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AN EMPRICAL INVESTIGATION INTO THE EFFECTS OF PUBLIC INVESTMENT EXPENDITURE ON PRIVATE CAPITAL ACCUMULATION: CASE OF THE TURKISH ECONOMY BETWEEN THE YEARS 1963-85*

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Abstract:

The main focus of this work is to see whether or not higher public capital accumulation always results in a crowding out of private investment. Even though it is not usually seen as such, on neoclassical grounds, the composition of public expenditure is an important factor both in terms of analyzing differential economic impacts of public capital on the economy and guiding public investment policy. However, the present work primarily deals with the impact of an increase in public investment in infrastructure. For an increase in public investment in infrastructure nevertheless creates two opposite effects on private capital accumulation. On the one hand, it crowds out private investment by raising the national investment rate above the optimal level chosen by the private sector agents; and, on the other hand, it also raises the return to private capital, thereby inducing a crowding-in of private capital accumulation. But the final outcome of these two channels depends upon the degree of complementarity between public investment and private production, as well as the level of the public capital stock. The model

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performance results of the Turkish case show a high degree of complementarity between public investment in infrastructure and private capital accumulation. The policy simulation results suggest that expansionary public policy in the case of infrastructure has beneficial effects on the economy. However, in the case of state economic enterprises the converse is true.

Özet:

1963-85 Yılları Arasında Türkiye Ekonomisindeki Kamu Yatırım Harcamalarının Özel Sektör Kapital Birikimi Üzerindeki Etkileri Konulu Ampirik Bir Çalışma

Bu çalışmanın temel amacı kamu kapital birikiminin özel yatırımlar üzerinde her zaman dışlama etkisiyle sonuçlanıp sonuçlanmayacağını göstermektir. Neoklasik temellerde, genelde öyle görülmemekle birlikte, kamu harcamalarının içeriği hem kamu kapitalinin ekonomi üzerindeki farklı etkilerini analiz etmede hemde kamu yatırım politikalarını yönlendirmede önemli bir etkendir. Altyapı yatırımlarına giden kamu harcamalarındaki herhangibir artış özel sektor kapital birikimi üzerinde zıt yönlü iki etki yapmaktadır. Bir yandan ulusal ekonomideki genel faiz seviyesini arttırarak özel yatırımları olumsuz etkilerken, öte yandan özel kapitalin getirisini arttırarak onun kapital birikimini olumlu yönde etkilemektedir. Fakat bu iki ters etkinin sonucu kamu kapitali ile özel sektor üretimi arasındaki tamamlayıcılık derecesi ile kamu kapital stoku seviyesine baglıdır. Bu model çalısmasının sonuçları Türkiye'de altyapı kamu harcamaları ile özel sektor kapital birikimi arasında ileri derecede tamamlayıcılık özelliği olduğunu göstermektedir. 'Politika simülasyon sonuçları ise genisleyici kamu harcamalarının altyapı için olumlu etkilerini ortaya koyarken Kamu İktisadi Teşekkülleri için bu durumun tersi olduğunu göstermektedir.

1. Introduction

This paper considers the question of whether or not higher public capital accumulation always crowds out private investment. In general, a rise in public investment creates two opposite effects. On the one hand it raises the national investment rate, thereby inducing an ex ante crowding out of private investment. On the other hand, an increase in the public capital stock, especially infrastructure capital, raises the marginal productivity of private capital, thus crowding in private capital accumulation. As a result, the final outcome depends upon the degree of

complementarity between public investment and private production, as well as the level of the public capital stock.

In what fallows, first a summary of investment models and our model specification are sketched and then empirical evidence on the net effect of a rise in public investment in infrastructure on the Turkish economy between the years 1963-85 is presented.

2. Traditional Models

2.1 Theoretical Framework

In the following, a sketch of the constituent elements of the conceptual frameworks of the various economic paradigms is presented.

In the Neoclassical Approach: Among many others, Jorgensons' pioneering studies are noteworthy and utilized widely. Jorgenson bases his model on the theory of a firm which maximizes its present value. In the process, the change in the desired level of capital stock is determined by the user cost of capital, which includes prices, interest rate, corporate tax rate, etc.[1]

In the Keynesian Framework: Until very recently, Keynes' original contribution to investment demand theory was most appealing. His work distinguishes the internal rate of return on various investment projects or assets from the alternative cost of investing, which is the interest rate prevailing in the economy. Put simply, Keynesian investment demand is explained by the relative price of a capital asset, which represents the ratio of the demand price of capital over the supply price of capital.

This ad-hoc determination of investment demand was later challenged by neo-Keynesians such as Tobin in the `60s and `70s. As a result, a new concept of Q theory emerged. Q theory, in its simple form, posits that Keynesian investment demand function is directly related to the gap between the marginal productivity of capital (MPK) and the cost of capital. Q is then a function of capital stock, labor demand, real interest rate, and depreciation rate.

The structure of the preceding Keynesian model rules out a perfect market in the existing capital stock in which firms can engage in trading their own existing capital. Instead, they add to their capital stock at a finite rate per unit of time.

