IS ALL PUBLIC CAPITAL CREATED EQUAL?

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Abstract—This paper uses a VAR approach to investigate the effects of public investment on private-sector performance in the United States. This approach is consistent with the argument that the analysis of these effects requires the consideration of dynamic feedbacks among the different variables. Estimation results suggest that all types of public investment have a positive effect on private output. Core infrastructure investment in electric and gas facilities, transit systems, and airfields, as well as in sewage and water supply systems display the highest rates of return, 16.1%.

The third equation is a quasi-differenced \( Q \) equation:

\[
- \Delta (Q_{t-1}) + \Delta (\gamma (Y/X, K)) (y_{t-1}, K)) + \eta (\gamma) (y_{t-1}, K)) = \epsilon^{Q}_{t-1},
\]

where \( Q_{t-1} \) is the difference between the financial value of the firm and the replacement value of capital at the end of period \( t - 1 \). (The effects of measurement error in \( Q \) are attenuated by normalizing equation (A3) by \( Q \); see Chirinko (1993).) The operator \( \Delta \) is real equals \( X, (X, (1 + r_{t+1})) \). The parameter \( \eta \) gives the degree of homogeneity of the production technology minus one, and equals zero for constant returns to scale.

Therefore, OLS estimates are spurious in the absence of cointegration. Moreover, OLS estimates suffer from simultaneity bias. Even if this bias is corrected, conclusions about causality still cannot be drawn. (See Jorgenson (1991) and Munnell (1992) for comprehensive discussion of these econometric problems.)

In this paper, we analyze the impact of public capital formation on private-sector performance, first at the aggregate level and then considering different types of public investment. We follow Pereira and Flores (1999) and adopt a multivariate time-series framework. This approach allows us to address the aforementioned econometric criticisms in a rigorous and comprehensive manner. It also brings a more precise conceptual focus to the debate about whether or not public capital is productive. In fact, the static single-equation framework typically used in the literature excludes the presence of feedbacks, and in particular dynamic feedbacks, among the relevant variables. This exclusion is of paramount importance for it is likely that feedbacks exist. If they do, a zero elasticity of private output with respect to public capital (as obtained from a single-equation static production function approach) is neither a necessary nor a sufficient condition for public capital to be ineffective in influencing output.

Dynamic feedbacks are essential to a conceptual understanding of the relationship between public capital and private-sector performance. Indeed, public capital affects private directly as an additional input in the production function. Moreover, as a positive externality to private production, public capital should, ceteris paribus, lead to higher private production. Public capital also affects private production indirectly via its effects on private inputs, capital, and labor. It is conceivable that a greater availability of public capital could reduce the demand for private inputs (a substitution effect). Higher availability of public capital, however, also increases the marginal productivity of private inputs. This lowers the marginal costs of production, thereby potentially increasing the level of private production (a scale effect).

The evolution of private inputs and outputs can, in turn, be expected to affect the formation of public capital. Indeed, increasing private output provides the government with a growing tax base and the potential for greater investment. Furthermore, declining private employment has often led to short-term policy packages that involve increased public investment. There is, therefore, a real possibility that reverse causality exists. By this, we mean that it is possible that private output and private inputs may be leading the evolution of public capital.
II. Data and Preliminary Empirical Results

A. Data: Sources and Description

We use annual data for the period 1956 to 1997. The data is obtained from Bureau of Economic Analysis sources as available from their Internet site. Private GDP (gd), private investment (inv), and public investment (pinv) are in billions of constant 1987 dollars, and private employment (emp) is in full-time equivalent employees. The data for private and public investment come from the U.S. Department of Commerce’s Fixed Reproducible Tangible Wealth in the United States, 1925–1989 (1993). The original data set, which ended in 1989, has now been extended until 1997.

