this model suggests that the relationship between private and public capital is potentially bi-directional in nature. The model allows public capital to have either a positive or negative short run impact on private capital through the short run private capital demand equation. In the long run, regional output may rise due to an enhanced competitive position of the region in the national and international markets and the entry of new firms to the region. This rise in output will put upward pressure on the demand for private capital (the price of private capital would not be affected by this increase in demand since it is assumed to be determined in the national market). Hence, the long run impact of an increase in the stock of public capital most likely will be

a rise in the employment of private capital in the basic sector.

The model also suggests that there may be a long run feedback effect from private to public capital. In the previous section, it was demonstrated that the link between the private and public sector takes place through the demand for labor in the basic sector. The impact of an increase in the stock of private capital on the provision of public capital can be shown to operate through this same link.

Assume that, in the aggregate, the basic sector employs a production function that gives rise to isoquants (between private capital and labor) that are negatively sloped, smooth, and convex in the economically relevant region; firms are cost minimizers; private capital and labor are not inferior inputs (i.e., the expenditure elasticity for each input is positive); and the factor price ratio (w/v) is constant. *Ceteris paribus*, a long run increase in the stock of private capital will place firms on a higher isoquant. Cost minimization occurs along the long run expansion path (which is positively sloped if both private capital and labor are not inferior inputs). Thus, an increase in the stock of private capital must bring about an increase in labor if the cost of producing this higher level of output is to be minimized. This then implies that private capital and labor are long run complements and that an increase in the stock of private capital will have a positive impact on

the provision of public capital (i.e., increase the wage bill of the basic sector).

As was shown in the previous section, though, an increase in the demand for labor will tend to put upward pressure on the nominal wage rate. Thus, given a constant price for capital (since the price of capital is assumed to be determined in a national market), the factor price ratio (w/v) will rise. A change in the factor price ratio will have two effects on the demand for inputs: a substitution effect and an output effect. An increase in the cost of labor may lead firms to increase the stock of private capital and reduce employment as the relatively cheaper capital is substituted for the more expensive labor in order to produce a given level of output. The extent of this substitution depends upon the elasticity of substitution between private capital and labor and corresponds to movement along a given isoquant. In addition, the rise in the nominal wage rate will increase the cost of production, increase the price of output, and, hence, result in a reduction in both capital stock and employment as firms reduce output to adjust to the smaller quantity demanded which exists at the higher price. The extent of the reduction in output depends upon the elasticity of demand for the firms' output. The total impact of the increase in labor cost on private capital depends upon the relative magnitudes of the substitution and output effects. The

impact on labor, though, is not ambiguous. The substitution and output effects both result in a decrease in labor.

The overall, long run impact of an increase in the stock of private capital on labor is uncertain when this rise in the factor price ratio is taken into account. As stated earlier, with input prices constant, an increase in the stock of private capital will result in a long run increase in labor in order for the cost of producing the higher level of output to be minimized. But this process may increase the cost of labor which will have a negative impact on employment through the substitution and output effects. The total effect on labor will depend upon whether or not the substitution and output effects are large enough to decrease labor more than the initial increase induced by the rise in the stock of private capital.

An argument can be made that an increase in private capital will still have a positive, long run impact on labor. First, private capital and labor have empirically been found not to be strong substitutes. For example, Garofalo and Malhotra (1984a) estimated the partial Allen elasticity of substitution to be about 0.85. The partial Allen elasticity of substitution between labor and energy, on the other hand, was estimated to range from 3.35 to 2.55, indicating that these two inputs are strong substitutes. Another study (Pindyck and Rotemberg, 1983) actually found private capital and labor to be complements. It should be

noted that a finding of a substitutive or complementary relationship between private capital and labor depends upon the measure of labor employed in the estimation. Brendt and Christensen (1984), for example, found private capital and non-production workers to be complements while private capital and production workers are substitutes.

Secondly, the output effect depends largely upon the price elasticity of demand for the region's output. Thus, the demand for this output must be very responsive to price changes in order for the output effect to be large. The only study to estimate the price elasticity of demand for regional output (Engle 1979) did so for the Boston metropolitan area. Engle found that for most industries, the price elasticity of demand is less than 1.0. Garofalo and Fogarty (1984b), in estimating the impact of the output effect (and substitution effect) on private capital (but not on labor) for a sample of SMSA's between the years 1976 and 1978, employed price elasticities between 0.50 and 1.0. These estimates of the elasticity of demand suggest that the output effect may not be very large. In fact, Garofalo and Fogarty found that, using an elasticity of 0.75, the average percentage output effect of labor costs on private capital stock was only seven percent.

Thirdly, as was demonstrated in the previous section, an increase in the wage rate will induce migration into the region. The long run effect of this increase in the supply

of labor will be to depress the nominal wage rate from what it would have been in the absence of the in-migration. This will tend to lessen the impact of the substitution and output effects on labor. In light of these factors, a tentative conclusion can be reached that an increase in the stock of private capital will have a positive, long run impact on labor even if labor cost does increase. Thus, private capital can have a positive impact on the wage bill of the basic sector and, hence, a positive effect on the provision of public capital. Clearly, though, there is a need for additional empirical analysis of this issue.

In summary, an increase in the amount of public capital provided to the basic sector may lead to a long run increase in the employment of private capital as new firms enter the region seeking the productivity benefits of the public capital and as the competitive position of the region improves. Furthermore, this increase in the stock of private capital will result in additional labor employment in the basic sector in order to produce the higher level of output. Thus, assuming a positively sloped long run labor supply curve, the wage bill of the basic sector will rise, increasing the income of the median voter.

The Question of Causality

Although the model allows for a potential bi-directional relationship between private and public capital,

a priori, there is no reason to expect one effect is significantly stronger than the other. Public capital may have a significant impact on private capital and/or vice versa. An intriguing characteristic of this relationship between private and public capital is the question of causality. In particular, if local governments use public capital as a local policy instrument, then public investment should precede or "influence" private investment. On the other hand, if local governments simply respond to the needs of private industry, then public investment should be preceded or "influenced" by private investment. Eberts and Fogarty (1985) investigated this causal relationship using investment data from 1904 to 1978 for a sample of 40 SMSA's. Employing the Sims test of "Granger causality" they could find a significant relationship between public and private investment in 33 out of the 40 SMSA's. In particular, half of the SMSA's were characterized by public investment significantly influencing private investment. For a slightly smaller number, the opposite was true. The main conclusion that can be reached from this analysis is that the direction of the relationship between private and public capital is not at all obvious. Although both private and public capital influence each other, the strength of this bi-directional relationship appears to differ between regions.

The Median Voter and Realization of the Benefits of Public Investment

Another interesting characteristic of this regional model is the median voter's perception of the link between his/her income and the effect of public capital on the payroll of the basic sector. It was assumed in the above discussion that an increase in public capital would have a positive long run impact on the income of the median voter and that this may induce him/her to approve additional capital outlay. In reality, though, this link may not be very strong. For example, the median voter may simply not realize (or misperceive) the effect of public capital on his/her income. Thus, expansion of the basic sector would have little, if any, effect on how the median voter votes on capital expenditure issues. One flaw of this theory, though, is that, in order for the misperception to persist over time, the median voter is required not to learn. On the other hand, persistent misperception is possible if the person assuming the role of the median voter changes frequently over time.

A more plausible theory is that the link between public capital and the median voter's income is fully perceived. Yet, the link between perception and votes is still weak because of the time lag involved with respect to the realization of benefits. The effect of public capital on the income of the median voter occurs only in the long run.

Most capital projects take several years to complete. In addition, there is usually a lag between completion and the entry of new firms and between entry and the impact on regional income. Thus, if the median voter is highly mobile and/or is relatively elderly, then the median voter would be less likely to approve capital projects because he/she may not be around to enjoy the benefits of these capital expenditures. Holcombe and Zarokoochi (1980) found empirical evidence that is consistent with this theory. In a study of state expenditure levels they found that the ratio of capital outlay to total state expenditures can be significantly and negatively explained by median age. In other words, the higher the median age of the state, the lower the ratio of capital outlay to total expenditures, *ceteris paribus*.

An implication of this relationship between perception and votes is that a decaying public infrastructure is not necessarily non-optimal for the median voter. Within the framework of this model, the level of public capital is determined by the median voter who seeks to maximize his/her perceived utility subject to perceived costs. If the median voter perceives that the probability of realizing the future benefits of public investment as being low, then he/she will rationally not vote for additional capital expenditures. Thus, from the median voter's point of view, decaying public infrastructure in a region in which 51 percent of the

population is over 55 years old is not non-optimal (as long as the median voter's utility is a function of only the benefits he/she directly receive from public capital).

This is potentially a serious problem, though, for future generations. As the American voting population grows older, the likelihood of capital projects being approved will fall (assuming the above theory is true and the median voter model is an accurate description of the local political process). Future generations will then be faced with severely decayed public infrastructure and possibly stagnant regional economies. Thus, from the point of view of median voters in future generations, decaying public infrastructure can be non-optimal although it may be a rational decision on the part of the current generation's median voter.

The Impact of Public Investment on Regional Growth

Although this study is concerned with the short run impact of public capital on private capital, an additional issue raised by this model is the manner in which public investment induces regional economic development (the following discussion is based on a study conducted by the Office of Economic Research, 1969). Public investment can lead to regional growth by inducing firms and industry to enter the region and, thus, increase regional output and

income. Yet, there may be a threshold below which regional growth cannot be expected. In spite of the investment in public infrastructure, there may exist certain "factor supply disadvantages" which must be overcome before regional growth can take place. For example, a given region may experience difficulty in attracting new industry because of a deficiency in the supply of skilled and managerial labor in the area. Also, an area may lack "sufficient" recreational and entertainment opportunities, housing, and public services which would provide an incentive for labor to move into the region. Thus, there may exist a period of time during which there is no return to public investment (in terms of regional output) as these factor supply disadvantages are overcome.

Once this threshold has been surpassed regional growth will be enhanced by the growth of ancillary industries. These industries can be of two types. The first type is an industry that supplies inputs to the primary industry(s) of the region. For example, a plastics firm may locate in Detroit in order to supply plastic parts to the automobile industry. This would tend to reduce imports and, thus, increase the expansionary multipliers. A second type of ancillary industry is one that purchases the output of the primary industry. Such industries may choose to locate in the same region as the primary industry in order to reduce transport costs. This explains why producers of aluminum

products often are located near aluminum mills.

Concerning the provision of public capital, there is an additional factor that will affect regional growth. Local governments must supply certain amounts of certain public capital goods in order for industry to locate in the region. For example, the absence of sewer, water, and electrical connections would completely exclude an area from development. The absence of other types of public infrastructure, though, such as parks and schools, may not exclude the region from development but may increase the firm's location costs (e.g., the firm may have to grant pay increases in order to entice its current managerial work force to relocate). These costs would tend to have a dampening effect on regional growth since they would provide a disincentive for entry into the region.

Finally, there is the issue of the timing of public capital projects. A considerable lagged response of regional growth to public investment may exist. Initially, there will be a lag between the completion of a public capital project and a firm's decision to locate in the region. In addition, there is a lag between a firm's decision to enter the region and the time when plant construction is complete. Finally, there is a lag between plant start up and the expansionary impact on regional growth. Given this considerable elapse in time between the decision to undertake a public capital project and the

regional benefits attributable to that project, there is an important implication for the timing of public investment projects. If local government officials wish to use public investment as a policy tool, then the necessary public infrastructure needs to be in place well before the target date for regional expansion.

Although the long run effects of public investment (i.e., impact on the region's competitive position and firms' location decisions) are deserving of theoretical and empirical analysis, they are not the concern of this study. Rather, this study is concerned only with the short run relationship between public and private investment. The above discussion suggests that the long run effect is most likely positive, although there may be a considerable lag involved. The short run response of private to public investment, though, is not a priori obvious. The model of the regional economy developed in this chapter will form the framework for the derivation of the estimating equations that will be used to determine the exact nature of this short run relationship. The construction of these estimating equations is discussed in the following chapter.

CHAPTER IV

DERIVATION OF THE ESTIMATING EQUATIONS, THE DATA,
AND PROBLEMS WITH THE EMPIRICAL ESTIMATIONDerivation of the Estimating Equations

In order to estimate the simple model of the regional economy developed in the previous chapter, some additional assumptions about the functional form of the production and utility relationships must be made. Specifications and derivations of the actual equations used to estimate the short run relationship between public investment and net private investment and labor demand are discussed below.

Private Sector

Only the short run demand equations for private capital and labor will be employed in the empirical analysis. The justification for this is twofold. First, the primary aim of this study is to examine the short run impact of public investment on the demand for private capital and labor. Second, given the sample employed in this study, there are insufficient data with which to estimate the basic sector labor supply curve (i.e., there are insufficient data with which to form an adequate proxy for Θ_t).

The general form of the aggregate production function employed by the basic sector is given by:

$$(19) \quad Q_t = e^{t\alpha} f(K_t, L_t, g_t)$$

It should be again noted that public capital is assumed to enter this production relationship as an unpaid input in the Meade sense. Although public capital may also have factor augmenting qualities, from the firms' point of view, it is assumed to effectively enter the production process as a separate input. The firm takes the level of public capital as given and has no direct control over how much public capital is supplied to it by the local governments in the region.

Solutions of equation (2) for the short run, desired levels of private capital and labor depend upon the exogenously determined level of output, input prices, and the fixed amount of public capital. Assume that these solutions take the following log linear form:

$$(20) \quad \begin{aligned} \ln K_t^* &= A + a_{11} \ln w_t + a_{12} \ln v_t + a_{13} \ln Q_t \\ &\quad + a_{14} \ln g_t + t \\ \ln L_t^* &= B + a_{21} \ln w_t + a_{22} \ln v_t + a_{23} \ln Q_t \\ &\quad + a_{24} \ln g_t + t \end{aligned}$$

where t captures underlying shifts in the production function over time (due to technological change) and the a_{ij} 's ($i = 1, 2$; $j = 3, 4, 5, 6$) are the short run, input demand

elasticities. There are at least three reasons for employing this simple, log linear form for the input demand equations. First, this functional form is commonly used for systems of factor demand equations (Intrilligator, 1978) and lends itself easily to multiple regression techniques.

Second, it is a first order approximation to any production function (e.g., translog). Finally, it will allow for the estimation of the congestion parameter discussed in Chapter III. As will be seen below, a more complicated functional form (e.g, one involving squared and interaction terms) would not allow for a unique determination of the value of this congestion parameter.

Following Nadiri (1972) and Nadiri and Rosen (1974), the input demand equations (20) represent the short run desired or equilibrium levels of private capital and labor. The adjustment of an input to its desired level entails costs that depend upon the speed of adjustment of the input itself as well as the speed of adjustment of other inputs. For example, if qualified workers are not readily available, then adjustments in the stock of private capital will be impeded. A simple model of this adjustment process is one that assumes that each adjustment cost is proportional to the difference between the desired and actual levels of each input. This adjustment process is assumed to take the following form:

$$(21) \quad \ln I_{it} - \ln I_{it-1} = c_{i1} [\ln I^*_{1t} - \ln I_{1t-1}] + c_{i2} [\ln I^*_{2t} - \ln I_{2t-1}]$$

where I_i ($i=1,2$) are the two variable inputs (K and L), I^*_i are the desired levels of K and L defined by (20), and c_{i1} and c_{i2} are constant adjustment coefficients. It should be noted that although public capital (g_t) can affect the adjustment of private capital and labor to their desired levels, it is not included in (21) because firms have no direct control over how much of the fixed input is supplied to them by the local governments in the region. That is, firms cannot adjust the level of public capital employed in the production process.

Substituting the desired levels of private capital and labor defined by (20) into equation (21) yields the following structural input demand equations:

$$(22) \quad \begin{aligned} \ln K_t &= A' + (1-c_{11})\ln K_{t-1} - c_{12}\ln L_{t-1} + d_{13}\ln w_t \\ &\quad + d_{14}\ln v_t + d_{15}\ln Q_t + d_{16}\ln g_t + t \\ \ln L_t &= B' + (1-c_{22})\ln L_{t-1} - c_{21}\ln K_{t-1} + d_{23}\ln w_t \\ &\quad + d_{24}\ln v_t + d_{25}\ln Q_t + d_{26}\ln g_t + t \end{aligned}$$

where $A' = c_{11}A + c_{12}B$, $B' = c_{21}A + c_{22}B$, and the d_{ij} 's ($i=1,2$; $j=3,4,5,6$) are defined in Appendix A.

Several features of the adjustment process described by (22) should be noted. First, the "own" adjustment of a dependent variable (c_{ii}) is expected to be positive and less

than unity. The cross-adjustment parameters (c_{ij}) may be positive, negative, or zero. The signs of the cross-adjustment parameters indicate whether the inputs are "dynamic" complements or substitutes. The notion of dynamic complementarity (or substitutability) differs from the traditional, equilibrium or short run concept. Dynamic complementarity refers to the adjustment of private capital and labor to their desired levels. For example, if c_{21} is negative, then a bottleneck in the acquisition of private capital will reduce the demand for labor as both inputs adjust to their desired levels, implying that private capital and labor are dynamic complements. Yet, once this adjustment has taken place, private capital and labor may exhibit a short run substitutive relationship in response to changes in factor prices (in fact, most empirical studies have found private capital and labor to be short run substitutes).