The theoretical foundations of this weak ad-hoc Keynesian investment demand theory were later enhanced and rationalized by economists such as Eisner, Strotz, Lucas, Gould, and Treadway, all of whom incorporated the concept of the costs of adjustment into the neoclassical profit maximizing behavior of a firm (Sargent 1979).

The Accelerator Theory of Investment: This is mainly concerned with the explanation of investment behavior. The simple form of this theory postulates a certain fixed relationship between the optimum capital stock and output, in that it is a special case of the neoclassical theory (Ott 1975).

2.2. Policy Implications

In traditional Keynesian macroeconomic models, scant attention is given to the analysis of any possible differential economic impacts of various forms of public spending. This is primarily due to the fact that the demand-side oriented nature of the Keynesian model does not allow for a consideration of such effects on private capital accumulation; if anything, it would be a result of government purchase of goods and services, rather than the composition of such spending (as opposed to tax-financed), which might either induce an ex post crowding-out of private investment through raising real interest rates, or which might crowd-in private investment via a rise in output to permit higher private and public expenditure (Eisner 1986). Bailey (1971), however, considered the possibility that households might internalize the future taxes implicit in current public debt issuance, while at the same time differentiating between public consumption and public investment spending. He worked out government spending multipliers under differing sets of assumptions, such as households regarding public consumption as a perfect substitute for private consumption. In this instance, an increase in government consumption induces an ex ante decrease in private consumption in such a way that the output effect of the public spending is nil.

David and Scadding (1974) also emphasized the possibility of such an ex ante crowding out of private by public expenditure. Their argument was that a rise in government bond issuance crowded out an equal amount of private investment,

since deficit finance is regarded as public investment and public investment substitutes for private capital spending. Further, tax-financed government spending was treated as government spending, crowding out an equivalent amount of private consumption. Thus, the result was that fiscal policy had no effect on the level of aggregate demand. Certainly, this argument is consistent with the postulation of an "ultrarational" consumer only if public capital expenditures are, as a rule, debt-financed.

3. Aschauer Vis-a-Vis Neoclassical Models

3.1 Theoretical Framework

The following is obtained from a two-period representative agent model in an intertemporal setting in the context of the neoclassical framework. A Rise in Public Investment is given by[2]

$$\frac{d(ip)}{d(ig)} = -1 + \frac{f_{11}}{\Delta} - \frac{f_{12}}{\Delta} - \frac{\rho}{r}\frac{(f_1 - f_2)\frac{\partial c_1^*}{\partial w}}{\Delta} \qquad (1)$$

where:

$$\Delta = f_{11} - \frac{\rho}{r}\left[r\frac{\partial c_1^*}{\partial w} + \frac{\partial c_2^*}{\partial w} \right],$$

$$\frac{\partial c_1^*}{\partial w} = \frac{-ru'(c_1^*)u''(c_2^*)}{[u'(c_2^*)]^2}, and \frac{\partial c_2^*}{\partial w} = \frac{-ru'(c_2^*)u''(c_1^*)}{[u'(c_2^*)]^2}$$

$\partial\chi_1^*/\partial\omega$, $\partial\chi_2^*/\partial\omega$ are defined as the present and future marginal propensities to consume out of wealth; f_{11} is the marginal productivity of private capital and f_{12} that of public capital, respectively.

We may at this stage begin the discussion of the substitution and complementarity of private and public capital in the private production process.

As a reference case, suppose that private and public capital are perfect substitutes in the private production process, so that future output is dependent only on the national capital stock, such that $f' > 0$, $f'' < 0$. In this case only the first term

on the right hand side of equation (1) remains, indicating a complete crowding-out of private by public capital accumulation. For the most part, public investment policy would be irrelevant to private sector outcomes, the only exception being that private capital would become a smaller fraction of the national capital stock.

In general, however, public capital is likely to bear some complementary relationship to private capital, so that $f_{12} > 0$. In this instance, a rise in public investment and direct substitution for private investment would have additional effects.

First, the reduction in the private capital stock would boost the marginal product of private capital and, given the interest rate, would provide a mitigating effect on private investment expenditure; this is captured by the second term in equation (1).

Second, the rise in public capital, given $f_{12} > 0$, raises the marginal product of capital directly and provides an additional offset to the direct effect on private investment, as is evidenced by the third term.

Finally, the public capital stock may be too low, in which case $f_2 > f_1$, or too high, so that $f_2 < f_1$. If the public sector has over-accumulated capital, an addition to the public capital stock and an equal crowding-out of private capital would lower future output, creating a negative future income effect. The attempt by the agent to bear some of this future burden in the present results in a final possible partial offset to the direct effect of higher public capital accumulation on private investment expenditure, as in the last term in equation (1).

Thus, holding fixed the rate of return to the private capital stock (thereby putting aside the second and third terms in equation (1), higher public investment would be expected to crowd-out a nearly equal amount of private investment, somewhat more if the public sector has accumulated too much capital, but somewhat less in the alternative case.

In summary of the above analyses, an empirical study of the effects of fiscal policy on private investment should, according to the neoclassical model, produce results consistent with the following hypothesis. Basically, an increase in public investment expenditure, given the return to private capital stock, should have a significantly negative impact on the level of private capital formation. Given that

public and private capital are perfect substitutes in private production, the crowding-out of private capital should be complete, while in more general cases the crowding-out would be of a greater or lesser degree, depending on the extent to which the public sector has accumulated the appropriate level of capital.