We consider five types of nonmilitary public investment. (See table 1 for details.) The first type of public investment (pinv1) is core infrastructure investment in highways and streets. It represents 29.3% of public investment by the end of the sample period after experiencing a sharp relative decline through the 1980s from a high of 41.2% in the early years of the sample. This type of public investment affects private production through the provision of transportation services for both final and intermediate goods. The second type of public investment (pinv2) is core infrastructure investment in electric and gas facilities, transit systems, airfields, and so forth. It displays a slight upward trend as a share of public investment, to reach 19.1% in the 1980s. In more-recent years, it has declined to 11.1%. The third type of public investment (pinv3) is core infrastructure investment in sewage and water supply systems. With a clear upward trend through the 1980s, it accounts currently for 14.1% of public investment. These two types of public investment affect the measures of private production directly, because much of the output generated by their services is both final and intermediate goods. The fourth type of public investment (pinv4) is composed of educational buildings, hospital buildings, and other buildings such as industrial buildings, general office buildings, police and fire stations, courthouses, auditoriums, garages, and passenger terminals. It shows a stable pattern around 32.0%, with the exception of the 1980s, when it fell to 16.9%. These public buildings affect private output through the promotion of knowledge and well-being of the labor force as well as through the setting of rules and regulations affecting the productive environment. The fifth type of public investment (pinv5) consists of conservation and development structures (intended for water, land, and animal protection), and civilian equipment. It has sharply increased from 11.1% to 23.0% of total public investment through the 1980s and is currently 12.7%. This component of public investment plays a supportive role in the preservation of private capital stock, and it does not seem to have a direct connection to the productive process.

Overall, aggregated public investment shows a declining trend. In fact, the ratio of public investment to GDP declines steadily from 2.48 in the 1960s to just 0.60% in the 1980s. In more recent years, however, there has been a slight upward trend and public investment represents now 0.95% of the GDP. The data suggests that the decline through the 1980s is mostly due to a decrease in core infrastructure investment in highways and streets (pinv1) and public buildings (pinv4). The relative recovery in the last decade is also led by a greater public investment in these two categories.

B. Univariate and Cointegration Analysis and VAR Specifications

To determine the order of integration of the variables, we use the augmented Dickey-Fuller (ADF) t-test to test the null hypotheses of a unit root in log-levels of the different variables. We use the Box information criterion (BIC) to determine the optimal number of lagged differences to be included in the regressions, and we include deterministic components in the regressions if they are statistically significant. For all variables, the t-statistics are greater than the 5% critical values or at least the 1% critical values. Therefore, the ADF tests cannot reject the null hypotheses of a unit root of the variables in log-levels. Moreover, further ADF tests allow us to reject the null hypotheses of a unit root in the first differences of log levels for all of the variables at the 1% level of significance. This evidence suggests that the different times series are stationary in first differences.

We also test for cointegration among the different variables. We perform these tests both in the case of aggregate public investment and with each one of the five types of public investment. Following the standard Engle-Granger approach, we perform four tests in each case. This is because it is possible that one of the variables will enter the cointegrating relationship with a statistically insignificant coefficient. We do not know, a priori, whether or not this will happen. If it does happen, however, a test that uses such a variable as the endogenous variable will not pick up the cointegration. Therefore, a different variable is endogenous in each of the four tests. We apply the ADF t-test to the residuals from the regressions of each variable on the remaining variables. In all of the tests, the optimal lag structure is chosen using the BIC, and a deterministic component is included if it is statistically significant. For all six public investment variables, the value of the t-statistics are larger than the 5% critical values for at least three of the four cases considered. Moreover, the test statistics are larger than the 1% critical values in five of the six times in which they are smaller than the 5% critical values. Thus, the ADF tests cannot reject the null hypotheses of a random walk, and we cannot reject that the variables are not cointegrated.

