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PUBLIC INFRASTRUCTURE AND REGIONAL ECONOMIC DEVELOPMENT:..' A SIMULTANEOUS EQUATIONS APPROACH

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I. Introduction

Interest in the effect of public capital on regional economic development has increased in recent years in light of numerous reports of the fragile state of the nation's public infrastructure. Estimates of the shortfall between investment needed to provide "adequate" public infrastructure and available revenues to fund these projects range from $17.4 billion to $71.7 billion annually over the next several years.[1] A major concern about the inability to meet public infrastructure needs is the possible adverse effect on economic growth.

The importance of public capital for regional growth stems from its effect on the production and location decisions of private industry. Following Meade's (1952) classification of public inputs, public capital, such as highways, bridges, sewer systems, and water treatment facilities, can be viewed as inputs in the production process of private industry that contribute independently to output. However, unlike private inputs, which are purchased in a market on a per-unit basis, public capital is provided by the government sector and is financed to a large extent through taxes. Since these tax payments are not necessarily related to the quantity of public capital used by private industry, public capital is essentially an unpaid input. Moreover, assuming that firms have no direct control over how much public capital is supplied to them, public capital is an exogenous input from the firm's perspective.

Even though public capital is exogenous to the firm, its allocation is to a large extent endogenous to the local economy, since the level of public outlays is determined through the political process. Therefore, assuming a

median voter model of local collective decision-making, one can posit a simultaneous relationship between regional income growth and local public infrastructure investment.

Studies have looked at each side of the relationship between regional growth, typically measured by personal income, and public investment, but have not combined the two. The effect of public infrastructure on regional growth has received relatively little attention, primarily because of the lack of reliable measures of local public capital stock. Regional growth studies that have considered the effects of public investment typically use capital expenditures as a proxy for capital stock, instead of estimating capital stock directly.[2] For example, Helms (1985) and Garcia-Mila and McGuire (1987) find a positive and statistically significant relationship between highway capital expenditures and state personal income.

The literature estimating the demand for local public expenditures is much more extensive, tracing back to the seminal work by Borcherding and Deacon (1972). They found, as do more recent studies, large and statistically significant income elasticities for highway and water-sewer expenditures.

The primary purpose of this paper is to estimate the effect of public capital stock on regional income. Our study differs from the few studies that have examined the relationship between measures of public infrastructure and personal income in several ways. First, we construct a model that integrates three dimensions of the relationship between public infrastructure investment and regional income: public infrastructure as an input into the production process, public investment as a construction or "public works" activity, and

the determination of the level of public infrastructure as a consumption good in the median household's utility function.

Second, we attempt to improve the measure of public capital stock by constructing estimates based on the perpetual inventory technique for a sample of metropolitan areas. This approach provides a much better measure of the quantity and quality of local public infrastructure than can be obtained by simply using current capital outlays or adding up a short series of past expenditures.

Third, in order to avoid possible simultaneity bias arising from ordinary least squares (OLS) estimation of the personal income and public investment equations, the relationship between metropolitan personal income and local public investment is estimated using two-stage least squares (2SLS). In addition, the use of 2SLS reduces the possible bias due to measurement errors of various key variables, such as public capital stock estimates.

For a sample of 28 standard metropolitan statistical areas (SMSAs) during the first half of the 1980s, we find that both public investment and public capital stock have a positive and statistically significant effect on per capita personal income. We find that the offsetting effects of simultaneity and errors-in-variables biases cause the OLS and 2SLS estimates to differ significantly for public investment but not for public capital stock.

II. Model

This paper attempts to estimate the effect of public investment, both current outlays and public capital stock, on personal income within

metropolitan areas. However, the linkage between public investment and personal income works in two directions. Public investment influences personal income through its effect on the marginal product of labor. Personal income in part determines the level of public investment, as described by the median voter model. For purposes of our simple model, we assume that the source of personal income is wage and salary disbursement. Under this assumption, public investment can affect personal income through two channels: wages and employment.

