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Public infrastructure capital and private investment

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ABSTRACT

In contrast to the traditional macroeconomic models of fiscal policy which focus on the effects of government financing decisions on key private macroeconomic variables, more recent models downplay the relevance of fiscal financing decisions and focus instead upon the ability of variations in *real* fiscal variables such as tax rates and the current/capital spending mix to alter private incentives to invest, produce and consume. Although the recent work recognises the necessity for budgetary control as an important ingredient of responsible macroeconomic policymaking, cuts in the ratio of capital to current expenditure programs are recognised to have potentially adverse effects on the economy's infrastructure which may impede future performance. During the latter part of the 1980s in Australia, fiscal tightening resulted in the reigning in of capital rather than current spending programs. Concern with this development has hitherto primarily focused upon the implications for output, productivity and trade performance. The purpose of this paper is to extend this focus by examining the implications for private investment behaviour. More specifically, this paper formulates and solves a dynamic rational expectations model which is designed to analyse the extent to which public capital spending impacts upon private investment behaviour. The analysis builds upon the work of Aschauer (1989) in allowing for the effects of both public investment and the public capital stock on private rates of return and on the decision to invest. The model's steady state properties are first described and it is then simulated to illustrate the short, and long, run effects of variations in the level of public infrastructure provision, on the rate of private corporate investment and other macroeconomic variables. Amongst the main findings are that public infrastructure expenditure can 'crowd in' private investment.

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INTRODUCTION

In contrast to the traditional macroeconomic models of fiscal policy which focus on the effects of government financing decisions on key private macroeconomic variables, the more recent models downplay the relevance of fiscal financing decisions and focus instead upon the ability of variations in *real* fiscal variables, such as tax rates and the current/capital spending mix, to alter private incentives to invest, produce and consume. Although the recent work recognises the necessity for budgetary control as an important ingredient of responsible macroeconomic policymaking, cuts in the ratio of capital to current expenditure programs are recognised to have potentially adverse effects on the economy's infrastructure which may impede future performance.

These recent developments in the theory of fiscal policy have occured alongside a shift in macroeconomic policy setting towards fiscal restraint in many Western economies, which has been achieved by reigning in capital rather than current spending programs. Such has been the case in Australia during the period of fiscal tightening in the latter part of the 1980s. In fact, within the Commonwealth (Federal) budget sector, current outlays as a percentage of total outlays increased from 91.5 percent in 1980/81 to 96.3 percent in 1992/93, while capital outlays as a percentage of total outlays declined from 8.5 to 3.7 percent in the same sector over the same time period. The present government is, however, not alone in adopting this strategy. Public investment expenditures in Australia have declined as a proportion of GDP since the mid-1960's, with the exception of 1973/74 and the government's *One Nation* Statement of February 1992 which temporarily raised infrastructure spending.

What are the effects of variations in public investment spending on private investment? Concern about this issue is

neither novel nor exclusive to the recent Australian experience. For example, Langmore (1987), Nevile (1987), EPAC (1988), Alesina, Gruen and Jones (1990), McDonell (1990), Kearney (1991) and Chowdhury, Fallick and Kearney (1994) have expressed concern about recent developments within the Australian context, while Aschauer (1990), Malabre (1990), Munell (1990) and Tatom (1990 a,b) have done similarly for the United States. Within the Australian literature, however, the focus of concern about reducing public capital/current spending ratios has hitherto been centred on its implications for output, productivity and trade performance. The purpose of this paper is to extend this focus by examining the implications for private investment behaviour.

More specifically, this paper formulates and solves a dynamic rational expectations model which is designed to analyse the extent to which public capital spending impacts upon private investment behaviour. The analysis builds upon the work of Aschauer (1989), in allowing for the effects of both public investment and the public capital stock on private rates of return and on the decision to invest. The model's steady state properties are first described and it is then simulated to illustrate the short, and long, run effects of variations in the level of public infrastructure provision on the rate of private corporate investment and other macroeconomic variables. Amongst the main findings are that public infrastructure tends to 'crowds in' private investment.

THEORETICAL FRAMEWORK

How do variations in public capital spending programs influence private corporate sector decisions to invest? As alluded to in the previous section, two alternative frameworks have been employed in order to answer this question. The traditional post-

Keynesian macromodels, by emphasising only the demand-side effects of fiscal policy, generally find that the multipliers for capital spending programs are smaller than their current spending counterparts. This implies, of course, that the traditional *ex post* 'crowding out' effects of debt-financed fiscal expansions are smaller for capital than for current expenditures, because less pressure is put on the interest rate through higher transaction demands for real money balances.