Second, the coefficients on input prices, output, and public capital (d_{ij} , $i=1,2$; $j=3,4,5,6$) are the short run, input demand elasticities (a_{ij} , $i=1,2$; $j=1,2,3,4$) modified by the adjustment coefficients (c_{ij}) (see Appendix A). Hence, they describe the dynamic impacts of changes in input prices, output, and public capital on input demand.

Third, in deciding upon how much private capital and labor to hire this period, the firm must estimate what its output will be next period. Thus, the adjustment of private

capital and labor to their desired levels is with respect to the expected level of output in period t , Q_t^e .

Fourth, the amount of public capital used by each firm in the basic sector (g_t) is related to the total supply of public infrastructure (G_t) by the function $g_t = N_t^{-\gamma} G_t$. Hence, this expression can be substituted for g_t in (22).

Fifth, the aim of this study is to estimate the short run relationship between private capital formation and public investment since policy decisions are usually made with regard to investment. Capital stock is the result of past investment decisions. The private capital demand equation can be transformed into a short run demand equation for private net investment. A measure of private net investment can be derived by subtracting lagged private capital stock ($\ln K_{t-1}$) from both sides of the capital demand equation in (22). The resulting dependent variable ($NINV_t$) is simply $\ln(K_t/K_{t-1})$, or the growth rate of private capital stock.

Ideally, this study would like to estimate the short run relationship between net private investment and net public investment. But, unfortunately, a regional, public capital stock series was not available at the time of this study. Thus, public capital outlay must be used as a proxy for net public investment ($\dot{g}_t$). Since gross public investment is defined as net investment plus replacement expenditures, a rise in public capital outlay may not be due

to additions to the stock of public capital. Yet, during the time period from which the data were obtained for this study (i.e., the 1970's), gross and net public investment were highly correlated at the state and local level (see Hulten and Peterson, 1984). Thus, for the purposes of this study, it will be assumed that an increase in public capital outlay is at least partly due to a rise in the stock of public capital.

The modified, input demand equations are as follows:

$$\begin{aligned} \text{NINV}_t = A' - c_{11}\ln K_{t-1} - c_{12}\ln L_{t-1} + d_{13}\ln w_t + d_{14}\ln v_t \\ + d_{15}\ln Q^e_t + d_{16}\ln \dot{G}_t - \gamma d_{16}\ln N_t + t. \end{aligned} \quad (23)$$

$$\begin{aligned} \ln L_t = B' + (1-c_{22})\ln L_{t-1} - c_{21}\ln K_{t-1} + d_{23}\ln w_t \\ + d_{24}\ln v_t + d_{25}\ln Q^e_t + d_{26}\ln \dot{G}_t \\ - \gamma d_{26}\ln N_t + t \end{aligned}$$

where Q^e_t is the expected level of output in period t and γ is the private sector congestion parameter discussed in Chapter III. As suggested earlier, a more complicated functional form for these short run, input demand equations would preclude the estimation of this congestion parameter. Examination of (23) reveals that if $\dot{G}_t$ were entered as a squared term and interactively with the other right-hand side variables (as would be the case with, for example, a log quadratic functional form), a unique determination of the value of the congestion parameter would not be possible.

Public Sector

As suggested in Chapter III, the traditional median voter model can be slightly altered in order to take into account the influence of private industry on the local decision making process. This can be accomplished by assuming that the total local budget of the region is determined by the median voter with the composition of that budget (i.e., capital outlay) left up to the discretion of local government officials. Moreover, by entering net private investment into the budget equation for public capital outlay, this version of the median voter model will allow for an estimation of the impact of private on public investment.

Consider the following median voter utility function in which public capital (g_t) is replaced by z_t , the amount of the total, local public output consumed by the median voter (i.e., total budget):

$$(24) \quad U_{it} = e^t U_i(X_{it}, z_t)$$

Assume that maximization of (24) with respect to the budget constraint defined by (7) (with $P_t^Z Z_t$ replacing P_t^G) gives rise to a demand function of the constant demand elasticity type:

$$(25) \quad z_{it} = e^{tC} (P_t^X)^{a_1} (\tau_{it})^{a_2} (P_t^Z N_t^\Phi)^{a_3} Y_{it}^{D_{a_4}} b_1$$

This functional form yields a log linear equation which has been commonly used in median voter studies (e.g., Bergstrom and Goodman, 1973).

Assuming that the prices of private goods and unit costs of local public goods are the same in all regions and taking into account that the total amount of local public output demanded is N_t^ϕ times the quantity of z_t demanded, the demand function for total output can be written as:

$$(26) \quad Z_{it} = e^t \tau_{it}^{b_1} N_t^{\phi(1+b_1)} Y_{it}^{D_{b_2}}$$

In log form, the median voter's demand for Z is given by:

$$(27) \quad \ln Z_{it} = D' + b_1 \ln \tau_{it} + \phi(1+b_1) \ln N_t + b_2 \ln Y_{it}^D + t$$

Now, public capital outlay is a function of the total budget. That is:

$$(28) \quad \dot{G}_t = e^t(Z_{it}, F_t)$$

where e^t is a parameter capturing unspecified changes in the budgetary decision process over time and F_t represents a vector of variables which conceivably can influence this decision process. Among the other variables included in this vector is one that captures the influence of private industry on the provision of public capital. Conceivably, the larger the basic sector of the region, the more pressure that can be brought to bear on local government officials, either through the lobbying of business associations,

campaign contributions, or direct appeals to the voters who elect these government officials. A priori, this pressure would be expected to result in higher expenditures on public infrastructure. In order to capture this effect, the percentage of all nonfarm workers in the region who are employed in the industrial sector (PCTEMP) will be used to measure the industrial concentration of the region.

In addition to a variable that captures the pressure exerted on the local, budgetary decision process by the private sector, the vector F_t contains other variables which reflect the "taste" of local government officials for public investment. Some of these are demographic variables (such as population density and age of the population) which will help to explain differences in public investment across regions. In addition to these demographic variables, budget officials' taste for public investment may also be influenced by private net investment. For example, in regions marked by high levels of private investment, government officials may perceive that there is a greater need for expenditure on current consumption items relative to public investment. On the other hand, local government officials may perceive that a high level of private investment is beneficial to the region and, hence, will allocate more funds for investment in public infrastructure in order to retain the existing industrial base and entice more firms to enter the region. To capture this effect, the

vector F_t will include the growth rate of private capital, $NINV_t$.

For simplicity, assume that this budgetary relationship takes the following log linear, functional form:

$$(29) \quad \ln \dot{G}_t = D' + h_1 \ln Z_{it} + h_2 NINV_t + h_3 \ln PCTEMP_t + h_4 \ln F_t + t$$

where F_t is now a vector of demographic variables. The inclusion of $NINV_t$ in this budgetary expression has the added advantage of allowing for an estimation of the impact of private on public investment. As developed in Chapter III, the link between private and public capital was modeled as taking place through the basic sector labor market. In this expanded median voter model, that effect would operate through Z_{it} . That is, an increase in public capital may increase the wage bill of the basic sector leading to a rise in the income of the median voter and possibly a larger, approved, total budget. This, though, is an indirect effect and cannot be estimated with this model. But, the expanded model does allow for a direct estimation of the impact of private investment on public capital outlay. This estimate will give an indication as to how local governments respond to the production decisions of private industry.

In summary, the system of equations that will be estimated in this study is as follows:

$$\begin{aligned}
NINV_t &= A' - c_{11}\ln K_{t-1} - c_{12}\ln L_{t-1} + d_{13}\ln w_t + d_{14}\ln v_t \\
&\quad + d_{15}\ln Q^e_t + d_{16}\ln \dot{G}_t - \gamma d_{16}\ln N_t + t + u_{t1} \\
\ln L_t &= B' + (1-c_{22})\ln L_{t-1} - c_{21}\ln K_{t-1} + d_{23}\ln w_t \\
&\quad + d_{24}\ln v_t + d_{25}\ln Q^e_t + d_{26}\ln \dot{G}_t \\
(30) \quad &\quad - \gamma d_{26}\ln N_t + t + u_{t2} \\
\ln \dot{G}_t &= C' + h_1\ln Z_{it} + h_2 NINV_t + h_3\ln PCTEMP_t \\
&\quad + h_4\ln F_t + t + u_{t3} \\
\ln Z_{it} &= D' + b_1\ln \tau_{it} + \phi(1+b_1)\ln N_t + b_2\ln Y^D_{it} + t + u_{t4}
\end{aligned}$$

where u_{ti} , ($i=1,\dots,4$) are error terms.

The Data and Problems with the Empirical Estimation

Nature of the Data

The system of equations (30) is estimated using a pooled cross section-time series sample. The sample consists of 45 standard metropolitan statistical areas (SMSA's) for which the data span the period 1970-1978. The choice of this time period is based on the availability of data for all 45 SMSA's.

Most of the data employed in the estimation of the short run, input demand equations are reported in the Annual Manufacturing Survey (a complete description of variables and data sources is provided in Appendix B). Employment (L_t) is measured by the total number of employees in the manufacturing sector of the SMSA (assumed to be the basic sector of the region). Expected output (Q^e_t) is constructed

by regressing contemporaneous value added (in the manufacturing sector) on value added lagged from one to four years. The predicted output for each year obtained from this regression is then used as a proxy for expected output. The wage rate, w_t , refers to the average hourly wage of production workers in the manufacturing sector. The price of capital (v_t) is a composite variable based on Jorgenson's method (Hall and Jorgenson, 1967; Christensen and Jorgenson, 1969 and 1970). As shown in Appendix B, local variations in the price of capital depend on variations in the local property tax rate, state and federal corporate tax rates and the pattern of depreciation in each individual SMSA. The stock of private capital (K_t) was estimated using the perpetual inventory method (Faucett, 1979). At any given time t the stock of private capital is the sum of surviving past investments, which are adjusted for depreciation. This private capital stock series was made available for this study by Eberts and Fogarty (1984). Finally, SMSA population (N_t) and public capital outlay ($\dot{G}_t$) are taken from the Government Finance Series. Unfortunately, a public capital stock series for each SMSA was not available at the time of this study. Thus, gross public investment (capital outlay) is used.

The data employed in the estimation of the total budget and public investment equations are found in various Bureau of Census publications (see Appendix B). It should be noted

that the public expenditure data represent a summation of the expenditures of all local government units in the SMSA. Hence, these expenditure data do not include expenditures in the region by the state or federal governments. Although funds for some public capital projects (e.g., water, sewer, highways) may come from higher level governments, they must pass through local governments.

Public capital outlay ($\dot{G}_t$) and total direct general expenditures (Z_{it}) (i.e., the total local budget) are reported in the Selected Metro Area, Government Finance Series. As shown in Appendix B, disposable median income (Y^D_{it}) is constructed according to (9). The tax share faced by the median voter (τ_{it}) is measured by the ratio of the median house value to total property tax revenue collected in the region. The implicit assumption being made is that the person with the median income lives in and owns the house with the median value and this house constitutes his/her entire real property holdings. Also, this individual is assumed to know approximately his/her tax bill and how it changes in response to changes in municipal expenditures.

The percentage of all nonfarm workers employed in the manufacturing sector ($PCTEMP_t$) is derived from data reported in the Annual Manufacturing Survey and Bureau of Labor Statistics publications (see Appendix B). The variables F and D' are taste parameters that should control for

underlying differences in preferences across regions as well as differences in the regions themselves. Variables that will be included in the estimation of these equations to proxy these taste parameters are the population density of the SMSA, the percent of the population that is white, the median age of the residents of the SMSA, and the percent of the homes that are owner occupied.

A time trend variable (t) is included in each equation to account for unspecified changes in the underlying function over time. This variable takes on integer values starting at 0 in 1970 and progressively increases to 8 in 1978. Also, to account for unspecified regional differences, three regional dummies will be added to all equations. These dummies will denote whether or not the SMSA is located in the western, midwestern, or southern region of the U.S. The intercept will account for the northeastern region. Finally, all relevant variables are expressed in 1972 dollars.

Estimation Problems

Since the estimation of (30) employs both time series and cross section data, heteroskedasticity and autocorrelation may have serious consequences for the ordinary least squares (OLS) estimates. If heteroskedasticity is present in the data, then the OLS estimates are unbiased but inefficient, not having the least

variance of all unbiased estimators. The test used to check for heteroskedasticity is one suggested by Goldfield and Quandt (1965). For each year, the observations were sorted according to SMSA population (the suspected scale factor) and divided into three groups. The test examines whether the variance for the third group of observations is significantly greater than that for the first group (the middle group acts as a buffer). For all nine years used in this study, the null hypothesis of homoskedasticity cannot be rejected. This finding is not surprising since the raw data have been transformed into logarithms. Such a transformation will discount any scale factor that may exist and mitigate the problem of spurious correlation caused by the scale factor.

A problem inherent in most all time series is autocorrelation. In the presence of autocorrelation, OLS estimates are unbiased but the estimates of their standard errors are not. Thus, the t-statistics may be seriously overestimated in the case of positive autocorrelation. The standard test for autocorrelation is one suggested by Durbin and Watson (1950). Because of the small number of time series observations (9) used in this study, the computed Durbin-Watson statistic fell consistently within the inconclusive range. Thus, another procedure was used.

First, for each equation to be estimated, the sample first-order autocorrelation coefficient of the errors for

each SMSA was computed using the following formula:

$$r_i = \frac{\sum_{t=3}^{10} e_t e_{t-1}}{\sum_{t=3}^{10} e_t^2} \quad (i=1, \dots, 45)$$

where the e_t 's are the OLS residuals (note that because of lagged variables in the estimating equations and lagged residuals in the estimation of r , the first two years (1970 and 1971) are dropped). A test suggested by Bartlett (1946) for the significance of these estimated, first-order autocorrelation coefficients was then employed. In general, the variance of any autocorrelation coefficient (r_s) can be approximated by the following formula:

$$\text{var}(r_s) = 1/T \left(1 + 2 \sum_{i=1}^p r_i^2 \right), \quad s > p$$

which assumes that r_s is essentially zero for lags s greater than some value p (T is the number of time series observations). Under a null hypothesis of no first-order autocorrelation, $p=0$ and r_1 has a standard error $T^{-1/2}$. Hence, a standard t -test was employed to test the significance of each SMSA's estimated r using the criterion

$$|r| > 1.943 (1/7)^{1/2} = .7344$$

(1.943 is the critical t -value pertaining to six degrees of

freedom at a five percent level of significance and seven is the number of time series observations used in the estimation of r). Because of the small number of time series observations the variance of the estimated, first-order autocorrelation coefficients will be quite large (Nelson, 1973). Thus, the estimated r 's must be high in order for the null hypothesis of $r=0$ to be rejected. As the sample size increases, the variance of the first-order autocorrelation coefficients will fall, increasing the likelihood of finding significant values of r .

The correction procedure for autocorrelation entails quasi-first differencing the data for those SMSA's whose estimated, first-order autocorrelation coefficient is greater than .7344. For example, consider the following simple model:

$$y_t = a + bx_t + u_t$$

where a and b are the parameters to be estimated and $u_t = ru_{t-1} + e_t$. If the estimated, first-order autocorrelation coefficient ($\hat{r}$) is greater than .7344 for the i th SMSA, then the data for that SMSA would be quasi-first differenced. That is, the new model would become:

$$y_t - \hat{r}y_{t-1} = a(1 - \hat{r}) + b(x_t - \hat{r}x_{t-1}) + e_t$$

Estimation of this equation by ordinary least squares will yield unbiased estimates of the standard errors. Hence, in

the case of positive autocorrelation, the estimated t-statistics will not be positively biased.

One consequence of this correction procedure for autocorrelation is that the computer generated estimate of the R^2 will be artificially large. As can be seen in the above equation, this correction procedure requires that all variables in the model be quasi-first differenced, including the intercept. Operationally, a vector of one's is added to the equation which is transformed along with all of the other variables. When the transformed equation is estimated by ordinary least squares, the computer generated intercept is suppressed as the vector of transformed one's will account for the intercept. It is the suppression of the computer generated intercept that will result in an inflated R^2 . A more detailed explanation for this inflation is presented in Appendix C along with a discussion of how this problem has been corrected for in this study.

In addition to autocorrelation, the short run, labor demand equation is plagued by another, potentially serious problem due to the presence of a lagged dependent variable. Application of ordinary least squares to an equation with a lagged dependent variable and autocorrelated errors will yield both inconsistent and inefficient estimates of all parameters in the equation. There are several correction procedures that could be employed in order to arrive at unbiased and efficient estimates (see Johnson, 1972). One

technique involves the estimation of an instrumental variable to replace the lagged dependent variable. This is accomplished by regressing the contemporaneous value of the lagged dependent variable on all of the exogenous variables in the equation lagged several periods. This instrument is then lagged one period and substituted for the lagged dependent variable in the ordinary least squares estimation. A correction for autocorrelation, though, would still have to be made. Unfortunately, this correction procedure cannot be employed in this study because of the limited number of time series observations. Since an instrumental variable would have to be constructed for each SMSA, nine years of observations is not sufficient to estimate such an instrument (i.e., in the short run labor demand equation there are eleven exogenous variables). Another correction procedure simply uses a grid search over the permissible range of first-order autocorrelation coefficients (i.e., in the interval $(-1,1)$). Each value is then used to compute quasi-first differences, and ordinary least squares is applied to minimize the sum of squared errors. The estimated, first-order autocorrelation coefficient that gives rise to the smallest sum of squared errors is then employed in the final estimation. Again, for this sample, this procedure would be computationally unfeasible. Such a grid search would be prohibitively expensive since it would have to be executed for each SMSA.