Wages

By considering a neoclassical production function, wages can be equated with the value of the marginal product of labor,

$$w_t = p_t f(L_t, K_t, E_t, G_t), \qquad (1)$$

where w_t is the wage level and p_t is the price level. Labor (L), private capital stock (K), energy (E), and public capital stock (G) contribute positively to production. We assume that the rents gained by the firm in the short run through the contribution to output of public capital stock, an unpaid factor, are returned to workers through higher wages (see Negishi, 1973).

Several studies have found that public capital has a significant effect on production decisions at the regional level. Eberts (1986) estimates a production function with public capital stock, private capital stock, and

labor as inputs for manufacturing within 38 metropolitan areas. He finds that the marginal product of public capital is positive and statistically significant. Deno (1988), estimating a profit function, also finds a positive relationship between public capital and manufacturing output.

The effect of public capital stock on wages may be mitigated to some extent if either of two cases occurs. First, if labor and public capital are substitutes and labor supply is upward sloping, then an increase in public capital stock could decrease wages.' Second, some rents may accrue to factors other than labor, such as capital or entrepreneurship. However, wages could still be positively affected by an increase in public capital in the long run. If rents accrue to capital or entrepreneurship, then the higher returns due to the unpaid public capital input would attract additional firms into the area, increasing the demand for both labor and private capital. Additional firms move into the region until the rents are dissipated and capital earns a competitive rate of return.[4]

Employment

Local labor market employment is determined by equating labor supply with demand, assuming the labor market clears each period. We also take the long-run view that private capital and energy consumption vary. Consequently, we enter the prices of these factors, rather than the levels, into the wage equation (equation [1]):

$$w_t = p_t f(r_t, e_t, G_t), \qquad (1')$$

where r_t is the private capital price and e_t is the energy price. Public capital stock is considered to be quasi-fixed. The determination of the level of public investment will be considered in the following section.

Rearranging equation (1) yields the demand for labor (n^d_t):

$$n^d_t = n^d(w_t, p_t, r_t, e_t, G_t, \theta), \qquad (2)$$

where θ denotes technical production parameters.

The local labor supply depends on the real net wage (w/p) and the size of the local population (S). Higher wages, resulting from a larger-than-average public capital stock, may attract additional workers into the local labor market, until the rents accrued from the public capital stock are dissipated and the wages return to some equilibrium level across regions. Public capital stock also enters the labor supply function through the household's utility function. Although the labor market clears at the current wage, unemployment (U) may exist due to frictional aspects of the job-search process and intertemporal labor supply substitution. We therefore add the unemployment rate (U_t) to the labor supply equation (n^S_t):

$$n^S_t = n^S(w_t, p_t, S_t, U_t, \tau), \qquad (3)$$

where τ represents household preferences.

Equating the real wages in the demand and supply equations yields the long-run market-clearing employment level (n^*_t):

$$n^*_t = n(r_t, e_t, S_t, U_t, G_t, \tau, \theta). \qquad (4)$$

Combining the wage (equation [1']) and employment (equation [4]) equations yields a real personal income equation:

$$Y_t = Y(r_t, e_t, S_t, U_t, G_t, \tau, \theta), \qquad (5)$$

which is expressed in per capita terms to be consistent with the median voter model.[5]

Determination of Public Investment

Determination of the level of public investment follows the conventional median-voter model with the additional feature that public goods enter not only the utility function as a consumption good, but also the production function as an unpaid input. Consequently, public capital affects the household directly through the utility function and indirectly through its effect on the household's income.

Consider a representative consumer who lives and works in an urban labor market and who derives utility from consuming a private consumption good, X, and public capital stock, G. We consider public capital stock to be a rival good, in the sense that local public services, such as transportation and

highways, and water treatment and distribution systems, are subject to congestion. Therefore, we express public capital in per capita terms, under the assumption that individual household utility and firm production depend on the amount of public capital services each receives.[6]