We have now determined that all of the variables have the same order of integration, in particular, that they are stationary of first order. We have also determined that they are not cointegrated. Therefore, we estimate six VAR models, one for aggregate public investment and one for each of the five different types of public investment. Given the nonstationarity of the variables, we follow the standard procedure in

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1 Details on the tests discussed in this section are available from the author upon request.
the literature and determine the specifications of the VAR models using first differences of log-levels, that is, growth rates of the original variables (denoted by Δlgdp, Δlemp, Δlin, Δlpinv, and so on). The specifications of the VAR models for the different types of public investment are determined using the BIC. In all cases, the BIC selects a first-order specification with a constant and a linear trend term.

III. Identifying and Measuring the Effects of Innovations in Public Investment

We use the impulse-response functions associated with the estimated VAR models to examine the effects of the different types of public investment on the performance of private-sector variables. In this context, our methodology allows dynamic feedbacks among the different variables to play a critical role. This is true in both the identification of innovations in the public investment variables and the measurement of the effects of such innovations.

A. Identifying Innovations in the Public Investment Variables

The central issue for the determination of the effects of public investment on the private-sector variables is the identification of shocks to public investment that are not contemporaneously correlated with shocks in the private sector variables (shocks that are not subject to the reverse-causation problem). In dealing with this issue, we draw from the approach typically followed in the literature on the effects of monetary policy on the economy. (See, for example, Christiano, Eichenbaum, and Evans (1996, 1998) and Rudebusch (1998).)

Ideally, the identification of shocks to public investment that are uncorrelated with shocks in other variables would result from knowing what fraction of the Congressional appropriations in each period is due to purely noneconomic reasons. The econometric counterpart to this idea is to imagine a Congressional policy function that relates the rate of growth of public investment to the information in the relevant Congressional information set (in our case, the past and current observations of the growth rates of the private-sector variables). The residuals from this policy function reflect the unexpected component to the evolution of public investment and are uncorrelated with other innovations.

In the central case, we assume that the relevant information set for the Congressional policy function includes past values but not current values of the private-sector variables. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in public investment lead innovations in private-sector variables. This means that, although innovations in public investment affect private-sector variables contemporaneously, the reverse is not true.

We have two reasons for making this our central case. First, it seems reasonable to believe that the private sector reacts within a year to innovations in public investment decisions. Second, it also seems reasonable to assume that the public sector is unable to adjust public investment decisions to innovations in the private-sector variables within a year. This is due to the time lags involved in information gathering and public decision-making. Nevertheless, to determine the robustness of our central case results, we also consider all the possible alternatives in terms of the definition of which observations of the private-sector variables are included in the Congressional information set. This is equivalent to considering all the possible orderings of the variables within the Choleski decomposition framework. We report the corresponding range of results.

The policy functions for aggregate public investment as well as the different types of public investment are reported in table 2. These policy functions relate the evolution of the public investment variables to the evolution of the private-sector variables with a one-year lag. The specification of these policy functions was tested. In no case were variables lagged more than one period statistically significant. More importantly, in no case were the contemporaneous values of the private-sector variables statistically significant. This confirms that our central case scenario is the most plausible also from an econometric perspective.

The policy function for aggregate public investment suggests that changes in the evolution of public investment are positively correlated with lagged changes in private output, negatively correlated with lagged changes in private employment, and uncorrelated with lagged changes in private investment. Clearly, changes in private-sector variables affect the evolution of public investment. Accordingly, our attention to dynamic feedbacks when analyzing the effects of innovations in public investment is well justified.

More importantly, the policy function suggests a very strong pattern of response of Congressional public investment decisions to changes in the evolution of private-sector variables. A faster-growing private output generates greater tax revenues and allows for faster public investment growth. In turn, a negative evolution of private employment leads also to an acceleration of public investment (that is, public investment seems to be consistently used as a countercyclical tool).

