EFFECTS OF PUBLIC CAPITAL ON THE PRODUCTIVITY OF PRIVATE SECTOR

SHEKHAR MEHTA

NO. 2 FEBRUARY, 1993

Author is grateful to Prof. U. Sankar, H. Mukhopadhyay and the referee of this paper for their useful comments on the earlier versions of this paper.

EFFECTS OF PUBLIC CAPITAL ON THE PRODUCTIVITY OF PRIVATE SECTOR

ABSTRACT

The paper attempts to study the effects of public capital on the productivity of private capital in non-agricultural sector and the substitution possibility between private and public capital. The paper employs Cobb-Douglas and Translog production function approaches to examine these two issues. The ridge regression technique is found suitable to estimate both production functions. Using estimates of the coefficients of Translog production function, Allen partial elasticity of substitutions (AES) are estimated. In addition, Morishima elasticity of substitution are also estimated so as to check the reliability of estimates of AES. The results show that public capital in both infrastructure and non-infrastructure sectors are not complementary to private sector capital. Besides, a unit increase in private sector capital brings a larger rise in productivity of public sector capital (measured as private sector output per unit of public capital) than a unit increase in public capital in the productivity of private sector capital.

EFFECTS OF PUBLIC CAPITAL ON THE PRODUCTIVITY OF PRIVATE SECTOR

I INTRODUCTION

In developing countries the Government performs many functions which, according to the theory of public finance, should be performed by the private sector. This is perhaps because in the early stages of economic development of the country, economic agents in private sector are shy to undertake economic activities which require huge investment and involve high risk. This resulted in the dominant role of government in the economy. In India gross fixed capital formation (GFCF) in public sector at present accounts for a half of the total GFCF. It as percentage of gross domestic product (GDP) increased from merely 4 per cent in the early 1950's to 11 per cent in the late 1980's, while the corresponding rise in private sector was 9 to 11 percent. In addition, ratio of fixed capital stock in private sector to public sector has declined over the years in favour of public sector (9.22 in 1951 to 1.14 in 1985). Now the feeling is growing that the size of public sector should be slim as the doubts are raised on the role of public spending on the economic progress of country[1]. The doubts are strengthened by the recent failure of state controlled economy in the Eastern European countries.

In India the debate on the role of public sector in economic development gained significance, recently. It raised the question

---

1 This can be judged from the recent World development report 1991 which reports that a consensus is gradually forming in favour of market friendly oriented approach for development through out the world.

whether public spending should be raised or not? The question is closely related with the impact of public spending on the investment and output in the private sector. It may exert positive or negative impact on the expansion of private sector depending upon the nature of linkage between private and public sectors. Briefly a rise in public expenditure may have the following impacts. First it leaves the scarce physical and financial resources less for private sector. Second, it raises the demand for the scare resources which in turn make the resources costlier for private sector. Both effects tends to generate negative impact on private sector. On the other hand increased public expenditure raises the demand for private sector output and thereby investment and employment in private sector. The aggregate impact of public expenditure depends upon how strong is its positive or negative impact. Thus it is an empirical question to ascertain the direction of the impact of public expenditure.

In India there are a few studies which directly address the issue of the effects of public sector spending on investment and output of private sector. Most of the studies attempted to see the effect of public sector on the overall economy. They strived to seek the answer for industrial deceleration in the mid-1960s (Ahluwalia 1982, and Srinivasan and Narayana). They showed that a decline in public investment in infrastructure may be responsible for the deceleration in the mid-1960. Sundararajan and Thakur using neo classical growth model specifically examined the effects of public sector spending on investment and output in private sector. They found that public investment crowds out the private investment at least in short terms, however it raises the productivity of private sector in long run. Both inferences in their study depend on the sign of rental-wage ratio used as a variable in the equation for private investment and private sector output[2]. Krishnamurty examined the public investment on private investment in macro-economic framework. Overall they found that public investment squeezes the investment in private sector at least in the short run. They examined the effect of public investment in infrastructure on private sector separately. They inferred that increased investment in the infrastructure improves the productivity in industry and tertiary sector.

On the whole these studies seek the answers to two questions (i) as to the impact of public sector capital on the productivity of private sector economy and (ii) whether investment in public sector is substitute or complementary to that in private sector[3]. However, no serious attempt appears to have made to get the empirical estimates of

---

2 The second inference was derived from the negative coefficient of rental-wage ratio in the equation for private sector investment and the positive sign of the same coefficient in the equation for private sector output. These signs imply that a rise in rental-wage ratio resulting due to the increased public expenditure discourage private sector investment, but encourages the private sector output. The net effect is a rise in output of private sector per unit of private sector investment. However, the sign of public sector capital in that equation does not support the above implication. The sign of public sector capital is positive in the equation for investment and negative in the equation for output. Both gave the reverse impression.

3 The knowledge about the substitutability or complementary helps the investigate the implication of squeezing public investment on the expansion of private sector: If public capital capital is complementary (substitute) to private capital, then squeezing of public capital may adversely (favourly) affect the expansion of private sector economy.

measures of substitutability or complimentarity between public and private capital investment. The present paper aims to estimate the measure in non-agricultural sector. The paper is divided into five sections (i) Introduction - the present one, (ii) Approach (iii) Data, (iv) Estimation of production function, (v) Empirical Results, and (vi) Conclusions.

II APPROACH

In contrast with the traditional Keynesian macroeonomic models[4], we consider that public capital investment in infrastructure and other than infrastructure exert different types of effects on the private sector activities. The capital investment in infrastructure by government may be considered as the investment in the publicly-supplied inputs in the production process. For instance, production in textile industry constrained due to shortage of power may increase when the availability of power increases as a result of government capital investment in that sector. At present in public sector 62 per cent is GFCF in infrastructure sector (this includes power, transport, banking and social service sectors) and 30 per cent in non-infrastructure sector (excluding agricultural sector). Over the years government has shown a bias in favour of non-infrastructure. During the period from 1960-61 to 88-89, share of public capital investment declined from 66 to 62 per cent in infrastructure sector, while it has increased raised from 22 to 30 per cent in non-infrastructure sector[5]. Such a trend in public investment has

----

4 In traditional Keynesian macroeconmic models, little attention is paid on the possible differential impacts of various forms of public spending. The demand side orientation of the Keynesian model effectively rules out the variety of effects of public spending.

5 Such a trend is more pronounced in the share of fixed capital

important implication in private sector economy. Thus possibly if public capital is ignored while estimating the production function for a private economy, then estimated parameters may be biased.

In order to examine the effect of public investment on productivity of public sector, Aschauer(1989) employed a production function approach. His main objective was to see whether there is a shortfall in public capital investment in the USA? He used the Cobb-Douglas (CD) production technology with three inputs, namely capital stock and labour in private sector and capital stock in public sector. Broadly we follow his approach but employ a more flexible production function technology, that is, translog production function. As it is well known that CD assumes that factors have unit elasticity of substitution and thereby excludes the possibility of estimating production functions in which factors of production are complementary or have elasticity of substitution other than unity. Trnaslog production function does not have such restrictions. The results of a recent study show that the indian manufacturing sector does not conform to the Cobb-Douglas production technology (Ahluwalia 1991).

We assume that output net of materials in private sector (Q) is characterised by following function:

$$Q = F(X)$$

The production function F(.) is a twice continuously differential, finite and non-negative function of X. The arguments of

---

stock in different sectors in public sector: As a result of diversion of GFCF in favour service sector during the period 1960-61 to 88-89, the share of public sector capital stock in infrastructure raised from 61 to 63 per cent, while in non-infrastructure sector it raised from 13 to 21 per cent.

the function Q are a vector of inputs(X): where X represents collection of broadly homogeneous groups of inputs. The groups of inputs are assumed to be weekly separable[6]. In general production of an article uses many kinds of different inputs.In a estimable production function, parameters of all inputs can not be calculated. Such assumption is necessary if we aggregate inputs in some broad category of inputs. Using above assumptions, translog production function in the case of three inputs can be written as follow:

$$LnQ = \alpha_0 + \alpha_1 LnK + \alpha_2 LnL + \alpha_3 LnZ_i + \frac{1}{2}\alpha_{11}(LnK)^2 + \frac{1}{2}\alpha_{22}(LnL)^2 + \frac{1}{2}\alpha_{33}(LnZ_i)^2 + \alpha_{12}LnKLnL + \alpha_{13}LnKLnZ_i + \alpha_{23}LnLLnZ_i \qquad (1)$$

Symbols K and L denote respectively capital stock and labour in private sector, and Z_i is public capital in the ith sector: where i represents infrastructure and non-infra structure sectors.