3.2. Policy Implications

Aschauer's work basically departs from the conventional crowding-out models on two grounds. First, it is based on the inter-temporal optimization problem of a representative agent rather than the profit-maximizing behavior of a firm. Second, his theory of crowding-out is explained by the type of government expenditure rather than by the method by which a government finances its expenditures, as in the usual description of the crowding-out phenomenon.

The classical approach posits that if the government chooses to finance its expenditure by using bonds, which in turn raises interest rates, private investment expenditures would also tend to fall, thus causing a fall in private capital accumulation.

By contrast, in his own formulation, Aschauer argues that, in the neoclassical framework, the crowding-out of private capital accumulation is actually an inter-temporal issue, although it is not usually perceived as such. Hence, the determining factor is the inter-temporal incidence of benefits from public expenditure rather than the inter-temporal pattern of government finance.

The argument here is based on two assumptions: first, that individuals are rational in the full "Ricardian" sense, recognizing the future tax liabilities implicit in public debt issuance; and second, that there exists a welfare linkage between members of the current and future generations, also known as "operative intergentional transfers (Barro 1974)."

The equivalence between tax and debt finance is of crucial importance to the neoclassical analysis of fiscal policy, as it shifts the focus of attention from financial to real resource considerations. Aschauer goes on to say that previous neoclassical studies of the macroeconomic effects of public expenditure have either ignored the inter-temporal timing of benefits or have stressed the distinction between the temporary and permanent component of government spending. In contrast, his theoretical approach places the emphasis on the distinction between

government expenditure, which primarily provides current benefits, such as school lunch programs and postal service, and those which provide future benefits, such as public investment in highways, canals, etc. - that is, infrastructure.

Along these lines, Aschauer later embarked on an empirical investigation into the effect of public expenditure on private capital accumulation (Aschauer 1988). In this work, holding the rate of return to private capital fixed, he found public investment spending was significantly depressive to private investment.

However, in his more recent work (Aschauer 1989) entitled "Does Public Capital Crowd Out Private Capital?," Aschauer further analyzed the effect of higher or lower public capital on the rate of return to private investment. He found that the rate of return to private capital responds positively to an increase in public investment, thereby indicating that there has indeed been a historical neglect of infrastructure-related public spending, simply because private and public capital act as complements in the private production process.

Aschauer also carried out another study utilizing a different methodological track whereby he obtained productivity measures assuming competitive product and factor markets. His findings point to a strong correlation between infrastructure capital and private sector productivity.

In sum, according to the neoclassical model, it is hypothesized that a rise in public investment expenditure would induce a complete crowding-out of private capital by public capital accumulation if private and public capital are perfect substitutes in private production. However, in more general cases, there exists a complementary relationship between the two. If this is the case, the crowding-out then more or less depends on whether or not the public sector has accumulated the appropriate level of capital.

At this juncture, it is worth touching upon one of the assumptions of the Aschauer model, namely the "Ricardian" principle of the possibility of an equivalence between public debt and taxes in the financing of government spending. This has been a subject of controversy and a great deal of empirical investigation has in turn been devoted to it.

General surveys, such as those of Aschauer (1988), Bernheim (1987), Leiderman and Blejer (1989), and most recently Barro (1989), have cited

equations, below, we would like to discuss the appropriate estimation technique or methodology.

$$RIP_t = \alpha_0 + \alpha_1 * \sum_{T=t-2}^{t} MPK_T + \alpha_2 * \sum_{T=t-2}^{t} RIG_t + \alpha_3 * CUI_t + \alpha_4 * D787980 + \epsilon_1 \quad (2)$$

$$MPK_t = \beta_0 + \beta_1 * RIG_t + \beta_2 * CU2_t + \beta_3 * D77 + \beta_4 * D8485 + \epsilon_2 \quad (3)$$

where:

RIP = the ratio of private investment to G.N.P.,
RIG = the ratio of public investment to G.N.P.,
MPK = the marginal product of capital, exclusive of depreciation rate,
CU1 = the deviation of G.N.P. from its long-term linear trend,
CU2 = the deviation of the average G.N.P. per capital stock from its long-term linear trend,
D787980 = dummy variable having a value of 1 for the years 1978, 1979 and 1980, and 0 for the rest of the sample period,
D77 = dummy variable having a value of 1 for the year 1977 and 0 for the rest of the sample period,
D8485 = dummy variable having a value of 1 for the years 1984 and 1985, and 0 for the rest of the sample period,
ε = i.i.d. random error or disturbance term.

As pointed out in econometrics literature (Judge et al 1984 and Intriligator 1978), the use of ordinary least squares estimator (OLS) yields biased and inconsistent[4] structural parameter estimates of such a simultaneous equation model as the above. Nonetheless, if the system of equations (2) and (3) above is complete - that is, if the structural parameter matrix for endogenous variables is nonsingular or invertible - the so-called reduced form of the simultaneous equations system can be obtained by expressing the endogenous variables of the system as a function of the predetermined variables plus random disturbances (Judge et al 1984, pp.570-573). Consequently, although OLS is not a consistent way of estimating the structural parameters of the above system, it becomes consistent in estimating the parameters of the reduced form.