Finally, it should be pointed out that the coefficients of changes in private output and employment are of comparable magnitude but of the opposite sign. This suggests that decisions of the evolution of public investment are positively correlated with positive changes in the evolution of private sector labor productivity. This means that the slowdown in labor productivity growth in the last decades is to a

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<th>TABLE 2.—POLICY FUNCTIONS FOR DIFFERENT TYPES OF PUBLIC INVESTMENT</th>
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<tr>
<td>pinv: aggregate public investment</td>
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<td>pinv1: core infrastructure (highways and streets)</td>
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<td>pinv2: core infrastructure (electric and gas facilities, transit systems, airfields, etc.)</td>
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<td>pinv3: core infrastructure (sewage and water supply systems)</td>
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<td>pinv4: education buildings, hospital buildings, and other buildings (industrial, general office, police and fire stations, etc.)</td>
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<td>pinv5: conservation structures, development structures, and civilian equipment</td>
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NB—Standard-deviations in parenthesis.
B. Measuring the Effects of Innovations in Public Investment Variables

We consider the effects of one-percentage point, one-time random shocks in the rates of growth of the different types of public investment on private output, private employment, and private investment. We expect these temporary shocks in the growth rates of the different types of public investment to have temporary effects on the growth rates of the other variables. They will, however, have permanent effects on the levels of the private-sector variables.

In table 3, we report the long-term accumulated elasticities of the different private-sector variables with respect to each type of public investment. (Long-term is defined as the time horizon over which the growth effects of innovations disappear, that is, the accumulated impulse-response functions converge.) These elasticities represent the total percentage-point changes in the private-sector variables for each long-term accumulated percentage-point change in public investment once all the dynamic feedback effects among the different variables have been considered.

We report the long-term accumulated marginal productivity of public investment figures in table 4. These figures measure the dollar changes in private output for every one dollar accumulated change in public investment. We obtain them by multiplying the output to public investment ratio for the last ten years by the elasticity of private output with respect to public investment. The choice of the output to public investment ratio for the last ten years is designed to reflect the relative scarcity of public investment of the different types at the margin of the sample period without letting these ratios be overly affected by business-cycle factors. Finally, the annual rates of return, also reported in table 4, are calculated from the marginal product figures by assuming a life horizon of twenty years for all types of public capital assets. That is, the rate of return applied to one dollar over a twenty-year period yields the value of the accumulated marginal product.

It should be noted that we use the term marginal product in a way that departs from the conventional definition. In this paper, the term includes all of the dynamic feedbacks among the variables. Therefore, the marginal product that we calculate is a total marginal product. That is, it measures both the direct effects of public investment on output.
and the indirect effects of public investment on output through changes in the evolution of private inputs. Of course, this is the relevant concept from the standpoint of policy-making.

IV. Public Capital Formation and Private-Sector Performance

A. Aggregate Effects of Public Investment

When we estimate the effects of shocks to aggregate public investment on the evolution of private-sector variables, we find that the elasticity of private investment with respect to aggregate public investment is 0.22909. This means that, at the aggregate level, public investment crowds in private investment. The elasticity of private employment with respect to aggregate public investment, however, is small. In the central case, it is 0.00735.

We find that aggregate public investment has a positive effect on private output with an elasticity of 0.04253. This implies that a one-dollar increase in public investment leads to a total accumulated increase of $4.46 in private output. The corresponding annual rate of return is 7.8%. These figures suggest that, if output were taxed at a rate of 25%, one dollar invested in public capital would generate just over one dollar in tax revenues over time. Accordingly, public investment would approximately pay for itself.

B. Effects of Different Types of Public Investment

Now that we have established that public investment makes a positive and significant contribution to private-sector performance, we are ready to determine which types of public investment are the most productive. The effects of shocks to the different types of public investment on private investment are all positive. The strongest effect comes from a shock to electric and gas facilities (pinv2) with an elasticity of 0.09455. The weakest effect comes from a shock to highways and streets (pinv1) with an elasticity of 0.01154. In turn, in three of the five cases, the elasticities of private employment with respect to public investment are positive. The strongest effect comes again from shocks to electric and gas facilities (pinv2) with an elasticity of 0.01143. The largest negative effect comes from shocks to sewage and water systems (pinv3) and is −0.01159.