Production function follows the usual symmetric restriction in parameters $\alpha_{12} = \alpha_{21}$, $\alpha_{13} = \alpha_{31}$ and $\alpha_{23} = \alpha_{32}$. Since the production function represents the functional relationship between output and the flow of service from inputs, thus a assumption involved is that the flow of services from capital and lobour are proportional to their quantities. Further, if production function is characterised by a constant return to scale (CRS) over all inputs, the following relations hold

$$\sum_i \alpha_i = 1, \quad \sum_i \alpha_{ij} = 0, \quad \sum_j \alpha_{ij} = 0, \quad \sum_i\sum_j \alpha_{ij} = 0$$

---

6 In technical terms week separability between two groups of inputs means that marginal rate of substitution between two inputs pertaining to one group is independent from the change in a input pertaining to another group of inputs. That is, $\frac{\partial}{\partial x_k}\left(\frac{\partial F/\partial x_i}{\partial F/\partial x_j}\right) = 0$ where xi and $x_j \in X^1$ group of inputs, while $x_k \notin X^1$.

Using these restrictions, the dependent variable in the above equation can be expressed in terms of per unit of K, L, or Z. The following TL is shown in terms of as per unit of capital.

$$Ln\left(\frac{Q}{K}\right) = \alpha_0 + \alpha_2 Ln\left(\frac{L}{K}\right) + \alpha_3 Ln\left(\frac{Zi}{K}\right) + \frac{1}{2}\alpha_{22} Ln\left(\frac{L}{K}\right) Ln(KL) + \frac{1}{2}\alpha_{33} Ln\left(\frac{Zi}{K}\right) Ln(KZi)$$
$$+ \alpha_{12} Ln\left(\frac{L}{K}\right) LnK + \alpha_{13} Ln\left(\frac{Zi}{K}\right) LnK + \alpha_{23}\left(LnLLnZi - (LnK)^2\right) \qquad (2)$$

In the above equation output per unit of capital may be considered as the measure of productivity of private sector. In the literature it is argued that services emitted from public investment has the possibility of economies of scale. This suggests that specification of private production technology would involve a assumption of constant return to scale over private inputs K and L but increasing return to scale over all inputs including government. The conditions for CRS over K and L will be $\alpha_1+\alpha_2 = 1$, $\alpha_{11}+\alpha_{12} = 0$, $\alpha_{21}+\alpha_{22} = 0$, $\alpha_{13}+\alpha_{23} = 0$. In this case the above equation boils down to

$$Ln\left(\frac{Q}{K}\right) = \alpha_0 + \alpha_2 Ln\left(\frac{L}{K}\right) + \alpha_3 LnZ_i + \frac{1}{2}\alpha_{22} Ln\left(\frac{L}{K}\right) Ln(KL) + \frac{1}{2}\alpha_{33}(LnZ_i)^2 +$$
$$\alpha_{12} Ln\left(\frac{L}{K}\right) LnK + \alpha_{13} Ln\left(\frac{Zi}{K^{.5}}\right) LnK + \alpha_{23}\left(LnLLnZi - \frac{1}{2}(LnK)^2\right) \qquad (3)$$

In the case of Cobb-Douglas production technology (in that case $\alpha_{ij} = 0$) both equations will boil down to

$$Ln\left(\frac{Q}{K}\right) = \alpha_0 + \alpha_2 Ln\left(\frac{L}{K}\right) + \alpha_3 Ln\left(\frac{Zi}{K}\right) \qquad (4)$$

$$Ln\left(\frac{Q}{K}\right) = \alpha_0 + \alpha_2 Ln\left(\frac{L}{K}\right) + \alpha_3 LnZi \qquad (5)$$

We can use these equations with restrictions or without restrictions to look into the effect of public sector capital investment on productivity of private sector economy, and the estimates of parameters of Translog production function may be used to examine the nature of substitution between K and Zı. For this purpose Allen partial elasticity of substitution (AES) between K and Z is estimated using the following formula.

$$\sigma_{ij} = \frac{|F_{ij}| \Sigma f_i x_i}{|F| x_i x_j}$$

x_i represents K, L and Z inputs, f_i is partial derivative of production function, $|F_{ij}|$ is the co factor of the Bordered Hessian matrix and $|F|$ is the determinant of the matrix.

III DATA

The data required for the empirical exercise are output net of materials, capital stocks and lobour in private sector and capital stock in infrastructure and non-infrastructure. At the outset it will be useful to note that (i) the period of the study is 1960-61 to 88-89, (ii) all the data are at constant prices at 1980-81 as a base year and (iii) most of the data we required are available in National Accounts published by CSO.

Data on output in non-agricultural for the period from 1960-61 to 1988-89 are available for both sectors public and private separately from the national account statistics. Sector wise capital stock data net or gross both for the whole economy are available for the period from 1955-55 to 88-89. The same sector wise data are also available for both private and public sectors separately but for the period from 1980-81 to 88-89. The problem arises as to how to obtain the data on capital stock in infrastructure for the period prior to 1980-81. Fortunately data on gross fixed capital formation and consumption of fixed capital in all sector combined in public sector at current prices are available for the period from 1950-51 to 84-85. From these two sets of data it is not difficult to construct the series of net fixed capital stock for public sector using 1980-81's capital stock for public sector, and then that for private sector. The problem arises to derive from net fixed capital stock for all sectors combined the capital stock data on infrastructure and non-infrastructure in public sector and on non-agricultural sector in private sector. The methods used to construct these data are explained in Appendix. The data on sectorwise employment are available for private and public sectors separately for the period from 1960-61 to 1988-89. The data are available from publications of the Ministry of Labour. Sector wise employment data are also available from different censuses but for census years only. For other years employment data are computed using simple compound growth rate between two census periods. We used employment data in public sector given in the publication of ministry of labour, and the employment data in private sector given in the Censuses: The latter is obtained by subtracting employment in public sector from total employment compiled from censuses[7].

IV ESTIMATION OF PRODUCTION FUNCTION

Usually the parameters of TL model are estimated with the help of input share equations. The procedure has been to work with the conditions for profit maximization in competitive production and factor markets. Under this assumption, the condition for profit

---

7 Although sector-wise employment data in private sector are available from publications of the Ministry of Labour, we preferred to use the Census data. The reason is that the publications of the Ministry provide data on labour in organised private sector only, while the Census data cover both organised and unorganised private sectors. It is a well known fact that in India labour force in the unorganised sector comprises a substantial portion of total labour force in private sector.

maximization results in a set of semi logarithmic equations with one equation for each input. Each equation expresses the input share as a linear function of log of other inputs. Note that as long as the assumptions are valid there is no difference between the input share approach and the direct estimation procedure (Corbo and Meller). We estimated the TL model using the direct estimation procedure.

The results of both models[8] (CD and TL) are absurd, especially those relating with Translog Model (Table in Appendix A1 and A2). Some of the coefficients are in four digit which are unbelievable. The signs of some variables are not correct on a priori ground[9]. Such results may come about as a result of many statistical problems such as wrong specification and serial correlation. However, the most reasonable cause for such absurd results appear to be the presence of multi-collinearity among regressors[10]. The major factor for indication

----

8 Recently Hulton pointed out that it is the net measure of capitalwhich along with labour produces gross output. Accordingly the dependent variable is gross output net of materials in non-agricultural private sector and two explanatory variables, public and private capital, are net.

9 We estimated Translog Model on the transformed data expecting that the result would improve. However, the results did not improve much. The transformation was done by putting variables into deviation form from mean.