The more recent models shift emphasis away from the demand-side transmission mechanisms of variations in fiscal financing decisions, towards the supply-side transmission mechanisms of real variable shifts in fiscal stances. As Aschauer (1989) points out, this framework suggests two countervailing affects. On the one hand, higher public capital spending raises the national capital accumulation rate at above that which is chosen by the private sector, and *ex ante* 'crowds out' private investment as the private sector acts to restore its chosen optimal intertemporal resource allocation. On the other hand, however, higher public capital spending on infrastructure may 'crowd in' private investment by raising the marginal productivity of private capital. The model presented here includes both the 'crowding in' and 'crowding out' effects of public capital spending, and the simulations are specifically designed to shed light on the important issues which determine the net effect on private corporate investment and other macroeconomic variables. The model is presented in Table 1 overleaf. All the variables are in logs with the exception of the domestic and foreign interest rates.

Equation (1) describes the demand for real output (y^d) as comprising private consumption (c^P), private investment (i^P), government consumption (c^g), government investment (i^g) and the trade balance (t). The following four equations (2) – (5) describe the determinants of these components of aggregate demand. Specifically, private consumption depends positively on the level

of real income (aggregate supply) and real private sector wealth (w^P). Private investment which equals the change in the stock of private capital ($\dot{k}^P$), (we ignore replacement investment) depends on Tobin's q ratio (q). Government consumption spending is an exogenous policy determined variable, whilst capital spending arises from a gradual adjustment of the actual public capital stock (k^g) to its policy determined level (k^{g*}). The trade balance depends on the real exchange rate, the nominal exchange rate (e) deflated by the domestic price level (p), and on domestic aggregate demand and foreign income (y^*).

The asset market equilibrium conditions are described by equations (6) – (10). Equation (6) describes the money market equilibrium condition which equates the supply of real balances, the nominal money supply (m) deflated by the domestic price level, to its demand, which depends positively on the level of aggregate demand and negatively on the bond rate of interest (r). Equation (7) describes the return on private capital (R) as depending positively on the level of aggregate supply, negatively on the stock of private capital (k^P) due to diminishing returns, and positively on the stock of public capital. The latter holds because public capital and private capital are complementary in nature, the productivity of private capital rises as the government provides more public infrastructure. Equation (8) describes the change in Tobin's q ratio. It comes from the arbitrage condition equating the returns on domestic and foreign bonds and equity. Equation (9) defines private sector wealth as depending positively on the real domestic currency value of domestically held foreign assets (f) and on the value of private capital (k^P + q). Equation (10) defines the current account of the balance of payments, equivalent to the change in domestic holdings of foreign assets, as the sum of the trade balance, net interest income and the real exchange rate.

Table 1. The Model

Product Market

$$y^d = \alpha_1 c^P + \alpha_2 i^P + \alpha_3 c^g + \alpha_4 i^g + \alpha_5 t \quad (1)$$

$$c^P = c_1 y^s + c_2 w^P \quad (2)$$

$$i^P = \dot{k}^P = \eta q \quad (3)$$

$$c^g = \bar{c}^g, \; i^g = \dot{k}^g = (k^{g*} - k^g) \quad (4)$$

$$t = \mu_1(e - p) - \mu_2 y^d + \mu_3 y^* \quad (5)$$

Asset Markets

$$m - p = \sigma_1 y^d - \sigma_2 r \quad (6)$$

$$R = \varepsilon_1 y^s - \varepsilon_2 k^P + 3k^g \quad (7)$$

$$\dot{q} = \delta_3^{-1}[q - \delta_1 R + \delta_2(r - \pi)] \quad (8)$$

$$w^P = \gamma_1(f + e - p) + \gamma_2(k^P + q) \quad (9)$$

$$\dot{f} = {}_1t + {}_2r^* f - (1 - \rho_2)(e - p) \quad (10)$$

Wage Price Nexus and Aggregate Supply

$$p = \alpha w + (1 - a)\, e \quad (11)$$

$$\dot{w} = \phi_1(y^d - y^s) + \phi_2 \pi \quad (12)$$

$$y^s = \lambda_1 k^P + \lambda_2 k^g - \lambda_3(w - p) \quad (13)$$

Definitions etc

$$\dot{m} = \pi \quad (14)$$

$$\dot{e} = r - r^* \quad (15)$$

$$c = e - w \quad (16)$$

$$\ell = m - w \quad (17)$$

A dot ($\cdot$) above a variable signifies its rate of change.

Equations (11) – (13) define the wage price nexus and the aggregate supply (y^s) of output. The domestic price level, equation (11) is a weighted average of domestic nominal wages (w) and the world price of the imported good. Nominal wages adjust in line with a simple inflationary expectations (π) augmented Phillips curve. Aggregate supply is derived from a production function which includes labour (which is assumed homogeneous between the private and government sectors and earns the same wage in both sectors), and the private as well as public capital stocks.