In light of the above discussion, the short run, labor demand equation is corrected for autocorrelation but not for the presence of a lagged dependent variable. Thus, the parameter estimates in this equation will be biased. In general, the inability to correct for this problem will result in a positive asymptotic bias (assuming that the times series exhibits positive autocorrelation). Johnson (1972) shows that, for a two variable equation in which the only right-hand side variable is the lagged dependent variable, the asymptotic bias will be larger the smaller is the true coefficient on the lagged dependent variable and the larger is the first order autocorrelation coefficient. Taking hypothetical values of 0.80 for r and 0.20 for the true coefficient on the lagged dependent variable, the estimated coefficient will be positively biased by 0.66 (it should be noted that the true coefficient should be less than one (see the discussion on the derivation of the estimating equations)).

In spite of this, there is reason to believe that in this sample the bias may not be very large. First, the coefficient on lagged labor is not expected to be very small since there may be substantial costs associated with the adjustment of labor to its desired level. Johnson computes that, in a two variable equation when both the coefficient on the lagged dependent variable and r are large (0.80 and 0.80, respectively), the asymptotic bias is only 0.18.

Second, even though all of the estimated parameters in the short run, labor demand equation will be positively biased, Malinvaud (1966) has shown that the presence of exogenous variables in the equation tends to reduce the absolute values of the asymptotic biases. Finally, not all of the SMSA's in the sample exhibit a significant degree of autocorrelation. Thus, when the SMSA's are pooled, the bias of the aggregate estimates of the labor demand equation parameters may be reduced even further.

With respect to the short run, net private investment and labor demand equations, another problem may arise due to cross-equation correlation. Since the short run, input demand equations are derived from the same underlying production function, it may be the case that the error terms in both the net private investment and labor demand equations (u_{i1} and u_{i2}) are correlated. Zellner (1962) has devised a procedure that results in more efficient estimates of the parameters than those achieved with ordinary least squares under these conditions. Yet, this procedure can only be applied when the set of explanatory variables differs between equations. If the set of explanatory variables is the same, then Zellner's "seemingly unrelated regression" procedure will give the same parameter estimates as ordinary least squares. Thus, this technique will not be employed in this study.

A final problem with the ordinary least squares

estimation of (30) is that the model of the regional economy developed in this study is simultaneous. Simultaneity implies that there are one or more right-hand side variables that are correlated with the error term. Estimation by ordinary least squares when simultaneity is present will result in biased parameter estimates. Examination of (30) reveals the various simultaneous relationships present in this model. First, net private investment ($NINV_t$) and public capital outlay ($\dot{G}_t$) are both left and right-hand side variables. Thus, $NINV_t$ will be correlated with u_{t3} and $\dot{G}_t$ will be correlated with u_{t1} . Second, labor demand is a function of the basic sector wage rate (w_t). But the wage rate itself is affected by the demand for labor in the basic sector (as was seen in Chapter III). Hence, w_t will be correlated with u_{t2} . Third, public capital outlay enters both the net private investment and labor demand equations. Yet, labor and private capital were posited as having a feedback effect on public capital outlay. This implies that $\dot{G}_t$ may be correlated with both u_{t1} and u_{t2} . Finally, the level of public investment is dependent upon the total budget. The total budget is determined by the median voter whose income is affected by the level of public capital outlay. Although this is a long run effect, if the median voter acts upon perceived future income instead of realized income when voting, then the link between public capital outlay and median income may be simultaneous. Thus, Z_{it} will

be correlated with u_{t3} and Y^D_{it} will be correlated with u_{t4} .

The correction procedure for simultaneity bias would require the estimation of an instrumental variable for each of the endogenous, right-hand side variables listed above. Fair (1970) suggested that these instruments can be constructed by regressing each of the endogenous, right-hand side variables on at least the lagged and contemporaneous exogenous variables, the lagged dependent variables, and the lagged value of the endogenous, right-hand side variable in the corresponding equation. Such instrumental variables would have to be estimated for each of the 45 SMSA's in the sample. These instruments would then replace the endogenous, right-hand side variables and would not be correlated with the error terms. Estimation of (30) would then yield unbiased parameter estimates. Unfortunately, with only nine years of time series data for each SMSA, these instrumental variables cannot be constructed in this manner. Instead, actual values of the lagged, right-hand, side endogenous variables will be used as instruments. Justification for this correction procedure follows from the fact that these lagged variables are not correlated with the corresponding error terms and from the strong autoregressive nature of these variables (the first order autoregressive coefficients for $\dot{G}_t$, Z_{it} , Y^D_{it} , $NINV_t$, and w_t are 0.95, 0.99, 0.97, 0.75, and 0.96, respectively).

Thus, for empirical purposes, the simultaneous system

of equations to be estimated becomes:

$$\begin{aligned} \text{NINV}_t = A' &- c_{11} \ln K_{t-1} - c_{12} \ln L_{t-1} + d_{13} \ln w_t + d_{14} \ln v_t \\ &+ d_{15} \ln Q^e_t + d_{16} \ln \dot{G}_{t-1} - \gamma d_{16} \ln N_{t-1} + t \\ &+ u_{t1} \end{aligned}$$

$$\begin{aligned} \ln L_t = B' &+ (1-c_{22}) \ln L_{t-1} - c_{21} \ln K_{t-1} + d_{23} \ln w_{t-1} \\ &+ d_{24} \ln v_t + d_{25} \ln Q^e_t + d_{26} \ln \dot{G}_{t-1} \\ (31) \quad &- \gamma d_{26} \ln N_{t-1} + t + u_{t2} \end{aligned}$$

$$\begin{aligned} \ln \dot{G}_t = C' &+ h_1 \ln Z_{it-1} + h_2 \text{NINV}_{t-1} + h_3 \ln \text{PCTEMP}_t \\ &+ h_4 \ln F_t + t + u_{t3} \end{aligned}$$

$$\begin{aligned} \ln Z_{it} = D' &+ b_1 \ln \mathcal{C}_{it} + \phi(1+b_1) \ln N_t + b_2 \ln Y^D_{it-1} + t \\ &+ u_{t4} \end{aligned}$$

It should be noted that since $\dot{g}_t$ is defined as $\dot{G}_t/N_t^\gamma$,
 $\ln \dot{g}_{t-1} = \ln \dot{G}_{t-1} - \gamma \ln N_{t-1}$.

Identification of each equation can be shown through the rank condition which is a necessary and sufficient condition for identification (Maddala, 1977). Thus, the estimates obtained can be interpreted as the estimates of the parameters of the corresponding equation alone and are not some linear combination of the parameters of all four equations. The estimated equations themselves are presented in the following chapter.

CHAPTER V

EMPIRICAL ESTIMATION OF THE REGIONAL MODEL

The model of the regional economy defined by (31) is estimated using a pooled time series-cross sectional sample of 45 SMSA's during the period 1972-1978. The results of this estimation are presented in this chapter.

Estimation of the Short Run Input Demand Equations

The estimated input demand equations are presented in Table 1. These equations explain the data quite well, as evidenced by the adjusted R^2 's. Examination of these equations reveals that the dynamic impact of public investment on both net private investment and labor demand (given by the coefficient on $\dot{G}$) is positive. This, suggests that as private capital and labor are adjusting to their desired levels (holding output constant), additional public investment will induce the basic sector to increase private investment and employment. Thus, public capital exhibits a dynamic, complementary relationship with both private capital and labor, although this relationship is statistically significant only with respect to net private investment. This finding, though, does not necessarily imply that the inputs are short run complements (i.e., when

private capital and labor are at their desired levels). The determination of short run complementarity requires the computation of the short run, input demand elasticities.

TABLE 1. Net Investment and Labor Demand Equations
for Full Sample

Independent Variables	Net Investment		Labor	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	0.130	0.102	-1.306*	0.168
OUTPUT	0.027*	0.009	0.134	0.030
WAGES	0.039*	0.015	-0.027	0.041
CAPITAL PRICE	-0.086*	0.018	-0.207*	0.047
POPULATION	-0.018*	0.008	-0.010	0.018
K_{t-1}	-0.056*	0.006	-0.038**	0.016
L_{t-1}	0.028**	0.012	0.896*	0.032
PUB INV	0.013*	0.004	0.014	0.012
γ	1.380		0.710	
TREND	0.0004	0.0007	0.003***	0.002
DSOUTH	0.015*	0.003	-0.005	0.013
DWEST	0.010*	0.004	0.034*	0.013
DMIDWEST	-0.007***	0.004	0.011	0.011
R^2	0.47		0.99	
F	26.25		4,148.05	
# of obs.	315.00		315.00	

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

The short run, private capital and labor demand elasticities with respect to private capital outlay can be derived from the parameter estimates shown in Table 1 (see Appendix A). These elasticities, as shown in Table 2, are positive in both cases with the impact on private capital being approximately six times as large as the impact on labor. These estimates suggest that public capital exhibits a short run, complementary relationship with both private capital and labor. This is a peculiar finding because it indicates that public capital may be counterproductive. That is, given the level of output, an increase in public capital outlay may reduce the productivity of private capital and labor, thus requiring more of both inputs to produce the same level of output. One would expect that the opposite relationship is true, at least in the case of private capital. That is, public capital should make private capital more productive, thus making less of it required to produce the same level of output.

There are several possible explanations for this finding. First, this finding may again be the result of the failure of the expected output proxy to adequately control for the output of the basic sector. In this sample, value added by the manufacturing sector and public capital outlay are positively correlated over time (the estimated correlation coefficient is 0.65). Hence, it is possible that the short run input demand elasticity with respect to

public investment may be capturing both an output and substitution effect (with the output effect dominating).

TABLE 2. Summary of Estimates for Full Sample

Variable	<u>Dynamic Impacts</u>	
	Net Investment	Labor
OUTPUT	+0.027	+0.134
WAGES	+0.039	-0.027
CAPITAL PRICE	-0.086	-0.207
PUB INV	+0.013	+0.014
Variable	<u>Short Run Input Demand Elasticities</u>	
	Private Capital	Labor
OUTPUT	+0.969	+0.974
WAGES	+0.471	-0.450
CAPITAL PRICE	-2.161	-1.249
PUB INV	+0.252	+0.044
Variable	<u>Cross and Own Adjustment Signs</u>	
	Private Capital	Labor
K_{t-1}	+	+
L_{t-1}	-	+

Another possible explanation for this finding is that the short run input demand equations are misspecified. An

argument can be made that a more flexible functional form would place fewer restrictions on the data. Yet, it should be noted that such functional forms will not allow for an estimation of the congestion parameter with respect to the private sector. Moreover, one study (Garofalo and Fogarty, 1984a) did employ a translog production function in an investigation into the short run impact of factor prices on net private investment and found impacts similar to the ones found in this study. Thus, the use of a more flexible functional form may not significantly change the finding of a positive, short run elasticity of input demand with respect to public capital.

A third explanation for this finding is that the parameter estimates may be biased due to passive symmetry restrictions imposed upon the short run input demand equations. The response of net private investment and labor demand to an increase in public investment is implicitly assumed to be identical in all regions. Yet, it is conceivable that the response of net private investment (and labor demand) to public capital outlay differs among regions. In general, SMSA's can be categorized as either declining or growing regions. Estimation of short run, input demand equations for both types of regions combined implicitly assumes that the response of private net investment and labor demand to a change in the level of public capital outlay is simply an average of the responses

in the two types of regions. Yet, as shown by Haynes (1983) in another context, if asymmetric responses are permitted (i.e., asymmetric responses between types of regions), the expected value of the coefficient on public investment when symmetry is assumed is unlikely to lie between the two unconstrained parameter estimates. In fact, it is quite possible for the constrained coefficient to have a sign opposite that of the unconstrained coefficients. Furthermore, a symmetry restriction placed on any other variable in the equation (besides public investment) will bias every parameter estimate in the equation including the coefficient on public capital outlay. Thus, if the hypothesis of symmetric responses between growing and declining regions can be rejected, then an aggregate estimation such as the one shown in Table 1 will lead to incorrect inferences concerning the true relationship between public and private investment.

The existence of asymmetric responses is a distinct possibility and will be investigated thoroughly in this study. But before this discussion is presented, it would be instructive to briefly examine the other estimated parameters in these input demand equations.

Most of the signs of the other parameter estimates agree with a priori expectations. For example, the dynamic impact of expected output on net private investment and labor demand is positive and significant. Moreover, this

effect is about five times greater in the labor equation than in the net investment equation. This suggests that firms respond to increases in the expected demand for their product by relying more on increases in employment than on increases in the stock of private capital. The dynamic impact of the price of private capital is also smaller in the net investment equation, again indicating that the stock of capital is much slower to adjust than is labor.

The own-adjustment coefficients in each equation also agree with a priori expectations. In the net private investment equation, the coefficient of K_{t-1} is an estimate of $-c_{11}$, the own-adjustment coefficient for the stock of private capital. The coefficient of L_{t-1} in the labor demand equation is an estimate of $(1-c_{22})$, the own-adjustment coefficient for the stock of labor. The estimates of the own-adjustment coefficients are expected to be positive and less than unity. This is the case in both equations. Again, these estimates indicate that private capital adjusts relatively slowly (0.056) and forces labor to initially satisfy increases in the demand for the basic sector's output, even though labor is also slow to adjust (i.e., $c_{22} = 0.104$). The signs of the cross-adjustment coefficients ($-c_{ij}$) cannot be predicted a priori because they depend upon current market and technical conditions. For this sample of SMSA's, the feedback effect of labor on net private investment (c_{12}) is negative (i.e., the

regression coefficient on L_{t-1} is positive in the net private investment equation). This suggests that if the previous level of employment is high, net private investment has a tendency to increase, indicating that labor and private capital are dynamic complements. Yet, the feedback effect of private capital on labor (c_{21}) is positive, suggesting that the opposite relationship is true. Thus, in this case, a determination of whether or not private capital and labor are dynamic complements or substitutes cannot be made.

In fact, Nadiri (1972) suggests that symmetry in dynamic response is not guaranteed. For example, the availability of labor does not mean that a firm will necessarily invest more in its capital stock. Unfavorable conditions may characterize the capital market (e.g., high interest rates) prompting the firm to initially satisfy increases in the demand for its output by employing more labor as it waits for more favorable capital market conditions. This suggests that private capital and labor are dynamic substitutes. Yet, at the same time, increased private investment may bring about additional employment if there are no bottlenecks in hiring and training new workers. Thus, in this case, private capital and labor would exhibit a dynamic, complementary relationship.

The private capital and labor demand elasticities with respect to input prices and output as well as a summary of

the dynamic impacts and own- and cross-adjustment signs, are presented in Table 2. The effect of an increase in the expected level of output appears to have a significant impact on the demand for private capital and labor. Furthermore, the demand for private capital appears to be highly sensitive to the price of private capital (with an estimated elasticity of -2.161). This may have an important policy implication for local governments. Since, variations in the price of private capital reflect local variations in property and corporate income tax rates (in this sample, approximately sixty percent of the variation is due to local taxes), local and state governments may be able to have a sizable impact on the short run formation of private capital through their taxation policies.

The estimated own, input demand elasticities are of the correct sign (i.e., negative in both cases). Yet, the cross elasticity estimates do not give a clear indication as to whether or not private capital and labor are short run substitutes or complements. These estimated elasticities suggest that an increase in the wage rate will result in a substitution of private capital for labor (i.e., the private capital input demand elasticity with respect to the average hourly wage is $+0.471$). Yet, an increase in the price of private capital will reduce the demand for labor, which suggests that the short run relationship is complementary (i.e., the estimated elasticity is -1.249).

A possible explanation for this finding is that, econometrically, output is not being held constant. Thus, these estimated elasticities are picking up both an output and substitution effect. Holding output constant, an increase in the price of private capital should result in labor being substituted for the more expensive capital. However, the increase in the cost of production will also raise the price of the basic sector's product which will lower the quantity demanded, lower output, and reduce the demand for both private capital and labor. The total effect on labor may indeed be negative. Thus, the proxy for expected output used in this study may not be completely controlling for the level of output.

Finally, it should be noted that the estimation of the congestion parameter with respect to the basic sector (γ) indicates that public capital effectively enters the production process as a pure private input. γ is estimated from $\hat{s}_1/\hat{s}_2$ where $\hat{s}_1$ and $\hat{s}_2$ are the estimated dynamic impacts with respect to SMSA population and public capital outlay, respectively. Although the absolute value of γ is greater than one in the net investment equation and less than one in the labor demand equation, they do not differ significantly from one (significance is determined through a test of linear restrictions). Thus, N units of public capital must be produced by the public sector if the average firm is to obtain one unit of the input, where N is the total number of

users sharing public infrastructure.

Asymmetric Responses Between Growing and Declining Regions

As suggested above, one of the possible explanations for these positive input demand elasticities with respect to public capital outlay is that the estimated parameters are biased by a passive imposition of symmetry restrictions. The reason for this bias can be seen by considering the following simple, net private investment demand equation that passively imposes a symmetry restriction on the response of private net investment to public capital outlay:

$$\text{MODEL I: } \text{NINV}_t = a + b\dot{G}_t + u_t$$

Model I imposes a symmetry restriction since the response of net private investment to public capital outlay is assumed to be identical in both declining and growing regions. A test for the validity of this symmetry restriction can be performed by adding an interaction term to model I:

$$\text{MODEL II: } \text{NINV}_t = a + c\dot{G}_t + dD\dot{G}_t + u_t$$

where D is a dummy variable taking on a value of one if the SMSA is classified as a growing region and equals zero otherwise. Model II allows for asymmetric responses. If the SMSA is a growing region, then the impact of public capital outlay on net private investment will be given by

(c + d). If the SMSA is a declining region, then the short run impact is simply given by c. A test for the existence of asymmetry involves a test of the significance of the coefficient d. If d differs significantly from zero, then the null hypothesis that the response between regions is the same can be rejected. On the other hand, if d does not differ significantly from zero, then the null hypothesis cannot be rejected.