10 It can be shown how the multicollinearity may cause the wrong sign of the coefficients. Let denote by r_{12} the correlation coefficient between two regressors and r_{yi} the correlation between dependent variable y and regressor x_i. The OLS estimates $b=(X'X)^{-1}X'y$. This requires the computation of inverse of $(X'X)$. If variables are standardised , then

of multicollinearity problem is that many coefficients (seven in Translog and two in CD) are insignificant despite the high simple correlation between dependent variable and explanatory variables. A number of diagnostic tests are made to check the presence of multicollinearity. Of them the result of three diagnostic tests, namely characteristic root, condition number and variance inflation factor (VIF)[11] are presented in Tables 1, 2 & 3. Belsley, Kuh and

---

$$(X'_s X_s)^{-1} = \begin{bmatrix} 1 & -r_{12} \\ -r_{12} & 1 \end{bmatrix} \left(\det(X'_s X_s)\right)^{-1}$$

$$(b_s) = \begin{bmatrix} r_{y1} - r_{12} r_{y2} \\ r_{y2} - r_{12} r_{y1} \end{bmatrix} \left(\det(X'_s X_s)\right)^{-1}$$

From the above expression it can easily be seen that sign of b_s depend upon the magnitude and sign of r_{12} for given values of r_{y1} and r_{y2}. That how does the high magnitude of r_{12} lead to the wrong sign of b_s can be explained using hypothetical values of r_{y1} and r_{y2} (for detail see Vinod and Ullah). However, a simple condition can be derived as to what size of r_{12} may change the sign of b_s from that which would have resulted in the case of orthogonal explanatory variables. For r_{y1} and r_{y2} >0, the value $r_{12} > (r_{y1}/r_{y2})$ may cause $b_1<0$ (in the case of orthogonal explanatory variables $b_1 = r_{y1} > 0$).

[11] a The product of characteristic roots (eigen values) is the determinant of matrix, to which the eigenvalues belong. A small eigen may result in a small value of determinant. This, in turns, makes the matrix ill condition. Thus the collinearity is indicated by a very small value of eigen value. In fact collinearity among regressors results in a small value of

Welsch (1980) suggested after carrying out Monte-Carlo experiments that condition index between 30 and 100 may be considered to be the indication of the existence of moderate to strong collinearity among regressors that may seriously affect the estimates of regression coefficients. For VIF, Marquard and Sree (1975) suggested that a value of 5 or more is the indication of severe multicollinearity.

The results of these diagnostics tells us that we have a multicollinearity disaster on our hands. In CD model condition number related with the variables capital investment in infrastructure (ZI) and capital investment in other than infrastructure (ZN) are 119 and 133, respectively. Both exceed the limit suggested for moderate and strong multicollinearity. The values of VIF are more than 5 in the case of all regressors. The diagnostics relating with TL suggest the presence of severe multicollinearity among regressors. The presence of multicollinearity is also reflected from the following fact. The regressing dependent variable on each regressor separately results in the regression coefficients with the reasonable magnitude and correct sign. In the presence of multicollinearity simple OLS is unlikely to estimate CD and Translog Model satisfactorily.

The present paper approaches this problem by the use of an estimation procedure known as ridge regression (RR) technique. It will be worthwhile to briefly describe the technique. In this method, a constant, say k ($0 \le k < \infty$), is added to the diagonal of the matrix of cross products of regressors (X'X) before inverting it for least

----

characteristic root is an indication of severe collinearity;

b Condition numbers is $\sqrt{\lambda_{max}/\lambda_{min}}$ where λ is the eigen values; and

c Variance inflation factor is the element of diagonal of inverse of correlation matrix of regressors.

square estimates[12]. That is, the ridge estimator will be[13]

$$b_k = [(X'X)+kI]^{-1}X'y$$
$$var(b_k) = s^2[(X'X)+kI]^{-1}(X'X)[(X'X)+kI]^{-1}$$

where s^2 will be variance of residuals. If k=0, then ridge estimates reduce to the OLS estimates. It is to be noted that ridge estimates are biased but have the lower variance[14]. Further, the higher the value of k, larger is the biasedness of b_k, but the smaller is the variance of b_k[15]. Thus, for choosing the value of k, there is a trade-off

---

12 It is worthwhile to see how the addition of a constant, k, works. Note that in Footnote (9) the determinant of standardised (X'X) is $1-r_{12}r_{12}$. As the value of r_{12} approaches one, it leads to the indeterminacy of the matrix. However, an increment in the value of diagonal element for given value of r_{12} reverses this process.

13 In this paper X represents explanatory variables in matrix form.

14 $Bias(b_k) = E(b_k) - \beta = [(X'X+kI)^{-1}X'X\beta-\beta] = -k(X'X+kI)^{-1}\beta$ and tr Cov(b)] $=s^2\sum_i\lambda_i/(\lambda_i+k)^2$. If k = 0, then tr $Cov(b_k) = s^2\Sigma\lambda^{-1}$. It can be shown that ridge estimator has lower variance than OLS estimator, that is, $s^2\Sigma\lambda_i^{-1} > s^2\Sigma\lambda_i/(\lambda_i+k)^2$. This implies that $[s^2\Sigma\lambda_i^{-1} - s^2\Sigma\lambda_i/(\lambda_i+k)^2] > 0$. The bracket term, $[s^2\Sigma\lambda_i^{-1} - s^2\Sigma\lambda_i/(\lambda_i+k)^2] = s^2[\Sigma\lambda_i^{-1}\ (1-1/((\lambda_i+k)/\lambda_i)^2)$. Accordingly the bracket term will be grater than zero if $(1-1/((\lambda_i+k)/\lambda_i)^2) > 0$. The preposition that variance of RR estimator is less than OLS estimator will boil down to the condition $(\lambda_i/(\lambda_i+k))^2 < 1$. Since $k > 0$, therefore $(\lambda_i+ k) > \lambda_i$.

15 This can be checked by taking the derivatives of b_k and tr $Cov(b_k)$ with respect to k. The derivatives $\partial(bias)/\partial k>0$ and

between the large biasedness and small variance.

It is difficult to suggest the biased estimates for econometric analysis. Whole literature in econometrics revolve around correcting biased estimates. However, in the literature it is also underscored that one should not attach too much importance to the property of biasedness in the applied econometrics[16] (Theil, p.7). Besides, it is shown that RR estimates are superior to OLS estimates in the sense that there exist a non-negative value of k for which mean square error of b_k is lower than that of OLS estimates[17&18] A few methods are available to find the optimal value of k. We employed two methods. One is suggested by Hoel, Kannard and Baldwin (HKB) (1975). The second method used in this study is a simple graphical method, known as "ridge trace". Both methods fall under the category of adaptive ridge regression which means that value of k is deduced from the observed data.

HKB suggested an iterative procedure to find the optimal value of k. The procedure is as follows. First, the variables are standardised by putting them into deviation from their mean $(x_{ij} - \bar{x}_j)$ and then

----

$\partial trCov(b_k)/\partial k<0$.

16 The reason put forward is as follows. The term, unbiased means that in a large number of repetitions the average of the deviation of the estimates from the true parameters is zero, while in practice we do not have a large number of repetitions and mere averaging to zero of large positive and negative deviations may not be satisfactory [Vinod and Ullah,p. 170-171].

17 This is true even if the multicollinearity does not exist among regressors.

18 The condition for superiority of b_k over OLS estimates is $k \le 2s^2/\beta'\beta$. However, in practice this condition is too conservative.

divide by the square root of sum of squared deviation $[w_i = \{\Sigma(x_{ij} - \bar{x}_i)^2\}^{1/2}]$. The dependent variable y is not standardised but centered. The standardised model has the form, $y = X_s\beta_s + e_s$: subscript s means variables are standardised. The HKB estimator of k is

$$\hat{k} = \frac{(M-1)s^2}{\hat{\beta}_s'\hat{\beta}_s}$$

where M is the number of explanatory variables including intercept as a variable, and $\hat{\beta}_s$ and $\hat{s}^2$ are OLS estimates of regression coefficient and variance of residuals, respectively. Note that $\hat{s}^2$ is numerically identical to the usual unbiased estimator of s from the original unstandardised regression model $y = X\beta + e$. In the second step, the ridge estimates of β_s is estimated:

$$\beta_s(k) = (X_s'X_s + kI)^{-1}X_s'y$$

In the third step, a new value of k is computed by using the ridge estimates, $\beta_s(k)$,obtained from the above equation, and then reestimate the ridge estimates of β_s using the new value of k. This will continue until k coverage to some values. Finally the ridge estimates are transformed back to the origin units of the measure as follows:

$$\hat{\beta}(k) = W^{-1}\hat{\beta}_s(k) \text{ and}$$

$$Var\beta(k) = W^{-1}Cov(\beta_s(k))W^{-1}$$

where W is the vector of w_i. It is worthwhile to point out that HKB (1975) showed on the basis of Monte Carlo experiments that the ridge estimates computed by using the above iterative technique are superior to the OLS estimates.

Another method under the category of adaptive ridge regression used in this paper is the ridge trace. It is simply a plot of b_k against different values of k. There are many criteria to select the value of k using ridge trace. We will use the criteria suggested by Hoel and Kernard (1970b). According to which, select that value of k at which RR coefficients get stabilized with reasonable magnitude and sign[19].