In each time period t, an individual chooses the consumption good (X) and the per capita public capital stock (G/S) by maximizing utility subject to a budget constraint:

$$\max U(X_t, G/S_t) \quad \text{s.t. } Y_t = p_t X_t + \sigma Y_t, \tag{6}$$

where Y_t is the individual's income, σ is the local tax rate, and p_t is the price of X. Public capital stock, G_t, is supplied by a single local government, which encompasses each metropolitan area. Although total public capital stock affects production and utility, only a portion of it is allocated each year. Therefore, the decision variable of the median voter is gross public investment. The amount of capital stock present in year t depends on the gross investment in year t (g_t), the amount of capital stock in the previous year (G_{t-1}), and the rate of depreciation and discard (6) of the capital stock:

$$G_t = g_t + (1-\delta)G_{t-1}. \tag{7}$$

Substituting equation (7) for G_t in the utility function in equation (6), recognizing that public investment is funded by taxing a portion of the

household's income ($\sigma Y_t - g_t$), and then solving the median voter's maximization problem yields the demand for gross public investment:7

$$g^*_t = g(Y_t, S_t, p_t, \sigma, \tau), \tag{8}$$

where τ denotes household tastes.

Collecting the real personal income equation (equation [5]), the public investment equation (equation [8]) and the investment relationship (equation [7]) yields the following system of equations:

$$Y_t = Y(r_t, e_t, S_t, U_t, G_t, \tau, \Theta), \tag{5}$$

$$G_t = g_t + (1-\delta)G_{t-1}, \tag{7}$$

$$g_t = g(Y_t, S_t, p_t, \sigma, \tau) \tag{8}$$

Thus, from these equations, one can recognize the simultaneous relationship between public capital and personal income.

Estimating Equations

As stated earlier, the primary purpose of this study is to estimate the effect of public capital stock on regional income. Substituting equation (7)

into equation (5) and linearizing both functions yields the following two equations, which are estimated simultaneously:

$$Y_t = a_o + a_1 g_t + a_2 G_{t-1} + a_3 Z_{1t} + e^{y}_t \ , \qquad (9)$$

$$g_t = b_o + b_1 Y_t + b_2 Z_{2t} + e^{g}_t \ , \qquad (10)$$

where Z_{1t} and Z_{2t} are vectors of exogenous variables described in the next section.

Previous studies have estimated the effect of public capital on personal income using single-equation OLS estimation. It is obvious from equations (9) and (10) that OLS estimates may be biased upward if the effect of income on public capital stock investment (b_1) is significant and positive. On the other hand, measurement error in public capital stock estimates could bias the estimates downward.[8] Therefore, the net direction of the bias is ambiguous and depends on the relative magnitudes of the two biases.

Since both public capital expenditures and public capital stock appear in equation (9), this framework also allows us to compare the separate effects of expenditures and stock on personal income. Expenditures affect personal income as construction dollars are spent in the local economy (a_1). Capital stock affects personal income as an input in the production process, which enhances the marginal product of labor (a_2).

III. Data

Equations (9) and (10) are estimated using annual data from 28 SMSAs for the years 1980 through 1984. The sample of SMSAs is constrained primarily by the availability of public capital stock estimates. The time span includes both an economic recession and an expansion. A list of the SMSAs used in this study is presented in appendix A, and a summary of data sources is provided in appendix B.

Personal Income Eauation

Personal income for each SMSA was obtained from the Bureau of Economic Analysis and measured in per capita terms. The income series is deflated using the national Consumer Price Index (CPI). Time dummy variables are also included in the equation, since nationwide price shocks may occur to real personal income that are not fully reflected in the CPI. Prices also vary among regions. Although CPIs are available for selected SMSAs, they are not available for all of the metropolitan areas for which public capital stock estimates are available. Using the available CPIs would reduce the sample to a prohibitively small number of observations. Instead, we entered into the personal income equation the median house value for each of the 28 metropolitan areas. Since most of the regional variation in prices comes from housing costs, we considered it to be a reasonable measure of regional price differences.[9]

Public capital stock (G_t), expressed in per capita terms, is defined as the dollar value of the total stock of public capital in the SMSA. Public

capital includes: (a) sanitary and storm sewers and sewage disposal facilities, (b) roadways, sidewalks, bridges and tunnels, (c) water supply and distribution systems, (d) public hospitals, and (e) public service enterprises such as airports and ports. These estimates are constructed using the perpetual inventory method, which adjusts accumulated gross investment for retirement and depreciation. This method is based on the assumption that capital stock at any given time is a function of past investments in public structures and equipment. Over time, vintages of capital lose efficiency, and a portion are discarded each year.[10] The annual capital outlay series, used to estimate stock and to measure gross investment (g_t), was obtained from the Government Finance Series compiled by the Census Bureau.