Model II can be rewritten in the following mathematically equivalent form which will help to understand the reason behind the bias caused by the symmetry restrictions:

$$\text{MODEL III: } \text{NINV}_t = a + f_1 D_1 \dot{G}_t + f_2 D_2 \dot{G}_t + u_t$$

where D_1 is one if the region is declining, and zero otherwise; and D_2 is one if the region is growing, and zero otherwise. Thus, if the region is declining the impact of public capital outlay on private net investment is given by f_1 (i.e., $f_1 = c$). If the region is growing, then the impact of public capital outlay on private net investment is given by f_2 (i.e., $f_2 = c + d$).

If model III is estimated under the restriction that $f_1 = f_2$ (i.e., symmetry), then the actual model estimated would be given by:

$$\text{MODEL IV: } \text{NINV}_t = a + g[\dot{G}_{1t} + \dot{G}_{2t}] + u_t$$

$$\begin{aligned}
\text{where } \dot{G}_{1t} &= D_1 \dot{G}_t \\
\dot{G}_{2t} &= D_2 \dot{G}_t \\
g &= f_1 = f_2
\end{aligned}$$

The ordinary least squares estimate of g (see Haynes, 1983; Johnston, 1972) is given by:

$$\hat{g} = w_1 \hat{f}_1 + w_2 \hat{f}_2$$

$$\begin{aligned}
\text{where } w_1 &= [\text{Var } \dot{G}_{2t} + \text{Cov}(\dot{G}_{1t}, \dot{G}_{2t})]/K \\
w_2 &= [\text{Var } \dot{G}_{1t} + \text{Cov}(\dot{G}_{1t}, \dot{G}_{2t})]/K \\
K &= \text{Var } \dot{G}_{1t} + \text{Var } \dot{G}_{2t} + 2\text{Cov}(\dot{G}_{1t}, \dot{G}_{2t}) \\
w_1 + w_2 &= 1
\end{aligned}$$

and $\hat{f}_1$ and $\hat{f}_2$ are the unconstrained estimates of f_1 and f_2 . Finally, taking expectations yields:

$$E(\hat{g}) = w_1 f_1 + w_2 f_2$$

Note that if $f_1 = f_2$, then the estimation of model IV will yield an unbiased estimate of g (i.e., $E(\hat{g}) = f_1 = f_2$).

The reason why a symmetry restriction can yield biased estimates can now be seen. If either w_1 or w_2 is negative and $f_1 = f_2$, then $E(\hat{g})$ will not lie in the interval between f_1 and f_2 . Moreover, depending upon the magnitude of the negative weight, $E(\hat{g})$ may even reverse sign. Whether or not w_1 and/or w_2 is negative depends upon the sign and magnitude of the covariance between the public capital outlay series in declining and growing regions. The stronger the negative

correlation between $\dot{G}_{1t}$ and $\dot{G}_{2t}$, the greater the likelihood that w_1 or w_2 is negative.

If the model is expanded to include more than one explanatory variable, then the formulas for the weights become much more complex. This implies that a strong negative correlation between the public capital outlay series in declining and growing regions is no longer necessary for w_1 or w_2 to be negative. Negative weights can now be caused by strong negative correlations (between growing and declining regions) in some of the other series. The greater the number of explanatory variables in the equation, the greater the number of symmetry restrictions imposed when the equation is estimated for the full sample. Hence, the greater is the number of possible causes of a biased parameter estimate on public capital outlay as well as all of the other variables in the equation.

If the response of net private investment and labor demand to changes in the explanatory variables are asymmetric between growing and declining regions, then an aggregate estimation of the short run input demand equations (such as the one presented in Table 1) will lead to incorrect inferences concerning the true nature of the relationship between net private investment (and labor) and public capital outlay, as well as the other explanatory variables in the equation. The correct procedure then would be to estimate unconstrained, short run, input demand

equations that allow for asymmetric responses between growing and declining regions. This can easily be accomplished by estimating the short run, input demand equations separately for these two types of regions.

To determine whether or not the responses of net private investment and labor demand are asymmetric first requires that the SMSA's be categorized as either declining or growing. The procedure employed to classify regions as declining or growing during the 1970 to 1978 period is similar to that used by Bradbury (1984). An index is created that compares each SMSA with the other regions in the sample based on four components: percentage change in real manufacturing investment between 1970 and 1978; the percentage change in SMSA population between 1970 and 1978; and the unemployment rates in 1975 and 1977. This index is calculated from these four components in the following manner: SMSA's are ranked on each component and the resulting distribution is divided into fifths. Regions are then scored as to where they lie in each of these distributions. SMSA's in the most advantaged fifth are given a +2, the next fifth is assigned a +1, the middle fifth a 0, the next fifth a -1, and the most disadvantaged fifth is assigned a -2. Each SMSA's index score is then obtained by summing their component scores. Table 3 presents the computed index for each of the SMSA's in this sample. SMSA's with index scores less than zero are

designated as declining regions and those with index scores greater than or equal to zero are designated as growing regions.

TABLE 3. Classification of SMSA's

SMSA	Index Score	Class*	SMSA	Index Score	Class*
Akron	-5	D	Memphis	+1	G
Allentown	+2	G	Miami	-3	D
Anaheim	+5	G	Milwaukee	+2	G
Atlanta	0	G	Minneapolis	+5	G
Baltimore	-2	D	Nashville	+5	G
Birmingham	+4	G	Newark	-5	D
Buffalo	-7	D	New Orleans	+2	G
Chicago	-2	D	New York	-6	D
Cincinnati	+1	G	Philadelphia	-7	D
Cleveland	-1	D	Phoenix	0	G
Columbus	+1	G	Pittsburg	-2	D
Dallas	+6	G	Portland	0	G
Dayton	-1	D	Richmond	+7	G
Denver	+6	G	Rochester	-1	D
Detroit	-2	D	San Bernardino	0	G
Grand Rapids	+1	G	San Diego	-1	D
Greensboro	+4	G	Seattle	-1	D
Houston	+7	G	San Francisco	-3	D
Indianapolis	+2	G	San Jose	+2	G
Jersey City	-8	D	St. Louis	-1	D
Kansas City	+3	G	Tampa	+2	G
Los Angeles	-3	D	Toledo	-1	D
Louisville	+2	G			

*D denotes SMSA's classified as decline SMSA's.

G denotes SMSA's classified as growth SMSA's.

The means of the variables used in this classification for each of the two types of SMSA's are presented in Table 4. The means of these components support the classification shown in Table 4 to a large extent. For example, growth

SMSA's had significantly lower unemployment rates and significantly higher population growth rates than did declining SMSA's during the 1970 to 1978 period. Growth regions also experienced four times the rate of private investment growth as did the declining SMSA's during this period.

TABLE 4. Means of Component Variables Used to Compute SMSA Index Score

Variable	SMSA Classification		Difference (t-Statistics)	
	Growth	Decline		
1970-1978 Real Investment Change	0.75	0.17	0.58	(3.18**)
Population Change	0.20	0.04	0.16	(2.50**)
1975 Unemployment Rate	7.78	9.60	-1.82	(3.25**)
1977 Unemployment Rate	6.02	7.87	-1.85	(4.18**)

**indicates significance at five percent level.

Although Table 4 gives some indication of the overall trend in private and public investment, it does not provide enough information on how these trends differ between SMSA's. Tables 5 and 6 present the percentage change in net private investment and public capital outlay during the 1970 to 1978 period for growth and decline SMSA's, respectively. Of the SMSA's that are classified as growing regions, eighty percent experienced a positive percentage change in net private investment while only 43 percent of the declining

TABLE 5. Percentage Change in Net Private Investment
and Gross Public Investment During
the Period 1970-1978:
Growth SMSA's

SMSA	%Change in Net Private Investment	%Change in Gross Public Investment
Allentown	+ 1.95	- 29.50
Anaheim	+ 190.30	+ 15.00
Atlanta	- 19.80	- 15.70
Birmingham	+7,618.40	+ 12.70
Cincinnati	+ 36.80	+522.20
Columbus	- 66.00	- 14.60
Dallas	+ 42.30	+ 32.80
Denver	+ 74.00	+ 48.50
Grand Rapids	+ 431.50	- 25.20
Greensboro	+ 23.20	- 30.90
Houston	+ 22.30	+139.50
Indianapolis	+ 38.40	- 27.80
Kansas City	+ 116.70	- 33.50
Louisville	- 4.90	- 57.00
Memphis	+ 1.80	+ 8.50
Milwaukee	+ 181.50	- 46.85
Minneapolis	- 41.70	- 16.00
Nashville	- 45.60	+ 34.50
New Orleans	+3,049.50	- 30.90
Phoenix	+ 46.20	+ 80.40
Portland	+ 12.10	+ 7.90
Richmond	+ 325.60	- 24.60
San Bernardino	+2,539.30	+ 28.20
San Jose	+ 334.90	- 1.30
Tampa	+ 115.90	+ 33.90

regions experienced a positive percentage change. With respect to public capital outlay, 48 percent of the growing SMSA's experienced a positive percentage change while only 24 percent of the declining regions experienced a positive percentage increase. Furthermore, the average region in the growth sample experienced a 23 percent increase in public capital outlay during this period while the average region

TABLE 6. Percentage Change in Net Private Investment
and Gross Public Investment During
the Period 1970-1978:
Decline SMSA's

SMSA	%Change in Net Private Investment	%Change in Gross Public Investment
Akron	- 203.90	- 29.50
Baltimore	- 103.60	+ 25.10
Buffalo	+ 20.50	+105.30
Chicago	- 73.70	- 13.90
Cleveland	+ 81.50	- 20.10
Dayton	- 29.90	- 10.00
Detroit	+ 228.00	- 18.90
Jersey City	- 215.60	- 36.20
Los Angeles	+ 1.40	- 37.20
Miami	+ 34.80	+ 40.40
Newark	- 18.00	- 54.50
New York	- 18.30	- 72.40
Philadelphia	- 143.50	- 40.60
Pittsburg	- 140.50	- 35.70
Rochester	- 63.70	- 32.90
San Diego	+ 19.70	+ 28.10
Seattle	+3,615.30	- 54.90
San Francisco	- 25.90	+ 7.60
St. Louis	+ 211.20	- 11.10
Toledo	+ 39.40	- 22.40

in the decline sample experienced a 17 percent decrease. It should be remembered, though, that a negative correlation between public investment in the two types of SMSA's is not necessary for a symmetry restriction to result in biased parameter estimates. Strong negative correlations in some of the other explanatory variables included in the short run input demand equations will also cause biased coefficients.

As discussed above, the test for the validity of the symmetry restrictions imposed on the aggregate estimation of

the short run, input demand equations presented in Table 1 simply consists of the addition of interaction terms to each equation. These interaction terms are the explanatory variables multiplied by a dummy variable (D) which takes on the value of one if the SMSA is a growing region, and zero otherwise. For example, the net private investment equation becomes:

$$NINV_t = A' + \sum_i b_i \ln X_{it} + \sum_i d_i D \ln X_{it} + u_t$$

If the SMSA is growing, then the effect of any explanatory variable (X_{it}) on net private investment is given by $(b_i + d_i)$. On the other hand, if the region is declining, then the impact is simply given by b_i . Estimation of this unrestricted equation will allow for two tests to be performed. First, a t-test will indicate whether or not any of the d_i 's differ significantly from zero. This will identify which of the estimated coefficients exhibit asymmetric behavior. Second, employing the sum of the unexplained squared residuals (SSE) from the unrestricted and restricted equations, an F-test can be performed which will determine if the null hypothesis of symmetry for the equation can be rejected. If this F-test does indicate that null hypothesis of symmetry can be rejected, then the parameter estimates in the restricted equations (presented in Table 1) will be significantly biased. Thus,

unrestricted equations should be estimated in order to obtain correct inferences concerning the relationship between net private investment (and labor demand) and public capital outlay.

A summary of the findings from the estimation of the unrestricted, short run input demand equations are presented in Table 7. Six out of the eleven coefficients on the interacted explanatory variables are significantly different from zero in the net private investment equation while only two out of eleven are significantly different from zero in the labor demand equation. Thus, it appears that asymmetry poses more of a problem for the parameter estimates in the net investment equation than in the labor equation. It is interesting to note which variables exhibit asymmetric behavior. The response of both net private investment and labor demand to changes in the level of public investment appears to be symmetric between growing and declining regions. Labor demand, though, appears to exhibit asymmetric behavior with respect to the wage rate. The significantly negative coefficient on wages indicates that a change in the wage rate will have a smaller impact on the quantity of labor demanded in declining regions than in growing regions. This suggests that the elasticity of labor demand is smaller (in absolute value) in declining regions than in growing regions. A possible explanation for this finding is that the elasticity of substitution between

private capital and labor is smaller in declining regions that in growing regions. The smaller the elasticity of

TABLE 7. Summary of Tests for Asymmetric Responses Between Growing and Declining Regions

<u>Signs and Significance of Interactive Coefficients</u>		
Interacted Variables	Net Investment	Labor
OUTPUT	- ***	+
WAGES	+	- **
CAPITAL PRICE	- **	-
POPULATION	-	- **
K_{t-1}	+ **	+
L_{t-1}	+ ***	+
PUB INV	-	+
TREND	-	-
DSOUTH	- *	-
DWEST	+	+
DMIDWEST	- *	+
<u>F-Statistics</u>		
Net Investment		Labor
SSE_R	= 0.152	SSE_R = 1.023
SSE_{UR}	= 0.120	SSE_{UR} = 0.979
$F_{11,292}$	= 7.080*	$F_{11,292}$ = 1.190

*Significance at 1 percent level.

**Significance at 5 percent level.

***Significance at 10 percent level.

substitution, the less likely are firms to hire additional labor when the wage rate falls (holding output constant) because labor is not easily substitutable for private capital. Empirical evidence supporting this explanation was found by Garofalo and Fogarty (1984a). They found that the average, partial Allen elasticity of substitution in the east and midwest regions of the U.S. (where a majority of the declining's SMSA's are located) is 0.552 while the average elasticity in the south and west regions (where a majority of the growing SMSA's are located) is 0.716.

A similar argument can be made to explain the asymmetric response of net private investment to the price of private capital. Again, the significantly negative coefficient on the capital price interaction term suggests that the elasticity of private capital demand is smaller (in absolute value) in declining regions than in growing regions. This also may be attributable to the smaller elasticity of substitution between private capital and labor found to characterize declining regions by Garofalo and Forgaty.

An F-statistic is used to test the null hypothesis of symmetry for each equation. The F-statistic is computed according to the following formula:

$$F = \frac{(SSE_r - SSE_{ur})/q}{SSE_{ur}/(n - k - 1)}$$

where SSE_r = sum of the unexplained squared residuals
obtained from the restricted equation

SSE_{ur} = sum of the unexplained squared residuals
obtained from the unrestricted equation

q = number of symmetry restrictions = 11

n = number of observations = 315

k = number of explanatory variables = 11

This F-statistic is significant at the one percent confidence level (as shown at the bottom of Table 7) for the net private investment equation but is not statistically significant for the labor demand equation. This indicates that the null hypothesis of symmetry can be rejected only for the net private investment equation. Hence, the coefficients of this equation will be biased by the imposition of symmetry restrictions.

The results of the test for the validity of the symmetry restrictions suggest that correct inferences concerning the impact of the explanatory variables on net private investment demand can be obtained only from an unrestricted estimation of this equation. Hence, the short run, net private investment demand equation was reestimated for the two different sub-samples of SMSA's (i.e., growing and declining). In addition, although the null hypothesis of symmetry cannot be rejected for the labor demand equation, the presence of two coefficients which exhibit asymmetric responses suggests that the labor demand equation

should also be reestimated (i.e., symmetry restrictions placed on these two coefficients will bias all of the other coefficients in the labor demand equation).

Input Demand Equation Estimates for Growing SMSA's

The estimated, input demand equations for the sample of growing SMSA's are presented in Table 8. The dynamic impact of public capital outlay on net private investment is now negative but the coefficient does not differ significantly from zero (the estimated coefficient is only -0.002). This stands in stark contrast to the significantly positive coefficient on public investment shown in Table 1. Hence, this coefficient appears to have been biased by the symmetry restrictions. The dynamic impact of public investment on labor demand is still positive indicating that public capital and labor are dynamic complements.