V EMPIRICAL RESULTS OF RIDGE REGRESSION

For each model, CD and TL, two equations are specified, namely Specifications-A and B. In the former (SP-A) capital investment in infrastructure and in the latter (SP-B) capital investment in non-infrastructure by government are used as one of regressors. We will first discuss the results of CD Model.

(a) Cobb Douglas Model

For this model the iterative RR technique is employed to estimate the parameters[20]. The values of k in SP-A and B coverage to .0666 and .0857, respectively. The RR results of SP-A and B are based on these values of k. The estimates of both RR are significantly improved over OLS estimates (Table 4). The magnitude and sign of all coefficients of RR are plausible, and significant at one per cent level of significance. The OLS estimate of coefficient for private capital (K) was the largest coefficient and for public capital (Z) and labour (L) were negative, while the RR coefficient for L turns out to be the largest, and RR coefficients for K and Z are respectively the second and third largest coefficients, and all are positive.

---

19 Brown and Beatti (1975) suggested to select a value of k at the point where the last ridge estimates attain its maximum absolute magnitude having attain its ultimate sign.

20 In the Translog Model, before applying RR technique, we transformed the model by putting logs of variables into the deviation from theirmean ($Lnx_{ij} - L\bar{n}x_{i}$).

In the second section of this paper, two restricted CD models (Equations 4 & 5) are specified in terms of ratio of Q/K. The restriction is (1) the constant return to scale (CRS) over all inputs or (2) CRS over two inputs L and K but increasing return to scale over three inputs. Instead of estimating these equations in form as shown in the second section, these are estimated using Restricted Ridge Regression technique[21]. Equations 4 & 5 can be obtained by simple algebraic manipulation.

The results of the restricted models (Table 4) are satisfactory in terms of the significance level of regression coefficients, their relative magnitude and sign of the coefficients. In addition, $\bar{R}^2$ of the restricted models are also very high[22]. We will use the results of both restricted and unrestricted models to get a fair idea about the effects of public capital investment on the productivity of private capital.

Discussion

The results of unrestricted RR indicate that a percentage rise in private capital brings forth a half per cent rise in the output of private economy, while a percentage rise in public capital (in infrastructure (non-infrastructure) give rise to .16 (.10) per cent rise in the output in the private economy. The results of restricted models give interesting information. A percentage rise in public

---

21 The estimation of the models by both ways will yield the same results.

22 It is worthwhile to point out that the model does not obey the restriction embodied in the model (In order to test the restriction. F test is carried out, see Johnston (1984) p. 204-207). The test statistics indicates that model conforms to the increasing return to scale. However, for analytical purpose, we retained the results of the restricted models.

capital in infrastructure (non-infrastructure) per unit of private capital, ZI/K (ZN/K), causes .27 (.22) per cent rise in private sector output per unit of K (Q/K), while a percentage rise in private capital per unit of public capital, K/ZI (K/ZN), leads to .30 per cent rise in the private sector output per unit of public capital, Q/ZI (Q/ZN). This means that a per cent increment in private capital induces to a higher rise in the productivity of public capital than what a per cent rise in public capital causes a rise in the productivity of private capital.

The effect of public capital on the productivity of private capital may be further elaborated by manipulating the estimates in the restricted model in terms of output per unit of labour. A unit rise in capital in infrastructure. or non-infrastructure sectors brings .26 or .20 per cent rise in the output per unit of labour. In contrast to it, a percentage rise in private capital raises .35 per cent rise in Q/L (Columns 5 and 8 in Table 4).

The above two observations about the effects of public sector capital on the productivity of private sector may appear to be unreasonable as it is generally argued that the public capital help generate output not only in private sector but in public sector also. In order to verify this hypothesis we reestimated CD model (Equation 4) with three different dependent variables, (a) output in non-agriculture in private sector and output in infrastructure (Q_1), (b) output in non-agriculture in private and public sectors excluding output in infrastructure (Q_2), and (c) output in non-agricultural in both sectors(Q_3). In all three regression equations we found that magnitude of coefficients relating with Z_i is smaller than K though the magnitude of Z_i coefficients in these three equations are higher than that found in the equation in which dependent variable is private sector output only[23]. At this stage it is worthwhile to point out that the magnitude of partial elasticity dependents on the extent of marginal change in output to capital and the extent of average ratio of output to capital. That is, $(\Delta Q/\Delta K)/(Q/K)$ < or > $(\Delta Q/\Delta Z_1)/(Q/Z_1)$ depends on the magnitude of numerator and denominator. According to our data set average ratio of output and private capital remained 1.30 to 4.13 times higher than the average ratio of output and infrastructure capital during 1960-61 to 1988-89. Thus, for equal marginal change, partial elasticity of Z_1 should be higher than that of K however it is no so therefore it means that the marginal change relating with Z_1 $(\Delta Q/\Delta Z_1)$ is much lower than the marginal change relating with K $((\Delta Q/\Delta K)$.

Generally it is believed, particularly, in the case of capital investment in infrastructure that it is complementary to capital investment in private sector. Accordingly, a rise in productivity of K as a result of an increment in ZI or a rise in the productivity of ZI

---

23 Although we estimated these CD models using OLS and RR technique with and without restrictions, we are presenting the results of RR with restriction only merely because of saving space.

$$LnQ_1 = -2.4991 + .3793LnL_1 + .3247LnK + .2960LnZI; \quad \bar{R}^2 = .9573$$
$$LnQ_2 = -2.6700 + .4182LnL_2 + .3532LnK + .2285LnZN; \quad \bar{R}^2 = .9305$$
$$LnQ_3 = -2.5737 + .4229LnL_3 + .3142LnK + .2629LnZ; \quad \bar{R}^2 = .9266$$

All coefficients are significant at one percent level of significance. L_1= Labour in non-agriculture in private sector plus in infrastructure, L_2 = Labour in non-agriculture in both sectors excluding those in infrastructure, L_3 = Labour in non-agriculture in both sectors including those in infrastructure and Z = public capital in non-agriculture and infrastructure as a result of an increment in K should be the same. If it is no so, then it is possible that the level of public capital investment is already high enough, and a further rise in the level of public sector capital does not induce the output of private sector. Besides, two more reasons can be put forward so as to explain the small coefficient of Z_1. The first is the inefficient use of capital services. This is pointed out in one study on the productivity of Indian industry (Ahluwalia 1982). Second the value of public capital (in the case of results reported in footnote 21) may be undervalued. It is well known that the pricing of public sector activities does not reflect the market price. On the whole, whatever is the reason low coefficient of Z_1, diversion of capital from private to public appears to yield a social cost in the economy.

(b) Translog Production Function

For this model, as mentioned earlier, "ridge trace" technique is employed to find the optimal value of k. A number of RRs were estimated for the various values of k varying from .001 to 45. It was found that at many values of k, regression coefficients get stabilized. However, for a particular range of k values, RR produces reasonable regression coefficients in terms of sign and the level of significance. For instance, for SP-A, a maximum number of regression coefficients were found significant in those ridge regression which are associated with the values of k ranging between .077 and 3. The most suitable values of k were found to be .077 for SP-A and .095 for SP-A. It will be worthwhile to point out that although the significance level of coefficients vary from one RR to another depending upon the value of k, the magnitude of the coefficients do not vary much across the RRs.

We will first discuss the results of TL production function on the line of CD model, and then the results relating with the estimate of elasticity of substitution. It will be of interesting to find that the results of TL were the most absurd when simple OLS were employed, but the results turned out to be meaningful when RR is used. Almost all coefficients are significant at the reasonable level of significance, the signs are also as expected on a prior ground (Table 5). The monotonocity condition and quasi concavity conditions are met for sufficiently long range of observation points[24]. For the average values of the variables, the first order regression coefficients of RR-TL model can be compared with those of RR-CD model since variables in TL model are in deviation form from means[25]. The value of the first order regression coefficients (which indicate a percentage change in output due to a percentage change in a particular input) of the unconstrained RR-TL model stand by the inferences about the effects of public capital on productivity of private capital.