The remaining variables in the personal income equation fall within two categories. The first group contains variables related to the production process. Firms use various types of energy in the production process (e.g., electricity, natural gas). Following Carlton (1983), we use the price of electricity for the 300 KWH to 120,000 KWH industrial classification as a proxy for energy costs. In particular, we use the rate in the highest continuously listed rate schedule of the largest city in the SMSA, as listed in the rate schedules found in Typical Electric Bills.[11]

The remaining independent variables include factors that may affect the private sector demand for and/or supply of labor. Many factors affect both firms and households, which makes a priori interpretations of the signs of the coefficients difficult. Several measures of business climate are used. Presumably, firms will be less attracted to SMSAs located in states with a

relatively high percentage of union members (UNION), because of a perception by managers of less flexibility in personnel matters and higher associated labor costs. Thus, regions with high union representation may have lower personal income because of the negative effect of unions on labor demand. On the other hand, the wage component of personal income may be higher in highly unionized regions because of the union-wage premium.

Another business-climate factor is the Right-To-Work Law (RTW), which may provide potential entrants with information on the business climate of the region and on future wage levels while reducing the probability of union involvement. Thus, firms may be attracted to SMSAs that are located in states with right-to-work laws. This variable may also affect the migration decisions of workers, but in a direction that reinforces the effect on labor demand. Newman (1983) finds that UNION and RTW have a statistically significant effect on the growth of state manufacturing employment. The growth rate is higher in states with right-to-work laws and lower in states with a high percentage of unionized workers.

High tax rates may deter firms and households from entering a region, given equal levels and quality of public services. Taxes are measured as the metropolitan area's tax liability (STAX) of the median-income family. STAX is the ratio of state tax revenue to tax capacity as derived by the Advisory Commission on Intergovernmental Relations (ACIR). Since personal and firm tax liabilities are likely to be highly correlated, STAX may also capture the effect of the overall tax structure.

Firms' location decisions may also be influenced by the availability of labor. The population of the SMSA is used to measure the size of the labor pool. The SMSA unemployment rate measures the tightness of the labor force (UNEMP). Wages and thus personal income may also be higher in regions with higher-than-average concentration of manufacturing employment, since manufacturing wages are typically higher than wages in other sectors. The percentage of manufacturing workers (RMFG) accounts for this effect. Also, human capital has a large influence on wages and thus personal income. A variable measuring the average years of education of workers in each SMSA is included to reflect the level of human capital.

Workers and firms may find regions with favorable climates more attractive and migrate there. The average number of days with temperatures below freezing (FRZDAY) and above 90 degrees (T90DAY) per year are used to measure climatic effects on firm location. However, the sign of the coefficient is ambiguous since demand and supply effects are commingled.

Finally, three regional dummy variables are included to account for any unspecified regional factors that may affect per capita personal income (SOUTH, WEST, and MIDWEST); the Northeastern region is omitted.

Public Investment Equation

The dependent variable for equation (10) is real public gross investment per capita estimated for each SMSA. The explanatory variable of primary

interest is real personal income per capita (LYPN). Intergovernmental revenue per capita is also included to account for the income effect of state and federal revenue to local governments (LFINT). The median income family's tax liability (LSTAX) is included to measure local tax effort. Since property taxes constitute a large source of local government revenue, property tax rates (PROPRATE) are also entered into the public investment equation.

The remaining explanatory variables reflect differences in the preferences of median voters among SMSAs. These variables include median house value (LMEDVAL), percentage of owner-occupied housing (OWNOC), and percentage of the population below the poverty level (POVERTY). Median house value is included to capture variations in metropolitan price levels. Regional dummy variables and time dummy variables are also included.

IV. Estimation

Each equation is estimated using pooled data for 28 SMSAs from 1980 through 1984. Following Plaut and Pluta (1983), all coefficients except the intercept are constrained to be equal over the time period. The variables are entered in log-log form, except when the variables are expressed as percentages.[12] OLS and 2SLS estimates of the personal income and public investment equations are shown in table 1.