The sign of the private capital demand elasticity with respect to public capital outlay (as shown in Table 9) is now negative. This indicates that public and private capital are short run substitutes in the basic sectors of growing regions. Hence, additional public capital outlay reduces the amount of private capital required to produce a given level of output. The magnitude of this elasticity, though, is relatively small suggesting that this short run effect on private capital is not very large (i.e., a ten

TABLE 8. Net Investment and Labor Demand Equations
for Sample of Growth SMSA's

Independent Variables	Net Investment		Labor	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	-0.434*	0.145	-1.310*	0.342
OUTPUT	0.052*	0.016	0.120*	0.035
WAGES	0.031	0.039	-0.151*	0.074
CAPITAL PRICE	-0.094*	0.030	-0.061	0.054
POPULATION	-0.007	0.012	-0.014	0.023
K_{t-1}	-0.007	0.012	-0.014	0.023
L_{t-1}	-0.022**	0.011	0.002	0.022
PUB INV	-0.002	0.008	0.018***	0.009
γ	3.500		0.780	
TREND	-0.001	0.001	0.008*	0.002
DSOUTH	0.001	0.006	-0.018	0.028
DWEST	0.005	0.008	0.036	0.030
DMIDWEST	-0.032*	0.009	0.002	0.027
R^2	0.32		0.98	
F	7.04		1,027.06	
# of obs.	175.00		175.00	

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

percent increase in public capital outlay would induce only a 2.2 percent reduction in the stock of private capital).

Another interpretation of this finding is that a fall in public capital outlay induces more private capital to be

TABLE 9. Summary of Estimates for Sample of Growth SMSA's

<u>Dynamic Impacts</u>		
Variable	Net Investment	Labor
OUTPUT	+0.052	+0.120
WAGES	+0.031	-0.151
CAPITAL PRICE	-0.094	-0.061
PUB INV	-0.002	+0.018
<u>Short Run Input Demand Elasticities</u>		
Variable	Private Capital	Labor
OUTPUT	+1.426	+1.032
WAGES	+2.523	-1.226
CAPITAL PRICE	-3.749	-0.576
PUB INV	-0.224	+0.146
<u>Cross and Own Adjustment Signs</u>		
Variable	Private Capital	Labor
K_{t-1}	+	+
L_{t-1}	+	+

employed in order to substitute for needed or decaying public capital. For example, a firm may substitute its own capital for inadequate water and sewer facilities or for the wear and tear on its vehicles due to poorly maintained roads. Yet the finding of a relatively small elasticity is

not surprising. Given the aggregate measure of public investment used in this study, one would expect the elasticity to be lower than if a more disaggregate measure was used. For example, the substitution of private capital for nonexistent or inadequate roads or water and sewer systems is probably much higher than is the substitution of private capital for an aggregate measure of public capital that includes such infrastructure as schools, parks, police and fire stations (for which the elasticity of substitution is probably quite small).

The labor demand elasticity with respect to public investment is again positive suggesting that labor and public capital are short run complements in growing regions. Thus, an increase in public capital outlay increases the need for additional labor in order to produce the same level of output. This finding is not necessarily counterintuitive. Berndt and Christensen (1984) found that private capital and production workers are substitutes while private capital and non-production workers are complements. It may be the case that the ratio of non-production to production workers is relatively large in the manufacturing sector of growing regions. Hence, public capital and the aggregate measure of labor employed in this study can conceivably be complements in growing regions.

Most of the signs and magnitudes of the remaining estimated parameters are consistent with a priori

expectations. Yet, some do appear to have been biased by the imposition of symmetry restrictions in the estimation of the full sample.

The impact of expected output on net private investment and labor demand is again positive and significant with the effect being about twice as large in the labor demand equation than in the net private investment equation. The own-adjustment coefficients in each equation are positive and less than unity and again indicate that both private capital and labor adjust quite slowly to their desired levels (i.e., $c_{11} = 0.022$ and $c_{22} = 0.119$). The sign of the cross-adjustment coefficient for labor in the net private investment equation (c_{12}) is now positive indicating that this coefficient was biased by the symmetry restriction imposed in the aggregate estimation. The sign of c_{12} together with the sign of c_{21} , the feedback effect of private capital on labor, indicate that private capital and labor are unambiguously dynamic complements.

Although the absolute value of the congestion parameter derived from the net investment equation is 3.50, it still does not differ significantly from one. Likewise, the congestion parameter derived from the labor demand equation also does not differ significantly from unity indicating that public capital effectively enters the production process of the basic sector in growing regions as a pure private input.

The estimated, input demand elasticities with respect to input prices and output are also presented in Table 9 along with a summary of the dynamic effects. The demand for private capital and labor appear to be responsive to changes in the expected level of output, with the average estimated elasticity being +1.229. The estimated own demand elasticities are of the correct sign with the demand for private capital being extremely sensitive to local variations among growing regions, which are primarily due to property and corporate profit tax rates. The cross-elasticity estimates, though, still do not indicate whether or not private capital and labor are short run complements or substitutes. Again, these estimates may be picking up both a substitution and output effect.

Input Demand Equation Estimates for Declining SMSA's

The estimated, input demand equations for the sample of declining SMSA's are presented in Table 10. In comparing the estimated parameters in Table 8 with those presented in Table 10, it is interesting to note that, with respect to the labor demand equation, seven out of the eleven constrained coefficients (found in Table 1) lie in the interval between the unconstrained coefficients. Yet, with respect to the net private investment equation, only three of the unconstrained parameter estimates lie in the interval

TABLE 10. Net Investment and Labor Demand Equations
for Sample of Decline SMSA's

Independent Variables	Net Investment		Labor	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	-0.412*	0.110	-2.131*	0.401
OUTPUT	0.063*	0.009	0.179*	0.034
WAGES	0.066*	0.013	-0.027	0.047
CAPITAL PRICE	-0.039***	0.020	-0.080	0.073
POPULATION	0.030*	0.008	0.093	0.030
K_{t-1}	-0.043*	0.006	-0.008	0.024
L_{t-1}	-0.043*	0.013	0.762*	0.049
PUB INV	-0.004	0.004	-0.017	0.015
γ	7.500**		5.470*	
TREND	-0.001	0.001	0.006*	0.002
DSOUTH	0.065*	0.009	0.072**	0.034
DWEST	-0.003	0.005	0.004	0.017
DMIDWEST	0.005	0.003	0.024**	0.012
R^2	0.64		0.99	
F	26.72		3,106.16	
# of obs.	140.00		140.00	

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

between the unconstrained coefficients. Moreover, three of the constrained coefficients in the net private investment equation (found in Table 1) have signs opposite to both of the unconstrained coefficients (i.e., the coefficients on

lagged labor, public investment, and the trend variable). There are no complete sign reversals in the labor demand equation. Hence, these findings again reveal that symmetry restrictions seriously biased most of the coefficients in the constrained, net private investment equation, including the coefficient on public investment even though public capital did not itself exhibit a significant degree of asymmetry (as evidenced in Table 7).

The dynamic impact of public investment on both net private investment and labor demand is negative but, the coefficients do not differ significantly from zero (the estimated coefficients are -0.004 and -0.017 , respectively). In comparison with the estimates derived from the sample of growing SMSA's, the major difference is that the coefficient on public investment switched signs in the labor demand equation. Thus, in declining regions, public capital exhibits a dynamic, complementary relationship with both private capital and labor, although this relationship is not statistically significant.

The signs of the short run, private capital and labor demand elasticities with respect to public investment are both negative (as shown in Table 11). This indicates that public capital enters into a short run, substitutive relationship with both private capital and labor. Yet, the magnitude of these elasticities are quite small (-0.023 and -0.070 , respectively). Thus, the productivity effects of

TABLE 11. Summary of Estimates for Sample of Decline SMSA's

<u>Dynamic Impacts</u>		
Variable	Net Investment	Labor
OUTPUT	+0.063	+0.179
WAGES	+0.066	+0.027
CAPITAL PRICE	-0.039	-0.080
PUB INV	-0.004	-0.017
<u>Short Run Input Demand Elasticities</u>		
Variable	Private Capital	Labor
OUTPUT	+0.738	+0.727
WAGES	+1.471	+0.064
CAPITAL PRICE	-0.591	-0.316
PUB INV	-0.023	-0.070
<u>Cross and Own Adjustment Signs</u>		
Variable	Private Capital	Labor
K_{t-1}	+	+
L_{t-1}	+	+

public capital on private capital and labor are not very large. In fact, a ten percent increase in public investment will bring about only a 0.23 percent decrease in the demand for private capital. This stands in stark contrast with the estimated elasticity of private capital demand in growing

regions, which is ten times larger.

There are several explanations which may explain this difference in the estimated private capital demand elasticities between growing and declining regions. First, the industrial mix of the manufacturing sector may differ in both types of regions. The data capture regions at different points in their production life cycle. Declining regions may be characterized by an industrial mix that is skewed towards older, less technologically advanced industries (e.g., steel) that cannot as readily substitute public for private capital. Also, the mix of public capital outlay may differ in declining and growing regions. In declining regions, local governments may spend relatively more on atmospheric public capital (e.g., police and fire protection, welfare, health, education) and less on public capital that may directly enter the production process (e.g., highways). Firms may be less able to substitute private capital for this factor augmenting public capital. Both of these explanations suggest that it is not surprising to find a lower private capital demand elasticity in declining regions.

The dynamic impact of expected output on the demand for labor and net private investment is once again positive and significant. Yet, the impact is slightly larger in declining regions than in growing regions. This suggests that private capital and labor adjust faster to changes in

expected output in declining regions. The own adjustment coefficients are positive and less than unity in both equations. Again, private capital adjusts more slowly than labor but the speed of adjustment of both inputs is faster than in growing regions (i.e., 0.043 and 0.238 versus 0.022 and 0.119). The signs of the cross-adjustment coefficients ($-c_{ij}$) indicate, unambiguously, that private capital and labor are dynamic complements. This is consistent with the finding in the sample of growing SMSA's.

The estimated, absolute value of the congestion parameter for declining regions is significantly greater than one in both the net private investment and labor demand equations. This is a very peculiar finding in light of the fact that, theoretically, the congestion parameter is bounded by zero and unity. Romer and Rosenthal (1979), though, suggest an explanation for such a finding. They argue that the "estimated coefficient on population confounds economies of consumption (the crowding parameter) with scale economies or diseconomies in the production of publicly provided goods" (p. 152). As the population decreases in declining regions, the total output of public capital (G) decreases due to declining tax revenue. *Ceteris paribus*, this fall in G reduces the amount of public capital available to each firm because of congestion. On the other hand, the reduction in population, *ceteris paribus*, reduces congestion and, hence, increases the amount of public

capital available to each firm. When these two effects are combined, if the fall in G outweighs the fall in population, then the congestion parameter can be expected to be significantly greater than unity. This finding differs sharply from that derived from the sample of growing SMSA's in which the congestion parameter was found not to differ significantly from one.

The estimated, input demand elasticities with respect to input prices and output are also presented in Table 11. In spite of the fact that the dynamic impact of expected output on input demand is greater in declining regions, the average, estimated elasticity with respect to expected output is somewhat less than in the sample of growing SMSA's (+0.732 versus +1.229). Furthermore, short run responsiveness of private capital demand to variations in local tax rates is approximately six times smaller in declining regions than in growing regions (-0.591 versus -3.749). As suggested earlier, this may reflect the fact that the elasticity of substitution between private capital and labor is relatively lower in declining regions. Thus, as local tax rates increase, firms cannot easily substitute labor for the higher priced capital. This results in a relatively less elastic demand for private capital as compared to growing regions. In addition, the cross-elasticity estimates still appear to be confounded by the inability of the proxy for expected output to

econometrically control for basic sector output. That is, a determination of whether or not private capital and labor are short run substitutes or complements in declining regions cannot be made.

In summary, the major findings of the empirical estimation of the short run, net private investment and labor demand equations are as follows:

First, estimation of these equations for an aggregate sample of SMSA's leads to biased estimates of the coefficients. This bias results from the passive imposition of symmetry restrictions when the aggregate sample is used. That is, the impact of an explanatory variable on net private investment and labor demand is assumed to be identical for both growing and declining regions. An F-test reveals that the null hypothesis of symmetry can be rejected for the net private investment equation. Thus, this equation should be estimated separately for growing and declining regions in order to obtain correct inferences with respect to the effect of public capital outlay on net private investment. The labor demand equation was also estimated for the divided sample for comparative purposes.

Second, the dynamic effect of public capital outlay on net private investment and labor demand (i.e., as private capital and labor are adjusting to their desired levels) appears to be quite small in both growing and declining regions. Although public and private capital appear to be

dynamic substitutes, the estimated coefficients do not differ significantly from zero in either sample. On the other hand, public capital and labor exhibit a dynamic, complementary relationship in growing regions and a dynamic, substitutive relationship in declining regions. The coefficient on public capital outlay differs significantly from zero (at the ten percent confidence level), though, only in growing regions.

Third, the short run, input demand elasticities (i.e., holding the output of the basic sector constant) also are not very large. The elasticity of private capital demand with respect to public capital outlay is negative in both samples, but is ten times larger in growing SMSA's (i.e., -0.224 versus -0.023). The elasticity of labor demand with respect to public capital outlay is also not very large, being negative in declining SMSA's and positive in growing regions (i.e., -0.070 versus 0.146).

Hence, these findings indicate that the short run relationship between private and public capital is substitutive. That is, the basic sector appears to be able to substitute private capital for nonexistent or inadequate public infrastructure. Yet, the relative strength of this relationship (as compared to the other estimated, short run elasticities) is not very strong. Furthermore, the strength of this substitutive relationship differs between growing and declining regions. In particular, these findings

suggest that the ability of private industry to substitute private capital for nonexistent or inadequate public capital is much greater in growing regions, with the estimated elasticity of private capital demand being ten times larger in growing regions.

Estimation of the Public Expenditure Equations

The demand equation for total local output (i.e., direct general expenditures) and the budget equation that determines the level of public capital outlay are both estimated using the entire sample of 45 SMSA's. These equations are also estimated separately for declining and growing regions. The passive imposition of symmetry restrictions in the equations estimated for the entire sample may result in biased coefficients. Thus, these equations are estimated using both subsamples in order to allow for asymmetric responses between the two types of regions and to be consistent with the procedure employed in the estimation of the net private investment and labor demand equations.

The equation of primary concern is the budget equation. Estimation of this equation will reveal the impact of private industry on the local government decision making process. The median voter demand equation is also estimated for comparative purposes. That is, these estimates can be compared to those derived in other median voter studies that

have employed different samples.

Public Expenditure Equation Estimates
for the Entire Sample

The estimated public expenditure equations for the full sample of SMSA's are presented in Table 12. Inspection of the direct general expenditure equation reveals that most of the estimated coefficients are consistent, in both sign and magnitude, with those found in previous median voter studies (see Bergstrom and Goodman, 1973; Borcharding and Deacon, 1972; Pommerehnne and Frey, 1976). In particular, the tax share elasticity is less than one, negative, and differs significantly from zero. The income elasticity is also less than one, positive, and differs significantly from zero. Both of these elasticities are consistent with the findings of prior studies, most of which have found the demand for local public goods to be price and income inelastic (see Deacon, 1977).

Several of the taste parameters are also significant and of plausible signs. The positive coefficient on density may indicate that negative externalities associated with greater SMSA density tend to increase public service demands. The negative coefficient on the percent of homes that are owner occupied suggests that homeowners are more sensitive to property taxes and, hence, more likely to vote for lower public expenditures than renters with the same income.

TABLE 12. Public Expenditure Equations
for Full Sample

Independent Variables	Direct General Expenditure		Public Capital Outlay	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	5.756*	0.497	-4.606*	1.240
DGEXP	-----	-----	1.015*	0.023
NINV	-----	-----	1.313**	0.580
PCTEMP	-----	-----	-0.286*	0.065
TAXSHARE	-0.675*	0.025	-----	-----
INCOME	0.719*	0.026	-----	-----
POPULATION	0.352*	0.029	-----	-----
DENSITY	0.030*	0.008	-0.015	0.028
AGE	0.161*	0.073	-0.845*	0.259
%WHITE	-0.081*	0.062	0.456**	0.210
%OWN	-0.463*	0.064	0.771*	0.138
ϕ	1.08			
TREND	0.016*	0.004	-0.062*	0.007
DSOUTH	0.034**	0.014	0.224*	0.062
DWEST	0.003	0.014	-0.156*	0.058
DMIDWEST	0.016	0.012	-0.023	0.049
R ²	0.99		0.44	
F	2,052.60		24.08	
# of obs.	315.00		315.00	

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

The public sector congestion parameter (ϕ) is estimated from $\hat{b}_2/(1+\hat{b}_1)$, where $\hat{b}_2$ and $\hat{b}_1$ are the estimated elasticities of expenditure with respect to SMSA population and tax share, respectively. Although the estimated, absolute value of this congestion parameter is 1.08, application of a t-test to determine if the linear restriction $b_2 = 1+b_1$ is appropriate reveals that this parameter does not differ significantly from unity. Thus, total local public output effectively enters the utility function of the median voter as a pure private good. This finding also agrees with previous median voter studies.

The public expenditure equation of main concern is the budget equation which determines public capital outlay. Estimation of this equation reveals that the response of public capital outlay to changes in the total budget (given by total, direct general expenditures) is positive and unitary elastic. An interesting question raised by this finding is how does this estimated elasticity compare with the elasticities for the various other categories of local expenditure? In other words, as local budgets fall, which expenditure categories suffer the largest cut in budget allocation? The results of an investigation into this issue are presented in Chapter VI.