Using the restriction $\alpha_1+\alpha_2+\alpha_3=1$ (one of the restrictions

---

[24] A production function is considered to be well behaved if and only if output increases monotonically with all inputs and if isoquants are convex. That is, for a production function, say $Q= F(x_1, x_2,..,x_n)$, the monotonocity condition implies $\partial F/\partial x_i>0$, and the quasi concavity condition implies $\partial^2 F$ is negative definite or the principle minor of the Bordered Hessian matrix ($|H|$) should alternative in the sign beginning with $|H_2| > 0$. The TL production function does not satisfy these restriction globally. However, there are regions in input space where these conditions are satisfied. The well behaved region may be large enough so that the TL function can provide a fairly good representation of relevant production possibilities (Berndt and Christensen 1973)

[25] The average of the deviation will be zero. Thus, in the equation for the first partial derivative, the cross regression coefficient will turn out to be zero.

required for RR-TL to be CRS in the case of TL) the constrained model can be expressed as Q/K or Q/Z.[26&27] The results of the constrained RR-TL model indicate that a percentage rise in ZI/K brings a .10 percent rise in Q/K, while a percentage rise in K/ZI cause a .26 percent rise in Q/ZI. That is, a percentage rise in private capital raises the productivity of public capital much higher than that a percentage rise in Z/K increases the productivity of private capital. The result of RR-TR Model reinforce the results of RR-CD Model which says that the diversion of capital from private sector to public sector causes a social cost in the economy. The numerical value of social cost reflected from RR-TL model is higher that shown from RR-CD model[28].

----

[26] For the restricted models 2 and 3, the estimation should be performed by regressing Q/K or Q/L on the regressors expressed in a particular form (Equations 2 & 3 in the text), but with the help of some statistical packages the same restricted model can be obtained by estimating TL model expressed in absolute term by embedding restrictions separately. In this exercise, Shazam software was used.

[27] For the average values of variables the first order regression coefficient of the constrained model (CRS in inputs) may be considered as the share of inputs in output. The results indicate that the share of inputs reflected from TL model is more closer to the actual figure on the share than the share reflected from CD model. From TL model, the shares of labour, capital and infrastructure in the private sector output are 64, 26 and 10 per cent.

[28] This is judged from the fact that

$$\left[\frac{\partial Ln(Q/Z)}{\partial Ln(K/Z)} - \frac{\partial Ln(Q/K)}{\partial Ln(K/K)}\right]^{TL} > \left[\frac{\partial Ln(Q/Z)}{\partial Ln(K/Z)} - \frac{\partial Ln(Q/K)}{\partial Ln(K/K)}\right]^{CD}$$

Now a question is to see the scope of substitution between capital investment in private and public sectors. If the capital investment in public sector is complementary to that in private sector, then a rise in the investment in the former may induce the investment in private sector. Generally the investment in infrastructure is believed to be complementary to the investment in private sector. In order to examine this relation, we estimated Allen partial elasticity of substitution (AES) using the estimates of unconstrained RR-TL model. In order to check the reliability of the elasticity estimates, particularly of their signs, the AES is estimated for regression coefficients of many RR-TL models associated with various values of k (.019 to 1 for SP-A and .019 to 3 for SP-B). Besides, Morishima Elasticity of Substitution (MES) is also computed. In literature, MES () is considered to be more economically relevant measure of substitution than the AES (Chamber p 35-36). Its formula can be written as

$$\sigma^{M} = \frac{f_j x_j \left(\sigma^{A}_{ij} - \sigma^{A}_{jj}\right)}{f_i x_i}$$

where σ^{M} and σ^{A} are the Morishima and Allen partial elasticity of substitution, respectively; f_i and f_j are the partial derivative of the production function with respect to x_i and x_j inputs, respectively.

It is to be noted that (i) MES is an asymmetric measure of substitution[29] as $\sigma^{M}_{ij} \neq \sigma^{M}_{ji}$ and (iii) a pair of inputs can be

---

[29] It will be useful to highlight the concept of σ^{M} more detail. In economic jargons, it is a two factors-one price measure of elasticity of substitution, and AES is a one factor-one price

complementary in terms of Allen elasticity of substitution ($\sigma^{A}_{ij} < 0$), while the corresponding Morishima measure could class themas substitute ($\sigma^{M}_{ij} > 0$). These two properties of Morishima measure of the elasticity has important implication for classification of inputs as substitute or complimentary.

The estimates of AES and MES for various values of k are presented in Tables 6, 7a and 7b. The estimates from both measures appears to be consistent as the values of σ^{A}_{kzl} and σ^{M}_{kzl} for different values of k have the same sign. Another way to see the consistency of the result is to check the sign and value of σ^{A}_{kk}, σ^{A}_{ll} and σ^{A}_{zz} and which should be, on a priori ground, less then zero or equal to zero. The estimates of these elasticities in this exercise meet the condition.

----

measure of elasticity of substitution (For detail see Mundlak). The former means that inputs, x_i and x_j, are substitute if and only if an increase in price(p_j) of x_j causes input ratio (x_i/x_j) to rise, that is, $\partial(x_i/x_j)/\partial p_j > 0$, while the one factor-one price measure means that inputs x_i and x_j are substitute if and only if an increase in price of input x_j (p_j) cause input x_i to rise, that is, ($\partial x_i/\partial p_j > 0$). The distinction between them need little more elaboration. Note that the AES and MES can also be written as (For detail see Chamber pp 93-98)

$$\sigma^{A}_{ij} = \frac{e_{ij}}{S_j} \quad \text{and} \quad \sigma^{M}_{ij} = e_{ij} - e_{jj}$$

where e is the derived demand elasticity and S is the cost share of input x_j in total cost. Above formula implies that AES can be intuitively interpreted simply in terms of e_{ij} but dividing it by cost share disguised substitution relation.

The results of both measures (AES and MES) show that publicly supplied input (capital investment in infrastructures) does not appear complementary to capital investment in private sector. Similarly capital investment in non-infrastructure is not a complementary to that in private sector. Further it is to be noted that resources for allocating capital on infra and non-infra structures come from the same sources. Thus there may be a possibility of subtitution between them. This needs to be tested.

The first inference is against the general expectation of complementary relation between private capital and publicly supplied capital. The reason for this statistical relation may be as follows. First, the paucity of funds in private sector may perhapse not allow entrepreneurs to raise investment in response to a rise in publicly supplied inputs. Second, although a heavy public investment is made to provide infra structural service to private sector, the inefficiency prevailing in the management of public sector possibly does not allow private sector to exploit the infra structural service properly. Last, although there is a rise in public capital over the years, it is sufficiently higher to induce private investment. All these reasons may lead a complementary relation between private capital and publicly supplied inputs.

V CONCLUSIONS

This paper employs a production function approach to analyse the effect of public capital on private capital. Although statistical analysis indicates some problems with the estimates of both CD and TL models, the evidences presented in this article lead to two broad inferences. First, a percentage rise in private capital raises the productivity of public capital more than what a percentage rise in public capital raises the productivity of private capital. Second, contrary to general expectation, public investment in infrastructure is not complementary to capital investment in private sector. Both inferences suggest that there is a need to raise the level of investment in private sector, and at the same time to exploit the exiting level of public capital efficiently. The inferences do not mean that the level of public capital in infrastructure is sufficient for the level of private capital and there is no need to raise public investment in infrastructure. The basic finding is that there is no rise in private sector capital corresponding to a rise in public capital in infrastructure. The following descriptive statistics may be helpful to highlight that finding. The ratio of public capital in infrastructure and private capital has grown substantially over the years (Figure). On an average the ratio has grown from merely .15 in 1951-60 to .72 in 1981-89. Similarly the compound growth rate of capital stock in different periods always remained higher in infrastructure that in private sector (Table 8). Thus it looks that the need is to concentrate the efforts on using public capital efficiently. The inefficient use of public capital is pointed out to be one of the major reason for industrial deceleration in India (Ahluwalia 1982).

Table 1

Diagnostic Fest for Multicollinearity in CD Model

Variables	Eigen Values	Condition Index	Aux R^2	VIF
Specification - A				
LK	10.0380	1.00	.9950	200
LL	0.0360	16.63	.9970	333
LZ1	0.0007	119.74	.9790	47
det(X'X)	0.0002	-	-	-
Specification - B				
LK	14.6100	1.00	.9757	41
LL	0.0800	13.51	.9834	60
LZ1	0.82×10^{-3}	133.48	.9928	139
det(X'X)	0.90×10^{-3}	-	-	-

Abbreviations: det = determinant; Aux R^2 = Auxulary R^2 and VIF = variance inflation factor.