There now arises a question as to whether or not we can uniquely derive consistent estimates of the structural parameters from the estimates of the reduced form equations. This is the crux of the so-called "identification" problem in econometrics. The more rigorous treatment of the subject is discussed in most of the advanced econometrics books, (Judge et al 1984, pp. 573-586 , and Intriligator 1978, pp. 47-51) as it deals with satisfying necessary and sufficient conditions as to the rank and order condition of the parameter matrix, which is not dealt with here. Nonetheless, we show that our model is an over identified model in which there is more than one way of inferring structural parameters from the reduced form model. That is, the reduced form of the structural model above is given by

$$RIP_t = \gamma_0 + \gamma_1 * \sum_{T=t-2}^{t} RIG_T + \gamma_2 * CU1_t + \gamma_3 * D787980 + \gamma_4 + \gamma_5 * D77 + \gamma_6 * D8485 + \epsilon_1 + \gamma_7 * \epsilon_2 \quad (4)$$

$$MPK_t = \beta_0 + \beta_1 * RIG_t + \beta_2 * CU2_t + \beta_3 * D77 + \beta_4 * D8485 + \epsilon_2 \quad (5)$$

Where:

$$\gamma_0 = \alpha_0 + 3*\alpha_1*\beta_0 \;,\; \gamma_1 = \alpha_1*\beta_1 + \alpha_2 \;,\; \gamma_2 = \alpha_3$$
$$\gamma_3 = \alpha_4 \;,\; \gamma_4 = 3*\alpha_1*\beta_2 \;,\; \gamma_5 = 3*\alpha_1 + \beta_3 \;, \quad (6)$$
$$\gamma_6 = 3*\alpha_1*\beta_4 \;,\; \gamma_7 = \alpha_1$$

As seen above, there is more than one way of inferring the structural parameter a_1 from the reduced form model (eq. 4) above, which renders to an over identification.

4.2. Estimation Results

Estimation of the reduced form is undertaken by full-information methods, including both three-stage least squares (3SLS) and full-information maximum likelihood (FIML)[5] in order to accommodate the over identifying restrictions implicit in the structural model.[6] In these two methods, all structural equations are estimated jointly for the period 1968-1985 by improving upon the efficiency of the limited-information (single equation estimators) method. The TROLL econometric system on the mainframe is utilized for the estimation. Table 1 exhibits both 3SLS

and FIML estimation results with their statistical significance results, e.g., T-Statistics.

As Table 1. shows, the overall estimation results of both 3SLS and FIML methods are statistically significant at least at 95 percent confidence limit. They support the neoclassical argument of the crowding-out of private by public investment spending, since the estimated three-year moving average parameter measuring the sensitivity of private investment ratio to public investment ratio is .51 ($3*a_2$) for 3SLS and -.61 ($3*a_2$) for FIML. These coefficients indicate that higher public investment crowds out private investment in equipment and structures on a less than one-to-one basis, given the return to capital. Nonetheless, private capital accumulation responds positively to an increase in the rate of return to capital for a given public investment ratio. The estimated sensitivity coefficient of the private investment ratio to the return to capital is .33 ($3*a_1$) for 3SLS and .43 ($3*a_1$) for FIML as a moving average of three years.

Table 1. 3LSL and FIML Estimation Results

	3SLS	*RESULTS*	*FIML*	*RESULTS*
COEFF	*VALUE*	*T-STAT*	*VALUE*	*T-STAT*
α_0	.053	2.36	.37	1.52
α_1	.112	2.75	.143	3.08
α_2	-.172	-3.18	-.204	-3.08
α_3	1.4E-06	7.98	1.3E-06	6.00
α_4	.016	4.39	.016	4.61
β_0	.190	9.95	.178	10.1
β_1	.850	4.81	.960	5.89
β_2	.191	8.06	.192	3.14
β_3	-.020	-1.77	-.021	-2.00
β_4	.030	4.00	.027	3.68

Single Equation Statistics

3SLS	RSQ	SER	DW
EQ 1	.88	.0005	1.9
EQ 2	.76	.002	1.2
FIML	RSQ	SER	DW
EQ 1	.87	.0005	1.7
EQ 2	.77	.002	1.3

Where:

RSQ = R Square, which explains the percentage variation in the total variance,
SER = Standard error of regression,
DW = Durbin-Watson statistic which shows how to detect the presence of first-order autocorrelation.

The empirical results laid out above are consistent with Aschauer's empirical analysis in drawing the following conclusions: as higher public investment crowds-out private investment, given the return to capital, it also raises the return to capital, which, in turn, crowds-in private investment. Nonetheless, the combined effect of these two channels in our study is different from Aschauer's in that the return sensitivity coefficient to public investment ratio in both 3SLS and FIML results is almost one and renders a negative (g_1) of the reduced form above. Aschauer, on the other hand, has a positive (g_1) rendering to the combined crowding-in the private investment. The detailed representation of this phenomenon is explained in the policy simulation analysis of an increase in public investment on the private investment ratio in the next part.