Personal Income Eauation

Results in table 1 show that both public investment and public capital stock have positive and statistically significant effects on real per capita

personal income. Hausman's (1978) test of significance shows that the OLS and 2SLS estimates are not statistically different for public capital stock but they are for public investment.[13] Consequently, the OLS bias and the errors-in-variable bias are either each negligible or they are offsetting in the former case.

The coefficients of public investment and public capital stock reveal two separate effects of public infrastructure on personal income. The effect of public investment on personal income results primarily from the construction of public capital stock, either replacement or net additions. Public investment increases personal income by increasing employment and wages in the construction industry. The coefficient may also account for the multiplier effect throughout other sectors of the local economy, if the response is quick enough to occur within a year. A 10 percent increase in public outlays increases personal income per capita by 0.37 percent using OLS estimates and 1.1 percent using 2SLS. The coefficient on public investment lagged one year was insignificant (not shown), suggesting that most construction projects last less than a year and the multiplier effect dampens very quickly.

The public capital stock coefficient reflects the effect of public investment as a production input and as a household's consumption good, since the "public works" aspect of public investment appears to last less than a year and the public capital stock variable is lagged one period. A 10 percent increase in public capital stock is associated with a 0.94 percent increase in per capita personal income using OLS and a 0.81 percent increase using 2SLS. The OLS point estimates, which can be read as elasticities, suggest that the

effect of public capital as an input has nearly twice the effect on personal income as does public capital as a construction activity. When 2SLS is used, the effect of public capital stock on personal income is much smaller relative to the effect of gross investment. However, one can conclude that the contribution of public capital stock to economic growth clearly outlasts its initial construction phase.

The remaining variables, which were statistically significant at the 95 percent level using either OLS or 2SLS, have the expected signs. High tax liability is associated with low per capita personal income, presumably due to its deterrent effect on firm entry, which lowers labor demand. Areas with high unemployment rates, indicating a slack labor market, have low per capita personal income, primarily through the depressing effect on wages. The population of the metropolitan area is positively correlated with real per capita personal income. One explanation of this relationship could be the beneficial effects of agglomeration economies on firm location. The proportion of manufacturing employment in a metropolitan area is also positively correlated with per capita personal income, presumably due to wage premiums enjoyed by manufacturing workers over comparable workers in other industries. Education also positively affects earnings, as evidenced by the positive coefficient on average years of education.

Public Investment Equation

Although this equation is included only to control for possible simultaneity between per capita income and public investment, some of the

results are interesting to highlight. For instance, as shown in table 2, per capita real personal income has a positive and statistically significant contemporaneous effect on local public investment. The income elasticity estimate differs considerably depending on the estimation technique. Using OLS, the estimate is close to unity; using 2SLS, the estimate is close to 2. The second elasticity estimate is still consistent with results found by Borcherding and Deacon (1972) for some forms of infrastructure. We also find that federal and state grants have a positive effect on public investment The 2SLS estimates reveal that a 10 percent increase in intergovernmental revenues per capita raises public investment expenditures by 0.25 percent. The OLS estimate is virtually identical. Both OLS and 2SLS estimates are statistically significant at the 10 percent level.

The other variables are included to account for differences in preferences across metropolitan areas. For instance, areas with higher-than-average poverty rates spend a lower-than-average amount on public investment, presumably using their tax dollars to fund social programs instead of economic development. The negative relationship between the percentage of owner-occupied housing and public investment may also reflect preferences for other local government programs. However, one can only speculate on the tradeoff within the local government budget, without expanding the system of equations to include other government expenditures.

V. Summary and Concluding Remarks

The purpose of this study is to estimate the effect of public infrastructure on regional economic development, as measured by per capita personal income. The paper makes two contributions. First, we use public capital stock estimates instead of simply using expenditures. Second, we construct a simple model of both the effects of local public infrastructure on personal income and the effect of personal income on the allocation of local public outlays. The resulting system of equations highlights the potential single-equation estimation bias if public investment is considered exogenous, as is the case with other studies.

Results derived from annual data for 28 metropolitan areas from 1980 through 1984 reveal that public capital stock has positive and statistically significant effects on per capita personal income. The effects come through two channels. The first is through the actual construction of the public capital stock. The second effect comes through public capital stock as an unpaid factor in the production process and a consumption good of households. This second effect is twice as large as the first effect using OLS, but the relative magnitudes of the two effects are roughly reversed using 2SLS. Although single-equation estimation bias is a potential problem when estimating the effect of public capital stock on personal income, it is not possible to determine the magnitude of the problem because of the potential errors-in-variables bias.