Table 2

Diagnostic Fest for Multicollinearity for TL Model

Variables	Eigen Values	Condition Index	Aux R^2	VIF
Specification - A				
LK	7406.00	1.00	1.00	inf
LL	17.00	20.70	1.00	inf
LZI	0.29	159.36	1.00	inf
$(LK)^2$	0.10	268.08	1.00	inf
$(LL)^2$	$.17x10^{-2}$	2068.50	1.00	inf
$(LZI)^2$	$.18x10^{-5}$	$63x10^3$	1.00	inf
LKLL	$.43x10^{-6}$	$13x10^7$	1.00	inf
LKLZI	$.89x10^{-9}$	$29x10^8$	1.00	inf
LLLZ	$.24x10^{-10}$	$17x10^8$	1.00	inf
det(X'X)	$.10x10^{-26}$	-	-	-
Specification - B				
LK	9715.00	1.00	1.00	inf
LL	41.88	15.00	1.00	inf
LZN	0.41	154.00	1.00	inf
$(LK)^2$	0.11	290.00	1.00	inf
$(LL)^2$	$.45x10^{-2}$	1468.00	1.00	inf
$(LZN)^2$	$.35x10^{-5}$	$52x10^3$	1.00	inf
LKLL	$.32x10^{-6}$	$17x10^6$	1.00	inf
LKLZN	$.40x10^{-8}$	$15x10^5$	1.00	inf
LLLZN	$.29x10^{-10}$	$18x10^8$	1.00	inf
1xX1	$.10x10^{-25}$	-	-	-

Inf = infinity

Table 3

Dragnistic Test for Multicollinearity for TL Model (when variables in deviations)

Variables	Eigen Values	Condition Index	Aux R^2	VIF
Specification - A				
DLK	10.05	1.00	0.9997	$33x10^2$
DLL	1.17	2.93	0.9998	$55x10^2$
DLK1	0.01	28.12	0.9983	588
$(DLK)^2$	$.80x10^{-2}$	34.57	1.0000	inf
$(DLL)^2$	$.50x10^{-3}$	131.73	1.0000	inf
$(DLZI)^2$	$.57x10^{-4}$	420.74	0.9998	$55x10^2$
DLKDLL	$.65x10^{-5}$	1241.00	1.0000	inf
DLKDLZ	$.10x10^{-6}$	9932.00	1.0000	inf
DLZDLL	$.41x10^{-8}$	9626.00	1.0000	inf
det(XX)	$.10x10^{-26}$			
Specification - B				
DLK	14.97	1.00	0.9997	$33x10^2$
DLL	2.32	2.51	0.9993	$14x10^2$
DLZN	0.02	26.89	0.9985	667
$(DLK)^2$	0.10	34.44	1.0000	inf
$(DLL)^2$	$.78x10^{-3}$	137.82	1.0000	inf
$(DLZN)^2$	$.50x10^{-4}$	544.60	0.9996	$25x10^2$
DLKDLL	$.12x10^{-4}$	$11.00x10^2$	1.0000	inf
DLKDLLZN	$.57x10^{-6}$	$51.00x10^2$	0.9999	$10x10^3$
DLZNDLL	$.48x10^{-8}$	$56x10^3$	0.9999	$10x10^3$
det(X'X)	$.10x10^{-25}$			

Table 4

Results of RR-CD Model

Dependent variable Q.

Variables	Unrestricted Model		Restricted Model			
	Specification		Specification - A		Specification B	
	A	B	$b_1+b_2+b_3=1$	$b_1+b_2=1$	$b_1+b_2+b_4=1$	$b_1+b_2=1$
1	2	3	4	5	6	8
Constant(bo)	-16.8140	-18.7210	-3.3710	0.78132	-3.5084	-6.9902
LK(b_1)	0.5307 (25.6410)	0.5504 (25.5810)	0.2934 (6.6686)	0.3478 (12.6270)	0.2930 (8.2164)	0.3440 (13.053)
LL(b_1)	1.1436 (27.5090)	1.2380 (25.2600)	0.4316 (11.3900)	0.6527 (23.6570)	0.4880 (14.688)	0.6580 (25.005)
LZ1(b_3)/ LZN(b_4)	0.1585 (13.1830)	0.1042 (9.1835)	0.2740 (9.8043)	0.2626 (16.095)	0.2182 (9.6660)	0.2074 (13.403)
k	0.0666	0.0857	0.0666	0.0666	0.0857	0.0857
R^{-2}	0.9928	0.9905	0.9460	0.9752	0.9401	0.9036
SSE	0.0186	0.0245	0.1453	0.0664	0.7611	0.0981
σ^2	$.74\times10^{-3}$	$.97\times10^{-3}$	$.559\times10^{-2}$	$.25\times10^{-2}$	$.62\times10^{-2}$	$.37\times10^{-2}$

1 t-values in parentheses; and RR-CD = Ridge Regression Cobb-Douglas Model

Table 5

Estimates of RR-TL Production Function

Explonatry Variables	Unrestricted Model		Restricted Model	
	A	B	A	B
Constant	-.0194	-.0280	.0004	.0002
DLL	1.0945	1.1140	.6358	.6526
	(39.8267)	(32.6792	(405.630)	(275.86)
DLK	.4694	.4620	.2584	.2668
	(38.5272)	(42.5757)	(106.060)	(211.66)
DLZI/ DLZN	.1791	.1378	.1058	.0805
	(28.7517)	(28.3132)	(59.1570)	(65.1985)
$(DLL)^2$	2.9151	4.0853	-.0043	-.0009
	(2.67490	(4.0173)	(-3.0940)	(-.8279)*
DLK^2	.4897	.4580	-.0009	-.0343
	(2.7967)	(2.9358)	(-.6908)*	(-4.8078)
$(DLZI)^2$/ $(DLZN)^2$	-.1041	-.0036	-.0036	-.0022
	(-2.7710)	(-3.0128)	(-3.0345)	(-3.0560)
DLKDLZI/ DLKDLZN	-.0092	-.0086	.0001	.0024
	(-.5896)*	(-.6162)*	(.2090)*	(6.2140)
DLKDLL	.5997	.6902	.0007	.0011
	(3.8997)	(4.7088)	(.8288)*	(1.6808)*
DLZIDLL/ DLZNDLL	-.0280	.0096	.0035	-.0001
	(-.5558)*	(.2638)*	(3.0179)	(-.1668)*
Value of k	.0770	.0950	2.0000	3.0000
R^{-2}	.9947	.9989	.7446	.7423
SSE	.0109	.0125	.6079	.6134
σ^2	$.578x10^{-3}$	$.667x10^{-3}$	.0264	.0267

1 t-values in parentheses; 2 RR-TL = Ridge Regression Translog model; and * coefficients are not significant

Table 6

Elasticity of Substitution Between

Value of k	K & ZI		K & ZN	
	Allen	Morishima	Allen	Morishima
0.019	.0220	.0315	.1060	.1114
0.027	.0272	.0421	-	-
0.028	-	-	.1298	.1487
0.037	.0320	.0536	-	-
0.043	-	-	.1580	.2014
0.051	.0370	.0671	-	-
0.061	-	-	.1818	.2587
0.064	.0405	.0775	-	-
0.077	.0432	.0863	.1976	.3019
0.095	-	-	.2115	.3428
0.800	.0799	.2052	.3063	.6588
1.000	.0867	.2234	.3130	.8784
2.000	-	-	.3347	.7359
3.000	-	-	.3493	.7710

Table 7a

Partial Elasticity of Substitution Between Factors (Specification - A)

Value of k	KZ	KL	LZ	KK	LL	ZZ
0.019	.0220	$-.75x10^{-5}$	$.59x10^{-5}$	.0037	$.66x10^{-8}$	-.1662
0.027	.0270	$-.85x10^{-5}$	$.97x10^{-5}$	.0038	$.66x10^{-8}$	-.2042
0.037	.0320	$-.95x10^{-5}$	$.15x10^{-4}$	.0037	$.63x10^{-8}$	-.2462
0.051	.0370	$-.10x10^{-4}$	$.21x10^{-4}$	.0037	$.57x10^{-8}$	-.2954
0.064	.0405	$-.11x10^{-4}$	$.26x10^{-4}$	.0037	$.52x10^{-8}$	-.3340
0.077	.0432	$-.12x10^{-4}$	$.31x10^{-4}$	.0037	$.47x10^{-8}$	-.3670
0.800	.0799	$-.17x10^{-4}$	$.94x10^{-4}$	.0013	$-.37x10^{-8}$	-.8220
1.000	.0867	$-.18x10^{-4}$	$.10x10^{-3}$	.0005	$-.49x10^{-8}$	-.8939