The effects of shocks to the different public investment variables on private output are all positive. The strongest effect comes from a shock to electric and gas facilities (pinv2) with an elasticity of 0.02103. This is closely followed by the effect of public buildings (pinv4) with an elasticity of 0.01732. In turn, the elasticity of private output with respect to conservation structures (pinv5) is the smallest, 0.00491. Finally, the effects of innovations in investment in highways and streets (pinv1) and sewage and water system (pinv3) are all within a very small range: 0.00550 and 0.00856, respectively.

It is important to highlight the importance of considering both the direct and the indirect effects of innovations in public investment. In fact, innovations in public investment on electric and gas facilities (pinv2), which have the strongest effects on private output, also have the strongest effects on both private employment and private investment. In turn, innovations in infrastructure investment in highways and streets (pinv1), which yield one of the weakest effects on private output, have both a negative effect on private employment and the weakest effect on private investment.

Let us now consider the marginal product figures. These figures are a better measure of the relative effects of different types of public investment, because they reflect the relative scarcity of the different types of public investment at the margin of the sample period. The marginal product figures suggest that all types of public investment are productive. Indeed, of core infrastructure investment in highways and streets (pinv1), in electric and gas facilities (pinv2), and in water and sewage systems (pinv3) has marginal products of $1.97, $19.79, and $63.5, respectively. In turn, investment in public buildings (pinv4) has a marginal product of $5.53, and investment in conservation and development structures (pinv5) has a marginal product of $4.06.

Another way of interpreting these results is by considering the rates of return on the different types of public investment. The rate of return to public investment in freeways and streets (pinv1) is 3.4% and is the lowest, while the rate of return on public investment in electric and gas facilities (pinv2) is 16.1% and is the highest. The rates of return on the other three types of public investment, however, are within a relatively narrow band. They range from 9.7% for water and sewage systems (pinv3) to 7.2% for investment in conservation and development structures (pinv5). Finally, investment in public buildings (pinv4) has a rate of return of 8.9%.

V. Summary and Concluding Remarks

This paper analyzes the effects of public investment on private-sector performance in the United States. We follow a VAR approach, which is consistent with the argument that the analysis of the effects of public investment on private-sector variables requires the consideration of dynamic feedback effects among the different variables.

We first analyze the effects of aggregate public investment. We find that, in the long term, public investment crowds in private investment and, to a lesser extent, private employment. We also find that aggregate public investment has a positive effect on private output. Indeed, we estimate that one dollar spent in public investment increases private output in the long term by $4.46. This evidence suggests that public capital may be a powerful instrument to promote long-term growth in the United States. It also opens the door to the next stage of our analysis: the study of the effects of different types of public investment on private-sector performance.

Consistent with the aggregate results, we find that all types of public investment crowd in private investment, while investment in core infrastructure in highways and streets and in sewage and water systems actually crowds out private employment. We also find that all types of public investment have a positive effect on private output. Core infrastructure investment in electric and gas facilities, transit systems, and airfields, as well as in sewage and water supply systems, display the highest marginal returns. They are closely followed by public investment in educational and other buildings.

It is instructive to compare our results with the literature. First, at the aggregate level, our results tend to confirm Aschauer’s assertion that public investment is a powerful instrument for growth in the United States. Indeed, we find substantial effects of aggregate public investment on private output, despite the fact that our effects are at least three times smaller than Aschauer’s. Second, the disaggregated results challenge the view that only core infrastructure investment (Aschauer, 1990) or only core infrastructure investment in highways (Finn, 1993) really affect private output. They also challenge the contention that only educational buildings matter. (See Cullison (1993) and Evans and Karras (1994).)

REFERENCES