Recent studies have concluded that the nation's public infrastructure is in serious disrepair. These findings take on added importance when considered

together with the findings of this study. Decaying public capital appears to be one factor that can retard regional economic development, as measured by per capita personal income. Our results show that the positive effect of public capital on a region's economy comes from more than simply a surge in construction activity. Public capital stock is shown to be an important input into the regional production process, which has long-run consequences for enhancing a region's productivity, and thus its competitive advantage. Therefore, well-maintained public infrastructure should be an important component of any policy package designed to promote regional economic development.

FOOTNOTES

1. The study by the Associated General Contractors of America estimates the largest gap, while the Congressional Budget Office comes in with the lowest estimate.

2. One notable exception is the series of studies done by Mera (1975) considering the effect of public infrastructure on regional development in both the United States and Japan. Mera develops a capital stock measure for the nine census regions and four prefectures in Japan. In the U.S. study, Mera concentrated primarily on the effect of infrastructure on manufacturing. Costa, Ellson, and Martin (1987) also construct capital stock measures for states and use these to examine effects on manufacturing.

3. Estimates of the relationship between public capital stock and labor depend on whether or not output is held constant. Eberts (1986), estimating a production function, and Dalenberg (1987), estimating a cost function, find public capital and labor to be weak conditional substitutes. On the other hand, Deno (1988), estimating a profit function, finds public capital stock and labor to be unconditional complements. Costa, Ellson, and Martin (1987) construct estimates of public capital stock for the state level. Using a three-input translog production function, they find that public capital and labor are conditional complements.

4. Eberts (1989) shows that local public capital stock has a positive and significant effect on the openings of firms in metropolitan areas. Other studies, including Charney (1983) and Bartik (1985), which use public outlays rather than public capital stock, find similar results.

5. For convenience, we assume that the income distribution is such that median income equals mean income.

6. One could also follow the approach used by Borcherding and Deacon (1972) to specify and estimate a congestion parameter, such that $G'=G/N^a$. Estimating the congestion parameter, a, would be an interesting extension. However, we feel that the assumption that a=l will not alter the main thrust of the paper.

7. By reformulating the maximization problem in terms of output, one can derive the standard result that the sum of the marginal rates of substitution equals the marginal rate of transformation, but in this case the latter is adjusted for public capital stock's contribution to output. Pestieau (1976) provides the optimality conditions within an median voter framework for allocating public inputs, when public goods enter the production function but not the utility function. Furthermore, as shown by Atkinson and Stiglitz (1980), the condition for the existence of an interior solution when the

number of workers varies depends upon the elasticities of consumption and production. We assume that the elasticities are appropriate to achieve an interior solution.

8. At least two possible sources of errors in variables are pertinent. First, the capital stock estimates may not include all the public capital stock in place in each SMSA. .We tried to include public outlays from all levels of government that were spent in the SMSA. Nonetheless, some sources could have been missed. Second, our assumptions about depreciation and discard rates could introduce some bias.

9. It could be argued that house values are also endogenous, since movement of firms into the area in order to capture the rents from the public capital stock could bid up land prices. We abstract from this possibility at this time.

10. Faucett (1977) discusses the perpetual inventory method in detail. Construction of the public capital stock estimates is discussed by Eberts, Dalenberg, and Park (1986).

11. Property tax rates were also included in the equation to capture their effect on the price of private capital. However, the estimates were statistically insignificant and omitted from the equation so they might be used in the public investment equation to help identify the personal income equation.

12. The log-log form appears to fit the data better than other functional forms. Moreover, this functional form reduces the likelihood of heteroscedasticity (Theil, 1971). The procedure described in Kmenta (1986) was used to correct for possible heteroscedasticity and autocorrelation. Estimates using this procedure were very similar to the estimates using OLS. Unfortunately, a similar correction procedure is not available for 2SLS, so the reported estimates do not correct for heteroscedasticity and autocorrelation. We used Hausman and Taylor's (1981) methodology to test whether the system of equations is properly identified. We found that the exogenous variables excluded from the personal income equation and entered in the public investment equation were not correlated with the 2SLS residuals of the personal income equation, which satisfied their test.