Table 7b

Partial Elasticity of substitution Between Factors
(Specification - B)

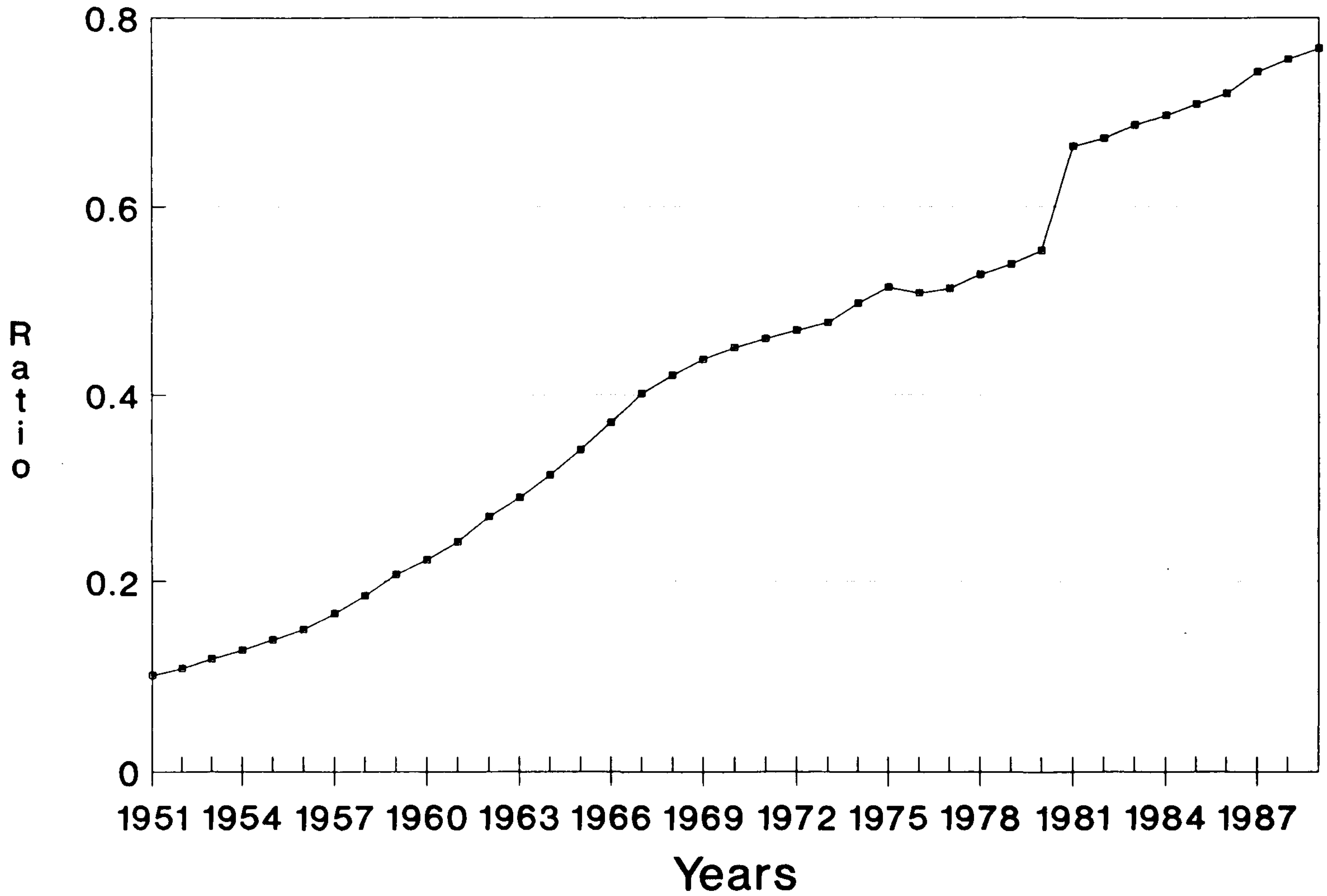
Value of k	KZ	KL	LZ	KK	LL	ZZ
0.019	.1060	$.51x10^{-8}$	$-.61x10^{-6}$	.0035	$.78x10^{-10}$	-2.6701
0.028	.1298	$.51x10^{-8}$	$-.60x10^{-6}$	.0029	$.87x10^{-10}$	-3.2706
0.043	.1580	$.50x10^{-8}$	$-.59x10^{-6}$	.0022	$.75x10^{-10}$	-4.2322
0.061	.1818	$.49x10^{-8}$	$-.58x10^{-6}$	.0017	$.74x10^{-10}$	-5.2308
0.077	.1976	$.48x10^{-8}$	$-.57x10^{-6}$	.0013	$.73x10^{-10}$	-5.9784
0.095	.2115	$.48x10^{-8}$	$-.57x10^{-6}$	.0015	$.72x10^{-10}$	-6.6817
0.800	.3063	$.38x10^{-8}$	$-.46x10^{-6}$	-.0014	$.58x10^{-10}$	-11.9647
1.000	.3130	$.36x10^{-8}$	$-.43x10^{-6}$	-.0016	$.55x10^{-10}$	12.2927
2.000	.3347	$.29x10^{-8}$	$-.35x10^{-6}$	-.0023	$.44x10^{-10}$	13.2760
3.000	.3493	$.24x10^{-8}$	$-.29x10^{-6}$	-.0027	$.37x10^{-10}$	13.8913

Table 8

Compound Growth Rate of ZI and K in Different Periods

Period	ZI (%)	K (%)	Ratio of ZI K
1951-89	8.17	2.66	-
1951-60	12.21	2.59	0.15
1961-89	6.58	2.70	-
1961-70	9.92	2.40	0.36
1971-80	4.82	2.78	0.51
1981-89	5.73	3.77	0.72

Trend in Ratio of ZI and K



REFERENCES

Ahluwalia, IJ (1982) *Industrial Performance in India: 1959-60 to 1978-79: An anlysis of Deceleration in Growth Since the Mid-Sixties*, Oxford University Press, Delhi.

Ahluwalia, IJ (1991) *Productivity and Growth in Indian Manufacturing*, Oxford University Press, Delhi.

Aschauer, D A (1989) Is Public Expenditure Productive?, *Journal of Monetary Economics*, 177-200.

Aschauer, D A (1989) Does Public Capital Crowd Out Private Capital? Journal of Monetary Economics, 24, 171-188.

Belsley, D, Kuh, D and Welsh, R E (1980), Regression Diagnostics, Wiley, New York.

Bhattacharaya, BB ( ) *Public Expenditure, Inflation and Growth: A Macroeconomic Analysis for India*. Oxford University Press, New Delhi.

Brown, W G and Beattie, B R (1975), Improving Estimates of Econometric Parameters by Use of Ridge Regression with Production Function Applications, *American Journal of Agricultural Economics*, 57, 21-32

Chambers, R G (1988) *Applied Production Analysis*, Cambridge University Press.

Corbo, V and Meller, P (1979), The Translog Production Function, *Journal of Econometrics*, 10, 193-199.

Dholakia, B H (1974), *The Sources of Economic Growth in India*, New Delhi, Good Companions.

Duffy-Deno, K T and Eberts, R W (1989) Public Infrastructure and Regional Economic Development: A Simultaneous Equation Approach, Working Paper 8909

Eberts, R W and Fogarty, M S (1987) Estimating the Relationship between Local Public and Private Investment, Working Paper 8703, Federal Reserve Bank of Cleveland.

Garcia-Mila, Teresa and Therese J McGuire (1987), The Contribution of Publicly Provided Inputs to States Economy. (Forthcoming in *Journal of Regional Science*)

Hoerl, A.E., Kennard, R.W. and Baldwin, K.F. (1975), Ridge Regression: Some Simulation, *Communications in Statistics*, A, 4, 105-123.

Hoerl, A.E.and Kennard, R.W. (1976), Ridge Regression: Iterative Estimation of the Baising Parameters, *Communications in Statistics*, A 5 77-88.

Hulton, Charles, R. The Measurement of Capital, in E.R. Berndt and J.E. Triplett (Ed.) (1990) *Fifty Years of Economic Measurement*, The University of Chicago Press, 119-158.

Krishnamurty, K and Pandit, V (1984), Macroeconometric Modelling of the Indian Economy: An Overview, *The Indian Economic Review*, 19, 1, 1-15.