Finally, equations (14) – (17) define the following. Equation (14) shows that inflationary expectations depend upon the monetary growth rate, while (15) is the uncovered interest rate parity condition in which exchange rate expectations offset domestic and foreign interest rate (r^*) differentials. Perfect capital mobility ensures that this condition holds continuously. Equations (16) and (17) define the real exchange rate (c) and real money balances (ℓ) respectively, which are useful for expositionary purposes (see Buiter and Miller (1981)).

The workings of the model with respect to the role of government investment in infrastructure capital is as follows. In equation (1), the level of government investment contributes to the level of demand for real output. Whenever the government raises (lowers) its investment, there will accordingly exist a direct aggregate demand effect through this equation. The higher real income from this direct demand effect will raise the demand for real balances and cause upwards pressure on the rate of interest in the LM equation (6). This is the traditional 'crowding out' effect of public investment. In this open economy with perfect capital mobility, however, the effect will be transferred to the exchange rate through equation (15).

The act of government investment will, however, raise the

stock of government capital as seen in equation (4). The higher level of public capital then improves the profitability of private capital as seen in equation (7), and this then impacts on Tobin's q ratio in equation (8) and in turn affects the level of private investment in equation (3). There will also be an associated wealth effect of the induced higher private investment since this raises the stock of private capital, and this, together with the revised valuation, impacts on private wealth through equation (9). In addition, the stock of public capital adds to the supply of real output in equation (13) and this acts to offset a proportion of the demand effects on wages and prices. The net effect of these forces is the subject matter of the model simulations.

STEADY STATE AND DYNAMIC PROPERTIES OF THE MODEL

The size and generality of the theoretical framework prevents the mathematical derivation of analytically unambiguous results, for both the steady state and dynamic properties of the model. However this difficulty can be overcome through the use of a numerical simulation procedure[1].

Steady state properties

The model has the following analytically unambiguous steady state properties:

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[1] The numerical simulation procedure utilised is known as 'Saddlepoint'. It is a numerical algorithm developed by Austin and Buiter (1982) for solving systems of linear differential equations with constant coefficients, and is based upon the solution provided by Blanchard and Khan (1980) for the case of systems of linear difference equations. Its analytical solution is derived and discussed in Buiter (1984).

$\dot{m} = \dot{e} = \dot{w}$

$\dot{r} = \dot{m} + \dot{r}^*$

$\dot{q} = 0$

$\dot{R} = \dot{r}^* = \dot{r} - \dot{m}$

The remaining endogenous variables of the model, and their response to exogenous shocks, are all highly analytically ambiguous. In the following section of the paper a simulation scenario is conducted focusing upon the case of an expansion in the public sector capital stock, and the steady state properties of the model for a number of key macroeconomic variables using the numerical simulation procedure are derived for this case.

Dynamic stability of the model

The model must exhibit dynamic properties which are consistent with the underlying behavioural assumptions of it. The dynamic equations of the model is assumed to consist of a set of dynamic endogenous control variables, namely real money balances (ℓ), foreign asset stocks (f), private capital stock (k^P), public capital stock (k^g), Tobin's q ratio (q) and the real exchange rate (c). The first four of these, because of assumed stickiness of price and quantity adjustment in non financial markets, are predetermined, or non jump, variables. The latter two variables, because they are determined in financial markets, are non predetermined or jump variables, capable of adjusting instantaneously to an exogenous shock.

Denoting these variables by the vector x, a linear approximation of the model around its equilibrium solution can be written in the following form:

$$\dot{x} = Ax' + Bz$$

where z is a vector of exogenous variables, x' denotes the deviation of x around its equilibrium value, and $\dot{x}$ is its time derivative. A and B are parameter matrices.

The stability of the model depends only upon the properties of the 'state' matrix A. The size and generality of the model presented, suggests that a complete algebraic analysis of model stability based upon the characteristic equation of matrix A is not a productive exercise. For the model under discussion to generate a stable saddlepath, based upon its underlying behavioural assumptions, there must be two unstable and positive roots associated with the non predetermined variables, and four negative and stable roots associated with the predetermined variables. Hence the determinant of A, which gives the product of the roots, must be positive. If this is not satisfied the model will be unstable as defined here, and the underlying dynamic adjustment will be incompatible with the behavioural assumptions of it.

SIMULATION SCENARIO

In this section, the results derivable from simulating the model for the case of an increase in public infrastructure (capital) expenditure is conducted. The presumed change is that of a 1% anticipated and permanent increase in the public sector's capital stock. This increase does not take place immediately due to the likely delay between the announcement of such a policy change and its actual implementation. Hence the change in the capital stock is assumed to come into effect in equal increments starting in the fourth quarter (i.e. approximately one year) after the policy is announced. In order to identify the steady state properties of the model arising from such a shock, as well as the adjustment process towards long run steady state, it is necessary to specify the numerical values of the parameters of the model. Table 2

summarises these. Utilising these values the steady state adjustment of thirteen key macroeconomic variables in the model can be identified for this scenario. An overall 1% increase in public infrastructure expenditure, assuming the parameter values are as those specified in Table 2, will produce the percentage deviation from base value adjustments summarised in Table 3.