The estimation of this budget equation reveals several other intriguing relationships. In particular, the coefficient on PCTEMP, the variable entered into the

equation as a proxy for private industry pressure on the budgetary process, is negative and differs significantly from zero at the one percent confidence level. This negative coefficient suggests that business pressure varies inversely with the size of the basic sector. This finding is counterintuitive and may indicate that the ratio of manufacturing employment to total nonfarm employment is an inadequate proxy for industrial concentration. On the other hand, if this proxy is adequately measuring the size of the basic sector, then the negative coefficient may suggest that the larger is the industrial sector, the smaller is the perceived need on the part of existing firms to pressure for higher public investment (i.e., free rider effect). A third interpretation of this finding is that the non-basic sector of the region has a greater demand for local public infrastructure and, thus, exerts more pressure on the budgetary process than does the basic sector. All three of these interpretations are counterintuitive, which suggests that future investigation into this finding is clearly warranted.

It is also interesting to note that the coefficient on median age is negative and differs significantly from zero at the one percent confidence level. This finding is consistent with the theory discussed in Chapter III. The benefits of public capital outlay are not realized until several years after such expenditures are approved. The

median voter of the region will be less likely to approve public capital expenditures if there is a good chance he/she will not be a resident of the region when these benefits are realized. Thus, one would expect that the age of the median voter will have a negative impact on public capital outlay. Although the model presented in this study allows government officials to determine public capital outlay, the median voter can still have an impact on the budgetary decision process because these government officials must answer to the median voter at election time. Thus, it is not surprising that this effect appears in the budget equation. This result accords with the finding of Holcombe and Zarokoochi (1980).

The short run impact (i.e., holding the total local budget constant) of net private investment on public capital outlay is positive with the estimated elasticity being significant at the five percent confidence level. This estimated elasticity is relatively large and indicates that a ten percent increase in the rate of growth of private capital in the basic sector will induce a thirteen percent increase in public capital outlay. This finding suggests that local governments perceive a large industrial sector as being beneficial for the region and, hence, will attempt to provide the necessary public investment in order to retain this industrial base and to attract additional firms to the region.

Public Expenditure Equation Estimates
for Growing SMSA's

The estimated public expenditure equations for the sample of growth SMSA's are presented in Table 13. Inspection of the direct general expenditure equation reveals that the tax share and income elasticities differ significantly from zero and are of the correct signs. The magnitudes of these elasticities, though, are somewhat different from those obtained with the full sample suggesting that the constrained parameter estimates may be somewhat biased. In addition, several of the estimated elasticities on the taste variables differ significantly from zero and have plausible signs. For example, the positive coefficient on median age is consistent with the life cycle hypothesis that expenditures on current consumption rise with age (Bergstrom and Goodman, 1973). According to this theory, an older person will demand a larger quantity of local public goods than a younger person with the same income and tax share.

The absolute value of the estimated congestion parameter is 0.029. The appropriate t-test reveals that this parameter value does not differ significantly from zero. This is a very peculiar finding since it indicates that in growing regions, public capital effectively enters the utility function of the median voter as a pure public good. Most all previous studies have found this congestion

TABLE 13. Public Expenditure Equations
for Sample of Growth SMSA's

Independent Variables	Direct General Expenditure		Public Capital Outlay	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	8.751*	0.668	-4.590*	1.756
DGEXP	-----	-----	1.020*	0.052
NINV	-----	-----	1.545**	0.729
PCTEMP	-----	-----	-0.254*	0.082
TAXSHARE	-0.864*	0.017	-----	-----
INCOME	0.530*	0.041	-----	-----
POPULATION	0.004	0.003	-----	-----
DENSITY	-0.002*	0.011	0.001	0.032
AGE	0.405*	0.108	-1.090*	0.379
%WHITE	0.047*	0.962	0.098	0.344
%OWN	-0.888*	0.137	1.354*	0.433
ϕ		0.029		
TREND	0.029*	0.005	-0.060*	0.010
DSOUTH	0.088**	0.036	-0.003	0.124
DWEST	0.066***	0.037	-0.308*	0.126
DMIDWEST	0.054	0.038	-0.026***	0.122
R ²		0.98		0.87
F		726.09		121.02
# of obs.		175.00		175.00

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

parameter to have a value close to unity for populations of the size employed in this study. This relatively small value appears to be due to the small coefficient on population. As Romer and Rosenthal (1979) suggest, the coefficient on SMSA population may be confounding economies in consumption with economies in the production of local public goods.

The estimated budget equation reveals behavior similar to that found for the full sample. The budget elasticity of public capital outlay is again unity and significant at the one percent confidence level. The coefficients on median age and PCTEMP are also negative and differ significantly from zero. Moreover, the short run impact of net private investment on public capital outlay is again positive. The estimated elasticity indicates that a ten percent increase in the growth rate of private capital will induce almost a sixteen percent rise in public investment. Thus, local governments in growing regions appear to be very responsive to the needs of the basic sector.

Public Expenditure Equation Estimates for Declining SMSA's

The estimated, public expenditure equations for the sample of declining SMSA's are presented in Table 14. In comparing the estimated parameters in Table 13 with those shown in Table 14, it is interesting to note that, with

TABLE 14. Public Expenditure Equations
for Sample of Decline SMSA's

Independent Variables	Direct General Expenditure		Public Capital Outlay	
	Coeff.	S.E.	Coeff.	S.E.
CONSTANT	3.246**	1.457	-1.493	3.220
DGEXP	-----	-----	1.038*	0.033
NINV	-----	-----	-2.929*	1.406
PCTEMP	-----	-----	-0.576*	0.137
TAXSHARE	-0.977*	0.011	-----	-----
INCOME	0.790*	0.050	-----	-----
POPULATION	0.005	0.008	-----	-----
DENSITY	-0.002	0.021	-0.023	0.070
AGE	-0.024	0.330	-1.888**	0.755
%WHITE	-0.133	0.101	0.461	0.385
%OWN	0.110	0.080	0.694*	0.231
ϕ		0.22		
TREND	0.003	0.006	-0.069*	0.012
DSOUTH	0.238*	0.059	0.524**	0.213
DWEST	0.018	0.017	-0.292*	0.087
DMIDWEST	0.015	0.016	-0.004	0.069
R ²		0.99		0.93
F		1,152.00		192.00
# of obs.		140.00		140.00

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

respect to the direct general expenditure equation, six out of the eleven constrained parameter estimates (found in Table 12) lie in the interval between the unconstrained coefficients. Only one of the constrained coefficients has a sign opposite that of the unconstrained parameter estimates (i.e., the coefficient on SMSA density). With respect to the public capital outlay equation, eight out of the eleven constrained coefficients lie in the interval between the unconstrained parameter estimates. These findings suggest that the symmetry restrictions imposed on the equations when they were estimated for the full sample did not seriously bias most of the coefficients, especially in the public capital outlay equation.

The estimated tax share and income elasticities shown in the direct general expenditure equation are again of the correct signs, plausible magnitudes, and differ significantly from zero. Both elasticities, though, are larger than those estimated for the sample of growing SMSA's. This suggests that the median voter in declining regions is more responsive to changes in his/her income and tax share than the median voter in growing regions. The estimated value of the congestion parameter (0.22) again does not differ significantly from zero. As in the sample of growing SMSA's, this can be attributed to the extremely small coefficient on SMSA population.

Inspection of the budget equation reveals that public

capital outlay is again shown to be unitarily responsive to changes in the total, local budget. Moreover, PCTEMP and median age continue to exhibit a strong, negative impact on public investment. The magnitudes of these impacts are larger in declining regions than in growing SMSA's. The short run effect (holding local public output constant) of private net investment on public capital outlay, though, is very different in declining regions. The coefficient on NINV is negative and differs significantly from zero at the one percent confidence level. The estimated coefficient indicates that a ten percent increase in the rate of private capital growth will induce almost a thirty percent decrease in public capital outlay. This finding is not surprising in light of the fact that this sample consists of only declining SMSA's. Apparently, local governments in declining regions respond to increases in net private investment by reducing public capital outlay, presumably spending their limited, and possibly declining, budgets on current consumption categories.

This finding is consistent with the model of the regional economy developed in Chapter III. There appear to be two effects at work. In the long run, additional public investment may induce new firms to enter the region, which will increase employment in the basic sector, raise the total wage bill, and, hence, increase the income of the median voter. Assuming total, local public output is a

normal good, the median voter, in turn, will approve a higher total budget. This will lead to increased expenditure on all spending categories including public infrastructure. A second effect exists, though, which may partially offset the first effect. As firms enter the region, net private investment will also rise. If budgetary officials perceive that this additional private investment is beneficial to the region, they may continue to invest more in public infrastructure in order to retain the existing industry and to attract new firms to the region. On the other hand, local government officials might be simply responding to increases in the local tax base. Growing regions appear to exhibit this behavior. Alternatively, if total available funds are limited (or declining), then local governments may choose to spend less on future consumption categories (e.g., public capital) and more on current consumption categories (e.g., police and fire protection) even in the face of a rising tax base. This appears to be the case in declining regions. The total effect on public capital outlay depends upon the signs and magnitudes of these two effects. In growing regions, both appear to have a positive impact on public investment. In declining regions, though, the second effect is negative and appears to outweigh the positive impact of median income on public investment.

Another interpretation of this negative impact of

private on public investment can be made in light of how the two investment series are defined. As mentioned in Chapter IV, public capital outlay is gross investment which is equal to net investment plus replacement expenditures (due to depreciation). Declining regions may have large private and public capital stocks which have accumulated during more prosperous periods in the region's history. These capital stocks require a large amount of replacement expenditures in order to maintain their current levels. Because of these expenditures, it is possible for net private investment to be negative and gross private investment to be positive. Thus, there may be a positive relationship between gross private and public investment at the same time there is a negative relationship between gross public and net private investment. A similar argument can be made with respect to net public and net private investment. Net public and net private investment can be positively correlated if net public investment is negative but is outweighed by positive replacement expenditures so that gross investment is positive. Unfortunately, only gross public investment was available at the time of this study so the true relationship between net private and public investment cannot be estimated. Assuming that gross and net public investment are positively correlated (as was done in Chapter IV), then in declining regions, net private investment will also have a negative impact on net public investment.

In summary, the major finding of the estimation of the public expenditure equations is that net private investment appears to have a very large impact on public capital outlay. In both subsamples the estimated, short run elasticities differed significantly from zero. A ten percent increase in the rate of growth of private capital in the basic sector will induce a sixteen percent increase in public capital outlay in growing regions and a thirty percent decrease in declining regions.

CHAPTER VI

THE EXISTENCE OF BUDGETARY TRADEOFFS

As was suggested in Chapter V, another interesting issue is the existence of a budgetary tradeoff between investment in public infrastructure and other categories of local government expenditure. In recent years, cutbacks in federal and state aid, the persistent effects of recession, and declining tax bases have severely affected the fiscal position of many local governments. In response to this fiscal distress, local governments may place different priorities on the various categories of public expenditure. Conceivably, as total budgets fall (or do not increase as quickly), local governments may engage in some sort of budgetary tradeoff where allocations for certain activities are increased relative to other public services. In particular, this tradeoff is likely to be intertemporal in nature. That is, relative allocations for current consumption categories such as police and fire protection may be increased while the relative allotment for future consumption items, such as public infrastructure, may be reduced. The relative reduction in capital expenditures in favor of other public services may have serious, long run consequences for regional growth. Such a policy may reduce

one of the incentives for firms to enter the region (i.e., the productivity incentives offered by public capital). Thus, regions that engage in such behavior may be forsaking future regional growth in favor of a relatively larger, and possibly less efficient, public sector.]

Several theoretical arguments can be made that may explain budgetary tradeoffs in the face of declining budgets. The first argument stems from traditional consumer theory. Deacon (1978) provided empirical evidence that supports the view that expenditure decisions in the public sector are analogous to consumer choices in the private sector. Employing a system of public expenditure equations, he was able to show that public sector allocations satisfy several of the postulates of traditional consumer theory (namely, negativity of consumption responses to own price changes and zero degree homogeneity of demands in all prices and income).

If expenditure decisions in the public sector are analogous to consumer choices in the private sector, then it is conceivable that some public services can be classified as "necessities" while others as "luxuries." For example, if these terms as applied rather loosely, then certain services, such as police and fire protection, are necessary for the health and safety of the entire community. On the other hand, public services such as parks and recreation and, to some extent, welfare programs, can be classified as

relative luxuries. Parks and recreational facilities are not as necessary for the well being of the community as are police and fire protection. Welfare services are consumed by only a small portion of a region's population and, thus, may not be perceived as being necessary for the well being of the entire community. Since expenditures on luxury goods are more sensitive to changes in income than expenditures on necessities, traditional consumer theory predicts that as local budgets fall, expenditures on such services as police and fire protection will decline relatively less than expenditures on "luxury" services, such as parks and recreation and welfare.

A second argument that may explain budgetary tradeoffs stems from public choice theory. Assume that the median voter model accurately describes the local political process. Then, whether or not elected government officials remain in office depends upon how well they satisfy the public service demands of the current median voter of the region. As local budgets decline, it is in the interest of government officials to minimize the reduction in outlays on those activities that are immediately perceived by the median voter as affecting his/her utility (e.g., police and fire protection). This minimization occurs at the expense of public services that may not be immediately perceived as having an impact on the median voter's utility (e.g., investment in public infrastructure) and those services that

may not have any impact at all (or very little), such as welfare programs. Hence, this theory predicts that expenditure elasticities (with respect to the total budget) should be relatively large (in absolute value) for such expenditure categories as public capital and welfare programs and relatively small for immediately perceived services such as police and fire protection.

Although the preceding theories support the existence of budgetary tradeoffs, they do not indicate the magnitude of these tradeoffs. Several studies, though, have estimated expenditure elasticities for various categories of public services. The estimates of three of these studies are presented in Table 15. None of these studies estimated an expenditure elasticity for capital outlay and two of the studies (Bergstrom and Goodman (BG), 1973; and Borcharding and Deacon (BD), 1972) used measures of personal income in lieu of the total budget. The only study to use total expenditures (Deacon, 1978) did not find much variance in the estimated expenditure elasticities (the estimated sample variance is 0.01). Yet, the elasticity for fire protection is the lowest which lends some support to the theories discussed above. The estimated sample variances for the BG and BD studies do not differ significantly from each other but both do differ significantly from that of the Deacon study (significance is determined by an F-test for the difference in population variances). Furthermore, the

TABLE 15. Summary of Expenditure Elasticities

Study	Sample	Income	Budget Categories				Sample Variance
			Police	Fire	Parks	Admin.	
Deacon (1978)	Time Series (Seattle)	Total Expend.	1.083	0.849	1.048	1.083	0.013
Bergstrom and Goodman (1973)	Cross-Section (Cities)	Median Income	0.710	-----	1.320	-----	0.186
Borcherding and Deacon (1972)	Cross-Section (Cities)	Avg. Pers. Income	0.815	0.880	2.736	-----	1.190

estimated elasticities for police and fire protection are consistently smaller than the elasticity for parks and recreation. Moreover, the average estimated elasticity for parks and recreation is quite large (2.03). This suggests that this public service may be considered a luxury and will suffer a relatively large reduction in allocation when the total budget declines. The relatively smaller elasticities for police and fire protection, on the other hand, indicate that these public services may be considered as relative necessities.

This same type of analysis can be performed using the sample of SMSA's employed in this study. Such an investigation will determine the response of public capital outlay to changes in the total budget relative to other public expenditures. The analytical framework developed in Chapter IV lends itself easily to an empirical estimation of the various expenditure elasticities. In particular, a budget equation of the type given by (29) can be specified which will allow for the estimation of expenditure elasticities for five major categories of local public expenditure. The expenditure categories that will be examined in this study are public infrastructure (expenditures on existing and new structures and equipment for all categories of public services), police and fire protection (current operating expenditures less capital outlay, i.e., wages and salaries, administration expenses,

etc.), parks and recreation (current operating expenditures less capital outlay), and welfare (current operating expenditures which include disbursed benefits). Analysis of the relative magnitudes of these elasticities will give some indication as to how regions respond to fiscal distress. Following the predictions of the theories discussed above and in light of past empirical analyses, one would expect the expenditure elasticities for police and fire protection to be positive but somewhat less than unity. The estimated elasticities for public capital, welfare, and parks and recreation, on the other hand, should be positive and greater than unity.

Following the model outlined in Chapter IV, assume that the total budget (Z_{it}) is determined by the median voter of the region. The expenditure on any public service category (E_{jt}) is a function, then, of the total budget, a vector of taste variables (F_t) that reflects the tastes and preferences of government officials who set budgetary priorities, and a vector of shift variables (S_t) that captures unspecified changes in the budgetary decision process over time and across regions:

$$(32) \quad E_{jt} = E(Z_{it}, F_t, S_t)$$

where j represents the j th expenditure category ($j=1, \dots, 5$).

Several items should be noted about the relationship given by (32). First, although budget priorities are

determined by local government officials, they still have to answer to the median voter at election time. Thus, the preferences of the median voter are conveyed not only through the approved local budget (which is determined by (26)) but are also partially conveyed through some of the variables included in the vector F_t (e.g., median age, percent owner occupied, and percent nonwhite). Secondly, a general argument can be made that total expenditures cannot be assumed to be an exogenous determinant of expenditure on a specific category of public service (Summers, 1959). Yet, in this model, total expenditures is assumed to be determined by the median voter. The median voter's demand equation for total public output is assumed not to be dependent upon expenditures on any given category of public service except for public capital outlay. Hence, in the estimation of these budget equations, only the equation for public capital outlay will have to be corrected for simultaneity bias. Thirdly, for simplicity, this study will also assume that the functional form of this budgetary relationship is log linear, yielding:

$$(33) \quad \ln E_{jt} = H + m_1 \ln Z_{it} + \sum_{k=2}^7 m_k \ln F_{kt} + \sum_{k=8}^{11} m_k S_{kt}$$

where k indexes the variables used to proxy the taste and shift parameters. As noted in Chapter IV, such a functional form lends itself easily to OLS estimation techniques.