4.3. On the Measurement of Marginal Productivity of Capital

In neoclassical models of investment and growth (Jorgenson) and neo-Keynesian models of investment (Tobin's q), marginal productivity of capital (MPK) is measured as being equal to the real user cost of capital and real profit rate, respectively.

Within the above-mentioned theoretical framework, as in most empirical works, we follow the same tradition of mainstream economics.

From the NIPA accounting identity, we write the following:

GDPV (at factor cost) ≡ Labor Compensation + Gross Profit

or

$$P_{gdp} * GDP \equiv P_l * L + p_k * K(-1)$$

where:

P_{gdp} = unit price deflator for GDP,

GDP = gross domestic product at constant prices,
P_l = unit labor cost,
L = number of people employed,
p_k = profit per unit of capital stock,
K(-1) = capital stock year-end value.

Therefore, real profit rate (RPR) is calculated as

$$P /(P_{gdp} * K(-1)) \equiv \pi_K / P_{gdp}$$

which is generally used as MPK-equivalent in the models.

Another possible way of measuring MPK is based on the theory of production functions. For a select functional form (e.g., Cobb-Dougles, CES, Translog, etc.), MPK is approximated as a first partial derivative. That is, for a Cobb-Dougles form of production function,

$$GDP \equiv f(K,L)$$
$$GDP \equiv K^{\alpha} L^{(1-\alpha)}$$

where constant returns to scale, (CRTS) is assumed to hold.

$$\frac{\partial GDP}{\partial K} \equiv MPK \equiv \alpha * \frac{GDP}{K}$$

Consequently, if we are able to estimate a in the above equation, MPK could also be estimated. However, there are certain problems associated with this approach:

- Knowing which functional fits the data.
- Estimation of a in an efficient manner is a difficult task if a's are time-varying and there is a structural breakdown in the coefficients, as is the case for the Turkish economy.
- If demand is also important in determining the prices in the market, then we need to incorporate the market structure, i. e., mark-up pricing phenomena, etc., into the picture.

Nonetheless, the two approaches should produce the same results, namely, that a is the relative share of profit to the output in the above production function.

That is,

$$\alpha \equiv \frac{\Pi}{GDPV}$$

In other words,

$$\alpha \equiv \frac{\Pi_k * K(-1)}{P_{gdp} * GDP}$$

since

$$MPK \equiv \alpha * \frac{GDP}{K}$$

$$MPK \equiv \frac{\Pi_k}{P_{gdp}} \qquad \text{(Real Profit Rate)}$$

In our model, MPK is measured as Π_k/P_{gdp}. Because of the difficulty associated with disaggregating the total profits into their private and public sector components, we were obliged to use aggregate profit rate as proxy for the private sector profit rate. Although we could in theory have measured MPK for the public and private sector on the basis of a production function, data limitations with respect to measuring the capital stock for the public and private sector separately caused us to adopt the above-mentioned proxy; that is to say, if

$$GDP \equiv K_p^{\alpha_p} K_g^{\alpha_g} L^{1-\alpha_p-\alpha_g}$$

CRTS holds.

$$MPK_p \equiv a_p * \frac{GDP}{K_p}$$

$$MPK_g \equiv a_g * \frac{GDP}{K_g}$$

Unfortunately, we have no reliable estimates of K_p and K_g for the Turkish case.

4.4. Data Construction and Sources

In an effort to compile the necessary data for our macroeconomic model, not only did we face such difficulties as the unavailability, unreliability, and constant revision of data common to most developing nations, but also those of establishing accounting consistency among data provided from a variety of sources. Thus, we chose to follow the meticulous methodology adopted on this subject by an expert, Demirors (1988).

In order to construct the database for our model, we have benefited immensely from the master database of the United Nations Department of Research and Policy Analysis (DRPA). In addition to the NIPA account data of the U.N., we utilized statistics from country-based sources such as the Turkish State Planning Organization (SPO) and State Institute of Statistics (SIS), as well as from the Statistical Annex of the Country Reports of the World Bank (WB).

We would like now to give a brief overview of how we reconciled data from various sources or accomplished accounting consistency.

In carrying out the aggregation of production data into seven sectors, the starting step was the 64-sector I-O table prepared by the SIS for use in preparing the Fourth Five-year Plan (1973-1978). This I-O table was aggregated into ten sectors by the SPO and into fifteen sectors by Celasun (1981), who attempted to reconcile I-O accounts with available NIPA accounts. These aggregation schemes are further reconciled by the WB researchers for utilizing both I-O data and NIPA data for their CGE model for Turkey. Consequently, a thirteen-sector aggregation scheme is adopted[7].

In our model, we considered a seven-sector aggregation scheme on the basis of the above thirteen-sector aggregation scheme of the WB, as we generated value added for seven sectors from the NIPA account provided by four different sources (SPO, SIS, U.N., and the WB Country Reports) to be consistent with our seven-

sector aggregation of the 1973 I-O table. We had difficulties in reconciling GDP at both constant 1968 prices and current prices obtained from the production side and the expenditure side of the various above sources. The reason for this difficulty arises from the fact that, while data for the production side on both current and constant 1968 prices were available for the period following the launching of the planning era in 1963, on the expenditure side data were available only in current prices. However, some estimated figures were available for the constant 1968 prices. These were introduced into the expenditure side by double-checking the data from the four sources cited earlier.