13. Hausman (1978) shows that if $(\beta_{2SLS}-\beta_{OLS})(\sigma^2_{2SLS}-\sigma^2_{OLS})^{-1}(\beta_{2SLS}-\beta_{OLS})$ is greater than chi-square with one degree of freedom, then one can reject the hypothesis of no statistically significant specification bias. For public investment, the test statistic is 7.46, which is greater than the 95 percent chi-square value of 3.84. For public capital stock, the test statistic is 1.17, which is less than 3.84. Thus, we can reject the null hypothesis of no significant bias for the public investment estimate, but we cannot reject the hypothesis of no bias for public capital stock.

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Table 1: OLS and 2SLS Estimates of Personal Income Equation

Variables		MEAN	OLS	2SLS
LCAPINV:	log(public investment per capita).	4.06	.037* (.019)	.113* (.034)
LCAPTOT:	log(public capital stock per capita; lagged)	7.63	.094* (.029)	.081* (.031)
RMFG:	ratio of manufacturing to total employment	.21	.480* (.118)	.508* (.126)
UNION:	percentage of workers unionized	.22	.190 (.179)	.170 (.190)
LPE:	log(electricity price)	7.51	.003 (.016)	.010 (.018)
LSTAX:	log(state tax liability)	4.62	-.277* (.042)	-.274* (.044)
LFRZDAY:	log(number of freezing days)	3.96	.017* (.008)	.008 (.009)
LT90DAY:	log(number of above 90 degree days)	2.59	-.013 (.012)	-.003 (.013)
UNEMP:	unemployment rate	8.14	-.009* (.004)	-.003 (.004)
LSMSAPOP:	log(SMSA population)	7.63	.044* (.009)	.033* (.011)
LMEANED:	log(average years of education)	2.56	1.026* (.338)	.953* (.360)
LMEDVAL:	log(median house value)	10.92	.255* (.032)	.256* (.034)
RTW:	-1 if right-to-work state	.19	-.021 (.026)	-.034 (.028)
SOUTH:	-1 if SMSA in South	.21	-.017 (.030)	-.051 (.034)
WEST:	-1 if SMSA in West	.25	-.099* (.025)	-.123* (.027)

MIDWEST:	-1 if **SMSA** in Midwest	**.36**	**-.089***	**-.099***
			(.017)	(.019)
Y81:	-1 if year-1981	**.20**	-.001	-.005
			(.013)	(.014)
Y82:	-1 if **year=1982**	.20	.009	-.005
			(.018)	(.020)
Y83:	-1 if year-1983	.20	.034	.029
			(.020)	(.021)
Y84:	-1 if **year=1984**	.20	.049*	.060*
			(.018)	(.020)
Intercept			3.01*	-3.05*
			(.805)	(.855)
Adjusted R^2			.82	.81

Note: Dependent variable is the log of real per capita personal income, deflated by CPI. Standard errors are in parentheses. Asterisk (*) denotes statistical significance at the 95 percent confidence level. The omitted regional dummy variable is the Northeast, and the omitted time variable is 1980. See text for data sources.

Table 2: OLS and 2SLS Estimates of the Public Investment Equation

Variables		MEAN	OLS	2SLS
LYPN:	log(real per capita personal income)	2.40	1.197* (.300)	1.976* (.387)
LFINT:	log(intergovernmental revenue)	6.24	.236 (.128)	.248 (.131)
LMEDVAL:	log(median house value)	10.92	-.727* (.157)	-.962* (.176)
PROPRATE:	property tax rate	3.45	.007 (.005)	.008 (.006)
LSTAX:	log(state tax liability)	4.62	.084 (.169)	.131 (.174)
OWNOC:	percentage owner occupied housing	60.92	-.029* (.004)	-.027* (.004)
POVERTY:	percentage below poverty	8.34	-.117* (.015)	-.099* (.017)
SOUTH:	=1 if SMSA in South	.21	.643* (.085)	.687* (.088)
WEST:	-1 if SMSA in West	.25	.301* (.090)	.407* (.097)
MIDWEST:	=1 if SMSA in Midwest	.36	.125 (.071)	.205* (.077)
Y81:	=1 if year=1981	20	-.016 (.054)	-.015 (.056)
Y82:	=1 if year=1982	20	-.027 (.055)	-.018 (.056)
Y83:	=1 if year=1983	.20	-.172* (.055)	-.179* (.057)
Y84:	=1 if year=1984	.20	-.276* (.058)	-.313* (.060)