Furthermore, Theil (1971) has shown that this specification minimizes the problem of heteroscedasticity (although heteroscedasticity was found not to be a problem in the sample used in this study).

Equation (33) allows only for variations in the intercept of the expenditure-budget relationship across regions. Conceivably, the slope of this relationship is also not stable and is affected by changes in the taste parameters over time and across regions. Failure to allow for such changes may result in imprecise estimates of the expenditure elasticities. In order to allow for variations in the slope, the total budget can be interacted with the various taste variables. The inclusion of these interaction terms in (33) yields the following equation:

$$\begin{aligned}
 \ln E_{jt} = & H + m_1 \ln Z_{it} + \sum_{k=2}^7 m_k \ln F_{kt} + \sum_{k=8}^{11} m_k S_{kt} \\
 (34) \quad & + \sum_{k=12}^{17} m_k (\ln Z_{it} \cdot \ln F_{kt}) + u_{jt}
 \end{aligned}$$

where u_{jt} is the error term.

Equation (34) is estimated for each of the five major expenditure categories (public capital, police and fire protection, welfare, and parks and recreation) using the same pooled time series-cross section sample of 45 SMSA's during the period 1970 to 1978. Each budget equation is corrected for autocorrelation following the procedure

outlined in Chapter IV. An explanation of how the expenditure elasticities are computed is given in Appendix D with the actual elasticities themselves presented in Table 16.

TABLE 16. Expenditure Elasticities with Respect to the Total Budget

Sample	Budget Categories					Sample Variance
	Public Capital	Welfare	Police	Fire	Parks and Recreation	
Entire	+1.948	+1.208	+0.969	+0.855	+1.094	0.186
Growth	+1.113	-3.393	+1.348	+1.276	+1.611	4.507
Decline	+1.131	+0.432	+0.964	+0.830	+0.978	0.071

Examination of the expenditure elasticities for the full sample of SMSA's reveals that investment in public infrastructure is highly sensitive to changes in the total budget. A one percent decline in the real total budget will elicit almost a two percent decrease in capital outlay. The relative sizes of the other elasticities accord with a priori expectations. Police and fire protection have the lowest elasticities, which are both less than unity. Expenditures on welfare programs and parks and recreation, on the other hand, respond elastically to changes in the total budget, with a one percent decline in the total budget resulting in a 1.2 and 1.1 percent reduction in expenditures on welfare programs and parks and recreation, respectively.

Although the sample variance in these estimated elasticities is quite small (0.19), these findings do suggest that different priorities are placed on the various categories of expenditure. A declining budget is met by reducing expenditures on future consumption items and luxury services relatively more than expenditures on necessary services.

These budget equations are also estimated separately for declining and growing regions. The passive imposition of symmetry restrictions in the equations estimated for the full sample may result in biased coefficients. Thus, these equations were estimated using both subsamples in order to allow for asymmetric responses between the two types of regions and to be consistent with the estimation procedure employed in the previous chapter.

The estimates for the sample of growth SMSA's (also presented in Table 16) tell a different story from that of the full sample. The estimated, welfare expenditure elasticity of -3.4 indicates that local governments in growing regions respond to budget increases by reducing expenditure on welfare programs. This very counterintuitive finding suggests that, in light of all the other estimated elasticities being positive, there may be a problem with the welfare data for the sample of growth SMSA's. This large and negative elasticity results in a relatively large sample variance (4.51) which differs significantly from that of the full sample. If welfare is ignored, the variance in the

estimated elasticities is reduced to 0.04, which does not differ significantly from that of the full sample. In addition, the relative magnitudes of the remaining elasticities are opposite those of the full sample. This suggests that the parameter estimates for the full sample may indeed be biased by the symmetry restrictions. The category that would experience the smallest, relative reduction in allocation, given a decline in the total budget, is public capital. This suggests that local government officials in growth SMSA's may consider public investment as being necessary to future growth of the region.

The estimated elasticities for the sample of declining SMSA's are also presented in Table 16. Comparing the estimates for all three samples reveals that only the restricted estimate for the public capital elasticity lies outside the unconstrained interval. Hence, the symmetry restrictions imposed in the estimation for the full sample appear not to have seriously biased most of the estimates. The sample variance in the estimated elasticities for the sample of declining SMSA's is larger than that for the sample of growth SMSA's (ignoring welfare in the growth sample). Yet, it does not differ significantly from the variances of the other two samples (again ignoring welfare in the growth sample). The most inelastic category of expenditure is welfare (+0.43). This finding is not

surprising. A relatively larger portion of the population consumes welfare services in declining regions. Thus, it will more likely be perceived as a necessary service and one that elected officials will strive to maintain in the face of declining budgets. It also interesting to note the relatively low expenditure elasticity for parks and recreation (+0.98). This is another counterintuitive finding since the theories discussed earlier suggest that this public service is a luxury and, thus, should have an expenditure elasticity greater than unity. Finally, the highest expenditure elasticity is that of public capital. Yet, it is not much larger than unity. These findings do suggest, though, that public capital outlay does suffer a relatively larger reduction in allocation in declining regions (when total budgets decline) than in growing regions. Hence, it appears that local governments in declining regions consider public capital outlay to be a relative luxury while in growing regions it is considered to be a relative necessity.

In summary, the estimated expenditure elasticity for public capital is the same in both growing and declining regions and not much different from unity. The relatively large estimate for this elasticity for the full sample may be biased by symmetry restrictions. Moreover, it is difficult to compare these estimates with those found in other studies because of differences in the samples

employed. Yet, the estimates for the full sample match those found by Deacon (see Table 15) fairly closely, although the sample variance is significantly different from that of the Deacon study. Since the estimate of the public capital elasticity for the full sample appears to be biased by symmetry restrictions, the estimates from the growth and decline samples capture the true relationship between public investment and the total budget. The estimate from the sample of growing regions indicates that public infrastructure does not suffer a relatively larger reduction in allocated funds as local budgets decline. In declining regions, this is not entirely true. Although the estimated elasticity is the same as in growing regions, the variance in the estimated elasticities is larger for the sample of declining SMSA's. These findings suggest that declining regions respond to fiscal distress by forsaking possible, future growth in favor of a relatively larger public sector.

CHAPTER VII

SUMMARY OF MAJOR FINDINGS, CONCLUDING ANALYSIS,
AND SUGGESTIONS FOR FUTURE EMPIRICAL ANALYSIS

The major findings of this study can be summarized as follows:

First, the dynamic impact of public capital outlay on net private investment and labor demand (i.e., as private capital and labor are adjusting to their desired levels) appears to be quite small in both growing and declining regions. Public capital appears to enter into a dynamic, substitutive relationship with private capital in both types of regions. In growing regions the dynamic relationship between public capital and labor is complementary while it is substitutive in declining regions. Yet, public capital outlay does not have a statistically significant impact on private capital in either region but does have a significant impact on the adjustment of labor in growing regions. Thus, for the most part, it appears that private capital and labor are not very responsive to public capital outlay as they are adjusting to their desired levels.

Second, the short run, input demand elasticities (i.e., holding the output of that basic sector constant) are also not very large. The elasticity of private capital demand

with respect to public capital outlay is negative in both types of regions, but is ten times larger in growing SMSA's (i.e., -0.224 versus -0.023). The elasticity of labor demand with respect to public capital outlay is also not very large, being negative in declining regions but positive in growing SMSA's (i.e., -0.070 versus 0.146). Again these estimates indicate that private industry is not very responsive to public capital outlay.

Third, net private investment appears to have a very large and statistically significant impact on public capital outlay in both types of regions. A ten percent increase in the rate of growth of private capital in the basic sector will induce a sixteen percent increase in public capital outlay in growing regions and a thirty percent decrease in declining regions. These findings suggest that local governments in declining regions will respond to additional net private investment by spending their presumably limited funds on current consumption categories of public expenditure. Local governments in growing regions, on the other hand, may not face such severe, budgetary limitations and are able to make an attempt to provide the necessary infrastructure in order to retain the existing industrial base and attract new firms to the region.

Finally, it appears that public infrastructure does not suffer a relatively greater loss of funds than other categories of expenditure as local budgets decline in

growing regions. In declining regions, the estimated, public capital outlay elasticity with respect to the total budget is the same as in growing regions. Yet, the variance in the estimated elasticities is larger suggesting that declining regions respond to fiscal distress by forsaking possible future regional growth in favor of current consumption categories of expenditure.

The major finding of this study, that, an increase in public capital outlay will lead to a reduction in the usage of private capital and labor in order to produce the same level of output, may be put in perspective by speculating on the implication of this finding for the popular contention that declining public investment has an adverse effect upon private industry. At first glance, one may conclude that because private industry appears to be able to substitute private capital and labor for nonexistent or inadequate public capital in the short run, a decrease in public investment does not adversely effect private industry. Yet, a closer examination reveals that this substitution occurs because the decline in public capital reduces the productivity of both private capital and labor, thus requiring more of both inputs to produce the same level of output. This suggests that declining public investment does have an adverse effect on the production process of private industry. 

In order for any relevant policy conclusion to be made,

though, requires that the full impact of declining public investment on private industry be known. This can be discovered only by considering the long run effect of public investment on private industry. Although this study does not examine the effect of public investment on regional output, its findings may shed some light on the long run implications of declining public investment. A decrease in public investment can have both a short run substitutive impact and a long run output effect on the production process of private industry. This study estimated only the short run, substitutive effect. That is, holding the output of the basic sector constant, a decrease in public capital outlay, in general, will induce a increase in the usage of private capital and labor. Now, the increased employment of private capital and labor may increase the total variable cost of producing a given level of output (since the marginal productivity of both private inputs has been reduced). Assuming the production process of the basic sector exhibits constant returns to scale, this increase in variable cost will raise the price of the basic sector's output and lead to a reduction in the quantity demanded by consumers of the region's output (Layard and Walters, 1978). This, of course, assumes that the demand for the basic sector's output is finite elastic; an assumption verified by Engle (1979). Hence, the long run impact of a decline in public capital outlay may be an erosion of the region's

competitive position in the national and international markets. In addition, there may be another long run impact of declining public investment. Deteriorating infrastructure may reduce one of the incentives for new firms to enter the region. Thus, the potential for future regional growth may be decreased.

As mentioned above, the findings of this study lend some support to this theory. In particular, it can be shown that for both types of regions examined in this study, a decrease in public capital outlay will increase the total variable cost of producing a given level of output. A discussion of this finding is presented in Appendix E. Perusal of Appendix E reveals that the total derivative of total variable cost with respect to public capital outlay is dependent upon the short run, input demand elasticities. Thus, the magnitude of the impact of a decline in public capital outlay on total variable cost depends upon the strength of the substitutive relationship between public capital and private factors of production. Moreover, it is possible for public capital outlay to have a negative impact on total variable cost even if one of the short run, input demand elasticities is positive, as is the case for growing regions. Now, whether or not an increase in production costs will be translated into higher output prices and, hence, an erosion of the region's competitive position depends upon the magnitude of the impact of public capital

outlay on total variable cost and the magnitude of the output effect.

Several general conclusions can be made in light of this finding that a decrease in public capital outlay will increase the total variable cost of production. First, given the estimated short run, input demand elasticities found in this study, it is not clear which type of region will experience a larger increase in production costs as public investment declines. In general, the more negative the short run, input demand elasticities are, the greater the impact of a decline in public capital outlay on variable costs and, presumably, the greater the effect on the price of the basic sector's output. These elasticities are generally larger in growing regions than in declining SMSA's. Thus, the long run impact of declining public investment on private industry may be greater in growing regions. Yet, the short run, labor demand elasticity was found to be positive in growing regions. This makes the magnitude of the total derivative of total variable cost with respect to public capital outlay smaller (in absolute value) in growing regions than in declining regions, suggesting that the impact of a decline in public capital outlay on variable cost is greater in declining regions. The first interpretation is more intuitively appealing in light of the relatively more limited substitution possibilities that were found to exist in declining regions

by this and other studies (e.g., Garofalo and Fogarty, 1984a). Also, the exact magnitude of these total derivatives is heavily dependent upon the scale of measurement of the data, the mean values of w and v in each type of region, and the value used to proxy the desired labor stock, L^* . Thus, it seems more prudent to consider only the sign of these total derivatives rather than the estimated magnitudes.

~~A~~ A second conclusion can be made, though, that is relatively more concrete. In light of the relatively small input demand elasticities exhibited by both types of regions, it appears that public capital outlay has very little impact on the short run production decisions of private industry. Nonexistent or inadequate public infrastructure appears not to have a very large effect on the cost of production and, hence, may have only a small impact on the competitive position of the regions in the national and international markets. Hence, the heightened concern expressed in recent years over the impact of decaying infrastructure on private industry may be unfounded. Yet, even this conclusion needs to be qualified. First, decaying infrastructure may have serious implications for regional growth as far as the entry of new firms into the region is concerned. Public capital may be a significant factor affecting firms' migration decisions. A determination of how significant a factor this is, though,

requires an empirical investigation based on a model of the firm's, location decision making process. Second, the measure of public capital outlay used in this study is an aggregate of expenditures on a variety of public capital categories. Thus, the use of a more disaggregated measure (e.g., highways) may result in a finding of larger, input demand elasticities which would suggest that the long run effect of declining public investment may be more serious. These two issues are certainly deserving of future empirical investigation. } *

In summary, the findings of this study do suggest that declining public investment increases the variable cost of production. Yet, the relatively small, short run, input demand elasticities indicate that this effect is not very large. Furthermore, the magnitude of the impact of this rise in production costs on the price of the basic sector's output and, hence, on the region's competitive position in the national and international market is unknown. Although theory predicts that there is an impact, future empirical analysis will have to determine the magnitude of this effect before any relevant policy conclusions can be made about the full impact of declining public investment on regional activity.

Clearly, further analysis of the relationship between public investment and private industry is needed. As seen above, several issues raised by this study can be resolved

left off here

only by future empirical investigation. For example, the positive, labor demand elasticity found for growing regions may be due to specification error. A more flexible functional form for the short run, input demand equations may result in more precise estimates of these short run, input demand elasticities. Also, an investigation into the output effect induced by public investment would indicate how sensitive output prices are to changes in the variable cost of production and, thus, how large is the effect of a decline in public investment on a region's competitive position. In addition, a disaggregation, not only by category of public investment, but also by type of industry may uncover different relationships between public capital outlay and net private investment and labor demand for the various types of manufacturing industries. Furthermore, the very counterintuitive finding that public capital outlay is negatively and significantly explained by a measure of industrial concentration suggests that the influence of private industry on the local budgetary decision process may not be modeled correctly. This also warrants further investigation. Finally, the use of public capital outlay instead of net public investment, although they are highly correlated during the period analyzed by this study, may be confounding the true relationship between public investment and net private investment and labor demand. A regional, public capital stock series, though, will soon be available.

This will allow for a reestimation of these relationships in order to discern how sensitive the estimated elasticities are to the definition of public investment.

In conclusion, the contribution of this study is twofold. First, it develops a slightly different, public intermediate good model with which to analyze the relationship between the public and private sector. Unlike most of the models presented in the public intermediate good literature, the model developed in this study incorporates the effects of a public intermediate good (i.e., public capital) on both the consumer and private industry and makes the income of the consumer explicitly dependent upon the wage income generated by private industry. This model should facilitate future empirical investigations into the relationship between public infrastructure and private industry.

The second contribution made by this study is that it provides one piece of the puzzle concerning the impact of public investment on the production decisions of private industry. Knowledge of how private industry will react to nonexistent or inadequate public infrastructure in the short run is essential to the understanding of the overall impact of public capital on private industry. Subject to the qualifications discussed above, the finding of this study suggests that declining public investment has only a small, short run impact on firms' production decisions. Yet, this

finding by itself is not enough to refute the contention that declining public investment has serious consequences for private industry. This finding must be coupled with the findings of other empirical analyses that investigate different aspects of the relationship between the public and private sector before any relevant policy conclusion can be made as to the true, overall impact of investment in public infrastructure on the production decisions of private industry.