On the cost composition of value added, only wages and capital consumption allowances were given explicitly at current prices; hence, we were supposed to generate the profit rate utilized in our investment equation.

The first task was to generate capital stock. Aggregate capital stock is generated by using the perpetual inventory method. The most significant part of this stage is to determine the right level of the capital stock for the benchmark year. To our knowledge, most of the researchers who dealt with building a sort of I-O or CGE model tried to obtain capital stock on an ad hoc assumption of a reasonable ratio of capital to output. Subsequently, on that basis capital stock levels are produced in proportion to output growth.

Accordingly, we utilized the approach of an SPO expert (Temel 1982) who made one serious attempt to generate capital stock figures at 1980 prices. The less painful task in the process was to convert this capital stock at 1980 prices into that of 1968 prices. As a result, we were able to obtain conclusive real profit rates. On the wage side, we did not use any given daily wage level from the country-based sources such as census data, Social Insurance Institute data, etc. Instead, we generated wages as an average yearly wage income by dividing labor employment compensation figures by aggregate employment figures.

In conclusion, despite all the difficulties faced in the compilation of our database, accounting consistency is to a large extent established as a basis for empirical analysis.

5. Policy Simulation

This part presents the results of a dynamic ex-post simulation over the sample period of 1968-1985. It consists of two sections. The first concentrates on the predictive ability of the estimated model (ex-post dynamic simulation). The second section describes the dynamic policy simulation experiment of our statistically estimated model. It analyzes the impact on the endogenous variables of a change in the public investment ratio variable, as others are kept unchanged. The difference between the controlled and simulated solutions is shown by the duration and degree of sustained impact.

5.1. Model Performance

The estimated model is simulated dynamically over the period 1968-1985 by adopting the TROLL's system-optimizing algorithm on the mainframe computer. As a first step toward validation, while suppressing the error terms, the dynamic simulation is performed to solve for the endogenous (left-hand-side) variables of the model, given the actual "historical" values of the exogenous variables, the values of the estimated coefficients, and the initial values of the lagged dependent variables. The simulation is dynamic because the solution or prediction of the endogenous variables from the previous period is used for the lagged dependent variables for the solution of the current period (Fair 1984). As a second step, to determine how the simulated model tracks with the historical data, a comparison between the actual and the simulated "predicted" data is made. This is regarded as a useful test of the validity of the model. Consequently, we have constructed Table 2, which exhibits the results of three most common measures of predictive accuracy produced by the TROLL for our simulation analysis. These are RMSE (%), Root-Mean-Square Percentage Error; ME (%), Mean Absolute Percentage Error; and STD, Standard Deviation of the simulation. If ex-post predictions are perfect, these three measures are zero. In the following, the description of these three measures is given.

Table 2. RESULTS OF EX-POST SIMULATION: 1968-1985

VARIABLE	RMSE(%)	ME(%)	STD
MPK	3.45	.3613	.53
RIP	5.62	.383	5.77

The RMSE (%) is defined as:

$$RMSE(\%) = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{\hat{Y}_t - Y_t}{Y_t}\right)}$$

Where:

$\hat{Y}_t$ = the simulated value of Y.
Y_t = the actual value.
T= the number of observations in the simulation.

In sum, the RMSE (%) error is a measure of the deviation of the simulated variable from its actual time path. The smaller the RMSE (%), the more closely the model tracks the actual data.

The above deviation can also be expressed in absolute terms by defining the ME (%) error as:

$$ME(\%) = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{\hat{Y}_t - Y_t}{Y_t}\right)$$

The standard deviation (STD) of the simulation is, on the other hand, defined as the deviation of the simulated values from their simulated means, namely:

$$STD = \sqrt{\left(\hat{Y}_t - \frac{1}{T}\sum_{t=1}^{T}\hat{Y}_t\right)^2}$$

Of the three statistics above, the RMSE (%) is a best measure of the simulation performance; it is often used, since ME (%) may be close to zero if large positive and large negative deviations cancel out. As the definition of the RMSE (%) error clearly shows, the lower the percentage error, the more adequately the model traces the actual performance of the Turkish Private Sector Profit Rate (MPK) and Investment Ratio (RIP). The RMSE (%) for MPK and RIP are 3.5 and 5.6 percent, respectively.

Aside from the above statistics, we have examined the adequacy of the simulated variables in tracking the "turning points" in the actual historical variables, by which we mean those points at which a change in the respective simulated variables switches its sign. While a new spectrum of econometric research is pushing the frontiers in the study of "turning points," nonetheless, for the purpose of this study, we must be satisfied with the following graphic exposition. As Figures (1) and (2) show, although MPK has the lower RMSE (%), the predicted RIP more closely tracks the actual turning points in the historical RIP. Consequently, the three test statistics must be supplemented by incorporating a "turning point" analysis into evaluating predictive accuracy of models.[8]

5.2. Ex-post Policy Simulation

In this section, within the framework of the above simulation model, we analyze the effectiveness of Turkish public investment policy (mainly, infrastructure policy) during the 1980s in stimulating the desire of the private sector to acquire new equipment and structure to add to its existing capital stock, or for building new capital stock. The analysis focuses on the direction, degree, and size of the endogenous variables of the simulation model when public investment is shocked as all other variables remain unchanged. Hence, the difference between the shocked and controlled solutions is manifested in the responses of the model.