Mundlak, Y (1979), Elasticities of Substitution and the Theory of Derived Demand, *Review of Economic Studies*, 35, 225-236.

Munnel A H (1990), How Does Public Infrastructure Affect Regional Economic Performance? in *Ia There a Shortfall in Public Capital Investment?* Proceedings of a Conference Held in June 1990.

Srinivasan, TN and Narayana, NSS(1977), Economic Performance since the Third Plan and Its Implications for Policy. *Economic and Political Weekly*, Annual Number.

Sundararajan, V and Thakur, S (1982) Public Investment, Crowding out and Growth: A Dynamic Model Applied to India and Korea. *IMF Staff Papers*.

Vinod, H D (1978) A Survey of Ridge Regression and Related Techniques for Improvements over Ordinary Least Squares, *Review of Economics & Statistics*, 60, 121-131.

Vinod, H D and Ullah, A (1981), Recent Advances in Regression Methods, Marcel, Dekker, New York.

CONSTRUCTION OF CAPITAL STOCK DATA IN PUBLIC SECTOR

As it is pointed in the text that we do not have sector wise capital stock data for public sector for the years from 1960-61 to 1979-80. The data on capital stock for all sector combined for pubic sector prior to 1980-81 are available but at current prices. Our problem is construct the sector wise capital stock data at constant price for public sector.

In fact we have data on gross fixed capital formation (GFCFz) and consumption of fixed capital formation (CFCz) at current prices for public sector for the period from 1950-51 to 84-85. From these data it is not difficult to construct the net fixed capital stock for public sector using 1980-81's net capital stock for public sector. However, we need to convert GFCFz and CFCz from current to constant prices. The data on GFCF and CFC pertaining to the whole economy are available at both current and constant prices. We derived two deflators: one obtained by dividing gross capital formation for the whole economy at current prices by that at constant prices and another obtained by dividing CFC for the whole economy at current prices by that at constant prices. These deflators were used to convert GFCFz and CFCz at constant prices (1980-81's prices). With the help of these two variables, a series of net fixed capital stocks (NFCSz) at 1980-81's price for public sector can be constructed using a perpetual inventory method. The method can be expressed as

FOR 1960-61 to 79-80

$$NFCS^z_t = NFCS^z_{(t+1)} - (GFCF^z_t - CFC^z_t)$$

where t represents 1979-80 ... 1960-61

FOR 1981-82 to 1988-89

$$NFCS^z_t = NFCS^z_{(t-1)} - (GFCF^z_t - CFC^z_t)$$

where t represents 1981-82 ... 1988-89

Although the data on $NFCS^z$ for the period from 1980-81 onward are available from national account statistics, these are estimated as well so as to examine the accuracy of our estimates. It is found that the difference between estimated data on $NFCS^z$ and those compiled from national account statistics for 1980-81 to 84-85 is insignificant. This indicates the reliability of our estimates.

Having obtained the series of $NFCS^z$ for 1960-61 to 1988-89, we using NFCS data for the whole economy computed two ratios for each years in the period from 1950-51 to 1979-80: one is NFCS in infrastructure to total NFCS and second NFCS in non-agricultural sector to total NFCS. These ratios are employed to obtain NFCS in infrastructure in public sector and NFCS in non-agricultural in private economy simply by multiplying the first ratio with aggregate NFCS in public sector and second with aggregate NFCS in private sector. Using sectorial proportion at national level to compute sectorial NFCS for public and private sector may be objectionable. However we found that there is a remarkable similarity between these ratios at national level and public and private sectors' level for the period from 1980-81 to 88-89 for which data on capital stocks are available for public and private sectors separately.

Table A1

OLS Estimates of CD and TL Models

Variables	CD Model Specification		TL Model Specification	
	A	B	A	B
Constant	-3.4741	-5.4362	26980	27991
LK	1.1561 (8.2401)*	1.3843 (16.9330)*	2548 (1.9728)	2436 (2.0962)*
LL	-.1431 (-1.3824)	-.0069 (-.0749)	-4557 (1.4222)	-4677 (-1.7181)
LZI/LNZ	.1283 (1.8017)	.0091 (.2808)	-225 (1.1243)	-109 (-1.5182)
$(LK)^2$	-	-	87.7800 (1.8193)	78.7500 (2.0429)*
$(LL)^2$	-	-	377 (1.5556)	383 (1.8167)
$(LZI)^2$/ $(LZN)^2$	-	-	-2.0470 (-1.5349)	-1.3863 (-2.2997)*
LKLL	-	-	-200 (-1.9401)	-189.1000 (-2.0981)*
LKLZI/ LKLZN	-	-	-.7206 (-.1042)	1.6104 (.5886)
LZILL/ LZNLL	-	-	14.3800 (.9525)	5.8287 (1.1024)
R^{-2}	.9963	.9961	.9973	.9975

Notes: 1 L denotes variables in natural log, 2 t-values in parentheses and 3 * Significant at the 5 per cent level of significants.

NIPFP WORKING PAPER SERIES : 1991-92

Working Paper No.	Title	Author's Name
1/91	Do Rate Schedules Affect Sensitivity of Personal Income Tax? An Evidence from a Developing Country	Pawan K Aggarwal (January, 1991)
2/91	Effect of Domestic Government Debt on Private Consumption And Saving in India	S Gopalakrishnan (April, 1991)
3/91	Reforms in Indian Sales Tax System	Mahesh C Purohit (June, 1991)
4/91	Monitoring Budget Deficits with Time Series Models Some Observations	JVM Sarma (June, 1991)
5/91	Public Expenditure in India: Emerging Trends	M Govinda Rao V B Tulasidhar (June, 1991)
6/91	A New Global Measure of Tax Progressivity	Pawan K. Aggarwal (August, 1991)
7/91	A New Hybrid Measure of Tax Progressivity	Pawan K. Aggarwal (August, 1991)
8/91	Priorities in Resource Allocation for Health Care in India: A Basic Needs Approach	K.N. Reddy K.K. Tripathy (August, 1991)
9/91	Domestic Market Structure And Exports in a Developing Country	Murali Patibandla (October, 1991)
10/91	Tax Reform in Developing Countries Agenda for the 1990s	Amaresh Bagchi (November, 1991)
11/91	Foreign Collaborations, Foreign Direct Investment And Taxation of Foreign Companies in India : Some Policy Issues	Manoj Pant (December, 1991)

12/91	Protection, Growth And Competitiveness : A Study of the Indian Capital Goods Industry	Sudipto Mundle Hiranya Mukhopadhyay (December, 1991)
1/92	Containment of Food Subsidy in the Context of Revenue Deficit	K.N. Reddy V. Selvaraju (January, 1992)
2/92	Some Simple Economics of Eximscrips	Mihir Rakshit (February, 1992)
3/92	Horizontal Equity and Disequalising Intergovernmental Transfers: An Example	A. Das-Gupta (April, 1992)
4/92	Analysing Progressivity of Personal Income Taxes: A Case Study of India	Pawan K. Aggarwal (May, 1992)
5/92	Trade and Exchange Rate Policy with a Binding Foreign Exchange Constraint	Mihir Rakshit (July, 1992)
6/92	Causality Between Public Expenditure and GNP: The Indian Case Revisited	J.V.M. Sarma V.V. Bhanoji Rao (July, 1992)
7/92	Framework for Design of Management Information System for Tax Administration: A Case Study of Somalia	M.C. Purohit (September, 1992)
8/92	Deficit Financing, Indirect Taxation and Exchange Rate Adjustment: A Preliminary Exercise	Hiranya Mukhopadhyay (September, 1992)
9/92	A Note on Central Government Expenditure	Sudipto Mundle Hiranya Mukhopadhyay (September, 1992)
10/92	Fertility Differential, Population Growth and Fiscal Operations	Mahesh C. Purohit D.N. Rao (September, 1992)
11/92	Maternal Education, Female Labour Force Participation and Child Mortality: Evidence from Indian Census	V.B. Tulasidhar (September, 1992)
12/92	Issues in Fiscal Policy	Sudipto Mundle M. Govinda Rao (November, 1992)
13/92	Evaluation of Concessions for Housing under Personal Income Tax	Rita Pandey (November, 1992)
14/92	Health Expenditure in India	K.N. Reddy (November, 1992)
1/93	Local Fiscal Response to Expenditure Reassignment and Fiscal Decentralisation in India	Shyam Nath Mahesh C. Purohit (January, 1993)