intercept	9.81*	9.87*
	(1.62)	(1.66)
Adjusted R^2	.59	.59

Note: Dependent variable is the log of real gross public investment per capita. Standard errors are in parentheses. Asterisk (*) denotes statistical significance at the 95 percent confidence level. The omitted regional dummy variable is the Northeast, and the omitted time variable is 1980. See text for data sources.

APPENDIX A: List of SMSAs

EAST REGION

Buffalo, NY
New York, NY
Newark, NJ
Philadelphia, PA
Pittsburgh, PA

SOUTH REGION

Atlanta, GA
Birmingham, AL
Baltimore, MD
Dallas, TX
Houston, TX
New Orleans, LA

MIDWEST REGION

Akron, OH
Chicago. IL
Cincinnati, OH
Columbus, OH
Cleveland, OH
Detroit, MI
Indianapolis, IN
Kansas City, MO
Milwaukee, WI
Minneapolis, MN

WEST REGION

Denver, CO
Los Angeles, CA
Portland, OR
San Diego, CA
San Francisco, CA
Seattle, WA

APPENDIX B: Variable Sources

LYPN: LOG(PER CAPITA PERSONAL INCOME), U.S. Department of Commerce, Bureau of Economic Analysis, "Survey of Current Business," advance tables and unpublished material.

LFINT: LOG(REAL INTERGOVERNEMTAL REVENUE), U.S. Department of Commerce, Bureau of Census, Survey of Government Finance and Census of Government Finance, books and tape files.

LMEDVAL: LOG(MEDIAN HOUSE VALUE), U.S. Department of Commerce, Bureau of the Census, County and City Data Book, various years.

LSTAX: LOG(STATE TAX LIABILITY), Tax revenue divided by tax capacity, Advisory Commission on Intergovernmental Relations, Measuring State Fiscal Capacity, 1987.

OWNOC: PERCENT OWNER OCCUPIED HOUSING, U.S. Department of Commerce, Bureau of the Census, County and Citv Data Book, various years.

LMEANED: LOG(AVERAGE EDUCATIONAL ATTAINMENT), U.S. Department of Commerce, Bureau of the Census, Current Population Survey tapes

LCAPINV: LOG(PUBLIC REAL GROSS INVESTMENT PER CAPITA), Unpublished data series derived from U.S. Department of Commerce, Bureau of the Census, Current Population Reports, various years.

LCAPTOT: LOG(PUBLIC CAPITAL STOCK PER CAPITA; LAGGED), Unpublished data series, see text.

RMFG: RATIO OF MANUFACTURING TO TOTAL EMPLOYMENT, U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings.

UNION: PERCENT OF WORKERS UNIONIZED, U.S. Department of Commerce, Bureau of the Census, Current Population Survey tapes.

LPE: LOG(ELECTRICITY PRICES), U.S. Department of Energy, Typical Electric Bills.

UNEMP: UNEMPLOYMENT RATE, U.S. Department of Commerce, Bureau of Labor Statistics, COSTAT and Local Area Unemployment Statistics tapes.

LTFRZDAY and LT90DAY, average number of days with below freezing temperatures and with temperatures above 90 degrees, Boyer, Richard and David Savageau, Places Rated Almanac, Rand McNally, 1985.

RTW: RIGHT-TO-WORK STATE (=1), U.S. Department of Commerce, Bureau of the Census, Statistical Abstract, various years.

POVERTY Percentage of population below the poverty level, 1980, Bureau of the Census

LSMSAPOP: Log(SMSA POPULATION), Bureau of the Census, various years.

PROPRATE: Property tax rate, computed by dividing total property tax revenue by true assessed value (assessed value times the assessment rate), Census of Governments, 1982.