Table 3. exhibits the results for the macro-adjustment of private sector investment together with its return to a 10% (2631.7 million Turkish Liras (T.L.)) sustained increase in real public investment, as is sketched out in later paragraphs.

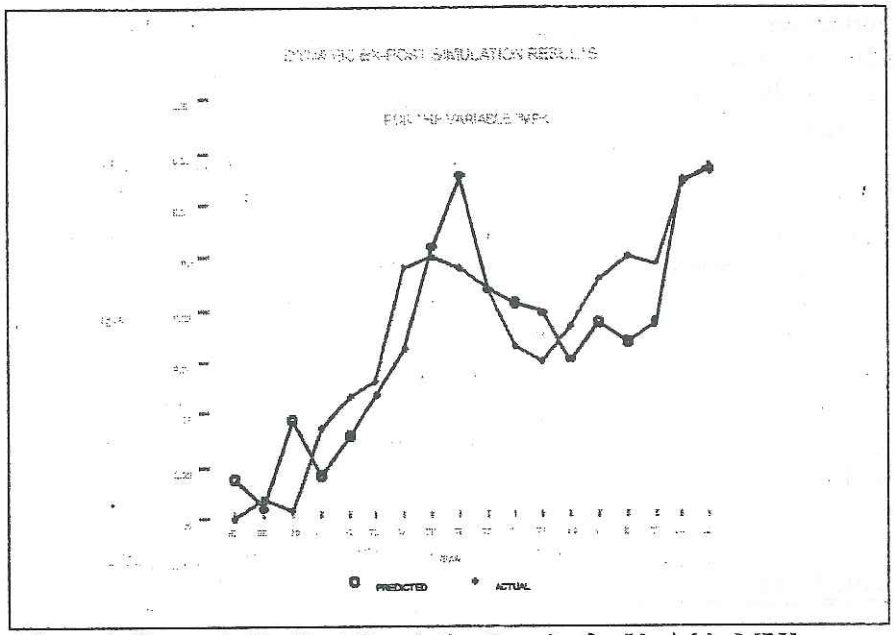

Figure 1. Dynamic Ex-Post Simulation Results for Variable MPK.

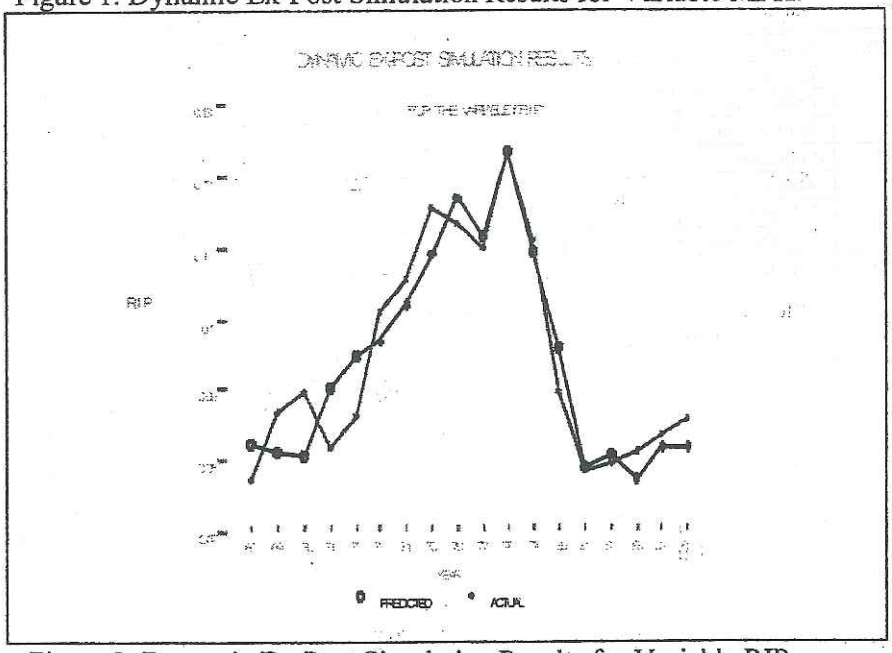

Figure 2. Dynamic Ex-Post Simulation Results for Variable RIP.

Furthermore, Table 3. presents the response of both the level of private investment and GNP to the studied public investment shock, as the model includes the general equilibrium identity, GNP, as equal to the sum of the components of aggregate demand, including IP and IG.