APPENDIX A

CALCULATION OF SHORT RUN INPUT DEMAND ELASTICITIES

Given the desired levels of private capital and labor (K_t^* , L_t^*) defined by (20) and the assumed adjustment process modeled by (21), the short run, input demand elasticities (a_{ij} , $i=1,2$; $j=1,..,4$) can be calculated in the following manner:

First, replacing I_i ($i=1,2$) with K_t and L_t in (21) yields the following equations:

$$\begin{aligned} \ln K_t &= c_{11} \ln K_t^* - c_{11} \ln K_{t-1} + c_{12} \ln L_t^* \\ &\quad - c_{12} \ln L_{t-1} + \ln K_{t-1} \end{aligned}$$

$$\begin{aligned} \ln L_t &= c_{21} \ln K_t^* - c_{21} \ln K_{t-1} + c_{22} \ln L_t^* \\ &\quad - c_{22} \ln L_{t-1} + \ln L_{t-1} \end{aligned}$$

Second, substitution of (20) into these equations and the insertion of G_t/N_t^γ for g_t yields the following input demand equations:

$$\begin{aligned} \ln K_t &= A' + (1-c_{11}) \ln K_{t-1} - c_{12} \ln L_{t-1} \\ &\quad + [a_{11}c_{11} + a_{21}c_{12}] \ln w_t + [a_{12}c_{11} + a_{22}c_{12}] \ln v_t \\ &\quad + [a_{13}c_{11} + a_{23}c_{12}] \ln Q_t + [a_{14}c_{11} + a_{24}c_{12}] \ln G_t \\ &\quad - \gamma [a_{14}c_{11} + a_{24}c_{12}] \ln N_{t-1} \end{aligned}$$

$$\begin{aligned}
\ln L_t = & B' + (1-c_{22})\ln L_{t-1} - c_{21}\ln K_{t-1} \\
& + [a_{11}c_{21} + a_{21}c_{22}]\ln w_t + [a_{12}c_{21} + a_{22}c_{12}]\ln v_t \\
& + [a_{13}c_{21} + a_{23}c_{22}]\ln Q_t + [a_{14}c_{21} + a_{24}c_{22}]\ln G_t \\
& - \delta[a_{14}c_{21} + a_{24}c_{22}]\ln N_t
\end{aligned}$$

Third, the short run, input demand elasticities (a_{ij} 's) can be found by substituting in the estimated values for the c_{ij} 's and solving simultaneously. For example, from the estimation of the net investment and labor equations for the full sample we find that the following:

$$\begin{aligned}
c_{11} &= +.056 & c_{21} &= +.038 \\
c_{12} &= -.028 & c_{22} &= +.104
\end{aligned}$$

The short run, input demand elasticities with respect to the average hourly wage can be found by simultaneously solving the following equations:

$$\begin{aligned}
a_{11}c_{11} + a_{21}c_{12} &= a_{11}(.056) - a_{21}(.028) = +.039 \\
a_{11}c_{21} + a_{21}c_{22} &= a_{11}(.038) + a_{21}(.104) = -.027
\end{aligned}$$

$$a_{11} = .471; \quad a_{21} = -.450$$

APPENDIX B

SOURCES OF DATA AND METHODS OF CONSTRUCTING VARIABLES

The data used in this study are yearly time series, 1970 to 1978, for 45 SMSA's. The major sources of data are: (a) Annual Survey of Manufacturing, U.S. Bureau of Census; (b) Selected Metro Area, Government Finance Series, U.S. Bureau of Census; and (c) State and Metro Area Data Book and the County and City Data Book, U.S. Bureau of Census. Other sources are noted where applicable.

Private Sector Variables

The output series refers to expected real value added by the manufacturing sector of the SMSA. This series was constructed by regressing contemporaneous real value added on real value added lagged one, two, three, and four years. The predicted value for each year was then used as a proxy for expected output. The nominal value added series reported in the Annual Manufacturing Survey was deflated by the producer price index to arrive at real value added.

The employment series and the average hourly wage series, which was constructed by dividing total production wages by total production manhours, are also derived from the Annual Manufacturing Survey. The wage series is

deflated by the implicit GNP deflator.

The capital stock series was made possible by work funded by the NSF to construct a capital stock series, using the perpetual inventory technique, for the manufacturing sector (Eberts and Fogarty, 1984; Garofalo and Fogarty, 1984). Real capital stock was obtained by deflating the nominal series by the producer price index.

The measure of private capital price follows the approach of Jorgenson (Hall and Jorgenson, 1967; Christensen and Jorgenson, 1969, 1970). This approach assumes that the value of an asset is equal to the discounted value of its service flow. The price of private capital was calculated by using the following formula:

$$P_{K,t}^i = \left[\frac{1 - u_t^i Z_t}{1 - u_t^i} (P_{A,t-1} \cdot r_t + P_A \cdot \delta_t^i) \right] + P_{A,t} \cdot T_t^i$$

where $P_{K,t}^i$ = service price of a unit of capital in SMSA i

u_t^i = federal and state rate of corporate profit tax in the state in which the i th SMSA is located. This tax rate was computed using $u_j = (FCT_j + SCT_j)/TY_j$ where FCT_j is the dollar amount of federal corporate income tax collected in state j (Annual Report of the Commission of Internal Revenue); SCT_j is the dollar amount of state corporate tax collected in state j (State Tax Collections, Government Finance Series, U.S. Bureau of Census); and TY_j is total corporate profits of each state. TY_j was calculated by computing the proportion of federal corporate income tax collected in each state, then allocating total U.S. corporate profits according to these proportions. Total U.S. corporate profits are reported in the Economic Report of the President.

- Z_t = present value of depreciation deductions on one dollar's worth of investment, assuming firms use sum-of-the-digits method for computing depreciation. Assuming the average asset life is 15 years, $Z_t = 0.643$.
- $P_{A,t}$ = price deflator for Fixed Non-Residential Investment (1972 = 100)
- r_t = rate of return, taken to be equal to Moody's AAA corporate bond rates (Federal Reserve Bulletin, Board of Governors of the Federal Reserve System).
- δ_t^i = rate of depreciation in the i th SMSA. The depreciation rate was computed using $\delta_t^i = (GINV_t - NINV_t)/K_{t-1}$ where $GINV_t$ is real gross investment (Annual Survey of Manufacturing), $NINV_t$ is net investment (i.e., current period capital stock less last period's capital stock), and K_{t-1} is the lagged value of capital stock.
- T_t^i = effective property tax rate in the i th SMSA. The effective property tax rate was computed using $T_t^i = PTR_t / (GASV_t / RATIO_t)$ where PTR_t is the total property tax revenue collected in the SMSA, $GASV_t$ is the gross assessed value of the SMSA, and $RATIO_t$ is the ratio of assessed value to market value. All data are from the Census of Governments, U.S. Bureau of Census.

The real price of capital was found by deflating $P_{K,t}^i$ by the Producer's Finished Product price index (1972 = 100).

Public Sector Variables

The public expenditure series (i.e., capital outlay and direct general expenditures) are reported yearly in Selected Metro Area, Government Finance Series, U.S. Bureau of Census. The general expenditure series was deflated by the implicit GNP deflator. The public capital outlay series was deflated by a public works investment index (Survey of

Current Business).

Yearly SMSA population estimates are reported in the Current Population Report Series, U.S. Bureau of Census.

The median voter's tax share, τ_{it} , was computed using $\tau_{it} = \text{MHV}_t / \text{PTR}_t$ where MHV_t is the median house value in the SMSA and PTR_t is total property tax revenue. Median house value is consistently reported only every ten years, but some data are available for selected SMSA's in intermediate years (Current Housing Report Series, Annual Housing Survey, U.S. Bureau of Census). In order to complete the series for each SMSA, the following procedure was employed. First, the percent change in median house value between the closest two years for which data exists was computed. Second, the percent change in the median sales price of new single family homes (Construction Reports, Price Index of New One-Family Houses Sold, U.S. Bureau of Census) for those same years and for the region in which the SMSA is located was computed. A scaling factor was then found by dividing these two percentages by each other. This factor was then multiplied by the yearly percentage change in the median sales price in order to approximate the percentage change in median value. This procedure was repeated for each interval of actual census data available on median house value. The implicit assumption behind this procedure is that changes in regional median house values follow the same pattern as changes in the regional median sales price of new homes.

This technique was found to give a better fit to the data than a simple logarithmic function since it picks up regional differences that are smoothed over by a log function.

Disposable median family income was computed using the following formula:

$$Y^D_i = Y(\text{gross})_i + \tau_i(S + F) - t^s_i - t^f_i$$

where $Y(\text{gross})_i$ = census reported, gross median family income. Since gross median income is reported only every ten years, the following procedure was used to estimate the missing data. First, the ratio of median income to per capita income (INCRATIO) was computed for 1970 and 1980. The difference in these ratios was then divided by 10 in order to arrive at an interpolation factor. Gross median income in any given year was then found using

$$Y_t = (\text{INCRATIO}_{70} + t \text{ FACTOR}) \times (\text{Per capita income in } t)$$

Per capita income is defined as the ratio of total personal income in the SMSA (Local Area Personal Income, Bureau of Economic Analysis) to total population.

- τ_i = median voter's tax share
- $S + F$ = total state and federal grants to the SMSA (Selected Metro Area, Government Finance Series, U.S. Bureau of Census).
- t^s_i = median voter's state tax liability. The state tax liability was computed by multiplying the effective state tax rate by gross median family income. The effective state tax rate was calculated as the ratio of total state tax collections for sales and gross receipts, licenses, and individual income to total gross income for the state (State Tax Collections, Government Finance Series, U.S. Bureau of Census).

t_i^f = median voter's federal tax liability.
 The federal tax liability was found in the tax tables contained in Your Federal Income Tax, U.S. Department of Treasury, Internal Revenue Service (three exemptions were assumed).

Disposable median family income was the deflated by the implicit GNP deflator (1972 = 100).

The population density of each SMSA was found by dividing total SMSA population by total land area (State and Metro Area Data Book, U.S. Bureau of Census).

The percent of homes that are owner occupied, median age, and the percent of the population that is white are reported only every ten years (State and Metro Area Data Book and the County and City Data Book, U.S. Bureau of Census). Missing data were estimated for all these variables in the following manner. First, the difference in the 1970 and 1980 values of the variables were found. This difference was then divided by 10 in order to arrive at an interpolation factor. Missing values were then estimated for each year by using $VARIABLE_t = VARIABLE_{t-1} + FACTOR$. The assumption behind this simple interpolation procedure is that regional demographics are slow to change. This is supported by the available data. Between 1970 and 1980, on average, median age changes by no more than two years.

APPENDIX C

CORRECTION PROCEDURE FOR THE R^2 WHEN THE COMPUTER
GENERATED INTERCEPT IS SUPPRESSED

The statistical computer package employed in this study (Statistical Analysis System, or SAS) will yield an artificially large estimate of the R^2 when the computer generated intercept is suppressed. Consider the following simple model:

$$\text{MODEL I: } y = \hat{a} + \hat{b}x + \hat{c}z$$

where $\hat{a}$, $\hat{b}$, and $\hat{c}$ are the estimated values for the intercept and slopes. In order to compute the R^2 , SAS will use the following formula:

$$R^2 = 1 - (\text{SSE}/\text{SST})$$

where SSE = sum of the unexplained squared residuals

= $y - \hat{y}$ where y is the actual value of the dependent variable and $\hat{y}$ is the estimated value

SST = sum of the total squared residuals

= $y - \bar{y}$ where $\bar{y}$ is the mean value of the dependent variable

If the model shown above is estimated with the computer generated intercept suppressed (i.e., $\hat{a}=0$), then SAS will

set the mean value of y equal to zero. This will increase the sum of the total squared residuals (SST) and, hence, increase the R^2 (the SSE is unaffected since it is defined as $y - \hat{y}$). This would occur even if a vector of one's is added to the equation in order to account for the intercept. Consider the following estimated model, with the computer generated intercept again suppressed:

$$\text{MODEL II: } y = \hat{b}x + \hat{c}z$$

where z is a vector of one's. The parameter estimates of model II will be identical to those derived from an estimation of model I in which the computer generated intercept is not suppressed (e.g., $\hat{a} = \hat{c}$). Yet, the R^2 for model II will be much larger because SAS will set the mean value of y equal to zero. SAS will treat the vector of one's as another dependent variable and not as a replacement for the suppressed intercept in the computation of the R^2 .

In this study, the estimated model takes the form of model II due to the correction procedure for autocorrelation (as discussed in Chapter V). A correction can be made for the R^2 through the use of the following estimated model:

$$\text{MODEL III: } y = \hat{c}z$$

where z is a vector of one's. Using the SSE from both model II and III an F-statistic can be computed which will be the "correct" F-statistic for model II. That is, this F-

statistic will reflect only the additional explanatory power attributable to the inclusion of another explanatory variable, x , and will not be biased by the omission of y in the SAS calculation of the F statistic. SAS calculates the F -statistic as the ratio of the SSR to the SSE (adjusted for degrees of freedom) where the SSR is defined as the sum of the explained squared residuals (i.e., $\hat{y} - \bar{y}$). Thus, the SSR will also be biased when y is set equal to zero. The "correct" F -statistic can be calculated according to the following formula:

$$F = \frac{[SSE(III) - SSE(II)]/q}{SSE(II)/(n - k - 1)}$$

where $SSE(II)$ = SSE from the estimation of model II
 $SSE(III)$ = SSE from the estimation of model III
 q = number of restrictions = 1 (i.e., in model III, $b = 0$)
 n = number of observations
 k = number of explanatory variables in model II = 2

This F -statistic can then be used to calculate the "correct" R^2 for model II by using the following formula:

$$R^2 = (F \cdot k) / [F \cdot k + (n - k - 1)]$$

All of the R^2 's in this study have been corrected in this manner.

There is still a problem, though, even with this

"corrected" R^2 . This R^2 will keep on increasing (till it reaches 1.0) as additional explanatory variables are added to the equation. In order to take into account this degrees-of-freedom problem, a new measure of the R^2 can be defined. This "adjusted" R^2 can be calculated according to the following formula:

$$R^2 = 1 - [(n - 1)/(n - k - 1)] (1 - R^2)$$

where R^2 is the "corrected" R^2 calculated above. This adjusted R^2 cannot be increased simply by adding more explanatory variables to the equation. All of the R^2 's reported in this study are adjusted R^2 's.

APPENDIX D

COMPUTATION OF EXPENDITURE ELASTICITIES

If the actual variables used in the estimation of (34) are substituted for F_{1t} and S_{1t} , then the following equation results:

$$\begin{aligned} \ln E_{jt} = & H + m_1 \ln Z_{it} + m_2 \ln NINV_t + m_3 \ln PCTEMP_t + m_4 \ln DEN_t \\ & + m_5 \ln WHITE_t + m_6 \ln AGE_t + m_7 \ln OWN_t + m_8 t \\ & + m_9 DWEST + m_{10} DSOUTH + m_{11} DMIDWEST \\ & + m_{12} (\ln Z_{it} \cdot \ln NINV_t) + m_{13} (\ln Z_{it} \cdot \ln PCTEMP_t) \\ & + m_{14} (\ln Z_{it} \cdot \ln DEN_t) + m_{15} (\ln Z_{it} \cdot \ln WHITE_t) \\ & + m_{16} (\ln Z_{it} \cdot \ln AGE_t) + m_{17} (\ln Z_{it} \cdot \ln OWN_t) \end{aligned}$$

Hence, the expenditure elasticity with respect to the total budget is simply given by the following equation:

$$\frac{\partial \ln E_{jt}}{\partial \ln Z_{it}} = m_1 + m_{12} \ln NINV_t + m_{13} \ln PCTEMP_t + m_{14} \ln DEN_t + m_{15} \ln WHITE_t + m_{16} \ln AGE_t + m_{17} \ln OWN_t$$

The expenditure elasticity with respect to any other independent variable can be found in a similar manner. In the computation of these elasticities, the mean values of the right-hand side variables are used.

APPENDIX E

REGULARITY CONDITIONS

A well behaved production function and its dual cost function must satisfy certain regularity conditions. One of these conditions is that total variable cost should be decreasing with respect to a fixed input such as public capital. Specifically, the total variable cost of producing a given level of output is given by the following equation:

$$TVC = wL^* + vK^*$$

where L^* and K^* are the desired levels of labor and private capital. Since firms are assumed to pay a lump sum tax and not a per unit price for public capital, public infrastructure does not directly enter this variable cost equation (i.e., it only affects fixed costs). But, if the cost function is well behaved, then an increase in public capital supplied to firms should reduce the total variable cost of producing a given level of output through the productivity effects on private capital and labor. Taking the total derivative of this simple, total variable cost function yields:

$$dTVC/dG = w \cdot \partial L^* / \partial G + L^* \cdot \partial w / \partial G + v \cdot \partial K^* / \partial G$$

Note that if the wage rate is assumed to be exogenous, as is the case with the price of capital, the middle term would be reduced to zero.

The sign and magnitude of $dTVC/dG$ can be found for both growing and declining regions by substituting values for the right-hand side terms. In particular, the estimated, short run, input demand elasticities are substituted for $\partial L^*/\partial G$ and $\partial K^*/\partial G$. w and v are replaced by the mean log values of these variables for each sample of regions. Since the desired stock of labor, L^* , is unknown, it is proxied by the average log value of employment in each type of region. Finally, the impact of public capital outlay on the basic sector wage rate can be found by estimating the reduced form wage equation given by equation (13). But, because there are insufficient data with which to form an adequate proxy for Θ , (13) cannot be estimated without severe specification error. Hence, the simple correlation coefficient between the wage rate and public capital outlay is used.

The estimated value of $dTVC/dG$ for growing regions can be computed as follows:

$$\begin{aligned} dTVC/dG &= (1.419)(0.146) + (11.581)(0.003) - (1.762)(0.244) \\ &= -0.1528 \end{aligned}$$

and the estimated value of $dTVC/dG$ for declining regions can be computed in a similar manner:

$$\begin{aligned} dTVC/dG &= (1.505)(-0.070) - (12.211)(0.039) - (1.703)(0.023) \\ &= -0.6207 \end{aligned}$$

Thus, in both growing and declining regions, an increase in public capital outlay will reduce the total variable cost of producing a given level of output.

Another regularity condition that must be satisfied by a well behaved production function and its dual cost function is that marginal cost is positive. That is

$$dTVC/dQ = MC = w \cdot \partial L^* / \partial Q + L^* \cdot \partial w / \partial Q + v \cdot \partial K^* / \partial Q > 0$$

This condition can also be shown to be true for both samples of SMSA's.

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