We find that a 10% sustained increase in public investment (equivalent to 10% of the real public investment value in 1981, which amounted to 2631.7 million T.L.) results in a continuum of crowding-out of private investment demand (IP) over the five-year simulation period. The crowding-out of IP accelerates from 1.74% in the first year to 4.77% in the second year, peaking to 7.62% in the third year, after which the crowding-out of IP begins to dampen. The private investment/GNP ratio (RIP) also follows the same trend as the private investment level. The return to capital (MPK), on the other hand, shows a moderate and stable upward movement, averaging around 3.2% per annum. Despite the crowding out of IP, GNP increases on a decreasing scale over the five-year simulation period.

Table 3. Effect of a 10% Sustained Increase in Public Investment

Variable		1st year	2nd year	3rd year	4th year	5th year
MPK	Simulated	0.307	0.310	0.309	0.324	0.327
	Actual	0.296	0.300	0.299	0.314	0.318
	Difference	0.010	0.010	0.010	0.009	0.010
	% Difference	3.501	3.424	3.446	3.179	3.056
RIP	Simulated	0.077	0.075	0.075	0.077	0.080
	Actual	0.079	0.079	0.081	0.084	0.086
	Difference	-0.002	-0.004	-0.007	-0.007	-0.006
	% Difference	-2.798	-5.518	-8.102	-7.758	-7.420
GNP	Simulated	21707 8	226026	231122	239991	246319
	Actual	214740	224243	229911	238818	245156
	Difference	2338	1783	1211	1173	1164
	% Difference	1.09	0.79	0.53	0.49	0.47
IP	Simulated	16605	16963	17229	18513	19572
	Actual	16899	17812	18650	19972	21040
	Difference	-294	-849	-1421	-1459	-1468
	% Difference	-1.74	-4.77	-7.62	-7.30	-6.98

Note 1: The first simulation experience is 1981.
Note 2: The statistics are calculated as follows:
Difference = (× - Y)
% Difference = ((× - Y)/Y)*100 ,
where:
Y = actual value of endogenous variables.
× = simulated value of endogenous variables.

Therefore, a 10% increase in public investment is still expansionary, expansion being fruitful in the short-run but fading away in the long-run, and is in agreement with the impact-multiplier analysis of Keynesian macroeconomics.

6. Conclusion

Given the results that have so far been presented in the model and policy simulation parts, it appears that expansionary public investment or infrastructure policy results in much less crowding-out of private investment than the one-to-one that neoclassical literature suggests. While public investment policy (inclusive of infrastructure) appears to be an effective tool in achieving a desired level of output growth in the short run, the effectiveness on output growth in the long run tends to dissipate as the dynamics of crowding-out, together with an upward movement in capital productivity, sets in. This raises a question concerning the adequacy of the public capital stock, for the estimated size and sign of the coefficients of the reduced-form model in the Turkish context imply that there might be an over accumulation of the public capital stock or infrastructure.

However, one needs to be very careful with this implication, since it might be an artifact of the necessary use of the limited data available for both public investment, as well as the estimate of proxy for the private sector rate of return. The former includes an investment component into the so-called inefficient statels, while the latter is, in essence, underestimated, given the overall inefficiency of the public sector, with its poor track record. Furthermore, in view of the significance of public investment in determining the private sector rate of return, and, in turn, both the former and the latter in explaining the private sector's behavior, as is evident in the large size of the coefficients, as well as in the model performance, there seems to exist a very strong complementary relationship between public and private investment. In sectors or industries where the private sector competes with the public, the relationship is then reversed. Therefore, if anything, the study suggests that, while public investment into the infrastructure has had an undeniably beneficial effect, its second component into the inefficient statels has brought about a drag on the economy, as is reflected by the magnitude of the under-utilized capacity.

Consequently, it is up to the public policy decision-makers and planners to determine the optimal level of public capital stock or infrastructure stock necessary for achieving a defined growth target, and at what point in the economic

development of the country the optimal level should be reached with given resource constraints.

Footnotes:

[1] See Ott (1975) for a thorough discussion.

[2] See Aschauer 1984 and Arslan 1993 for a complete exposition.

[3] Infrastructure Investment and Economic Development (Rural Strategies for the 1990's) by the USDA (December (1990).

[4] Unbiasedness, consistency, and efficiency are all the properties of estimators (see Intriligator 1978, pp 101-109 for further detail and description).

[5] For a rigorous mathematical exposition of these two full-information methods, see Judge et al (1984), pp. 599-602, and TROLL supplementary document entitled GREMLIN in reference to system-equation estimation.

[6] As cited in Judge et al (1984), pp. 614-615, "Consistent estimation of the parameters of a system of linear simultaneous equations requires identifying restrictions on the parameters. Therefore, the identifying restrictions are of a particular interest and tests are available for the overidentifying restrictions." Judge et al propose many alternative test statistics, one of which, also used by Aschauer (1989), is called Anderson's and Rubin's likelihood ratio test. Quoting from Judge et al, "The essential idea of the test is the following: if all the a priori restrictions on parameters are correct, then the ratio of the likelihood function for the restricted and unrestricted models should be close to one." Nonetheless, we utilized the restricted model for the estimation and did not estimate the reduced form in unrestricted fashion.

[7] See Appendix to the World Bank Country Report (1983) for a thorough exposition of the reconciliation of the various classifications of sectors adopted by above researchers and institutions.

[8] See Fair (1984) for alternative methods of evaluating predictive accuracy of models.

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