Table 3 indicates that the major long term benefits from such an expansionary policy are in regard to an increase in the private sector capital stock (which increases by 1.28% from its base level) indicating a net crowding in effect, aggregate demand/supply (which increases by 0.3% from its base level), the trade balance (which improves by 0.11% from its base level) and private sector real wealth (which increases by some 0.22% from its base level). The major loser from such a policy expansion is that of foreign asset stocks, which decline by some 2.22% from their base level. Other developments suggest a weakening of the real exchange rate by some 1.67% from its base value, primarily due to a depreciation of the nominal exchange rate (not shown here), no long term effect upon the q ratio, the nominal interest rate, the real profit on capital services and the rate of inflation. The latter effect arises since no monetary accommodation has occurred, due to the fact that the addition to the public sector's capital stock is achieved whilst maintaining a balanced budget.

Whilst these changes are indicative of the overall effects arising from such a policy, it is of interest to identify the adjustment process towards long run steady state. This is now conducted with the aid of Figures 1-3, which summarise the adjustment of twelve key macroeconomic variables from their initial steady state towards their new long run steady state. The interpretation of the simulation results is broken down into four distinct periods as follows. The impact period is that arising immediately on the announcement of the policy. The short run is described as that occurring over a period of two years, the

Table 2. Parameter Values

α_1	= 1.0	ε_2	= 0.5
α_2	= 0.1	ε_3	= 0.5
α_3	= 0.1	δ_1	= 0.5
α_4	= 0.1	δ_2	= 0.5
α_5	= 0.1	δ_3	= 0.5
c_1	= 0.8	γ_1	= 1.0
c_2	= 0.2	γ_2	= 1.0
η	= 0.7	ρ_1	= 1.0
θ	= 0.7	ρ_2	= 1.0
μ_1	= 0.5	α	= 0.7
μ_2	= 0.5	ϕ_1	= 0.7
μ_3	= 0.5	ϕ_2	= 1.0
σ_1	= 1.0	λ_1	= 0.1
σ_2	= 0.5	λ_2	= 0.1
ε_1	= 0.5	λ_3	= 0.1

Table 3. **Steady-state properties of the model — increase in the public sector capital stock (1%) (percent deviation from base value)**

ℓ	f	k^p	k^g	q	c	r	y^d	y^s
+0.78	-2.22	+1.28	+1.0	0	+1.67	0	+0.3	+0.3

t	w^p	R	p
+0.11	+0.22	0	0

medium run that occurring from two to five years and the long run from five years onwards.

The announcement of the policy change is felt instantaneously in asset markets (see Figure 2) where the q ratio, nominal interest rate and nominal exchange rate (not shown) are the relevant variables. The q ratio immediately rises in line with a rise in equity prices thereby increasing the market valuation of capital stock relative to its replacement value. The nominal exchange rate appreciates marginally and the expectation of a further appreciation of the exchange rate is created, contributing to a decline in the nominal interest rate so as to maintain the uncovered interest rate parity condition.

The impact effects gradually impinge upon developments in the product market, as the adjustment process moves into the short run. The increase in the q ratio previously identified stimulates private sector investment with a resulting accumulation of capital stock. Whilst real profit on capital services initially declines this is ultimately reversed as investment in the public capital stock is actually implemented. Thereafter real profit increases contributing to a further increase in the q ratio and stimulation of investment and accumulation of private capital stock. The eventual change in public capital spending stimulates aggregate demand for output and also money, with the latter pushing up the interest rate. Aggregate supply is also increased both directly and indirectly from this spending. The increased public stock of capital enhances output directly, but it also increases real profit on capital services and therefore private investment affecting supply indirectly. Inflation increases after an intial downturn, due to aggregate demand increasing more than aggregate supply. External developments during the short run suggest a further appreciation of the real exchange rate, a deterioration in the trade balance due to developments in the real exchange rate as well as aggregate demand and a continual de-

cline in foreign asset stocks as a result of current account deficits.

Over the medium run, the q ratio reverses its upward trend although it is still above its base level encouraging private sector investment, and this development is closely related to that of real profits. Private sector investment contributes to a further increase in capital stock, which favourably affects both aggregate demand and supply. This period is also characterised by falling inflation as aggregate supply increases more than aggregate demand. Domestic interest rates tend to fall during this period of declining inflation, although it is still above its base level due to persistent expectations of a further depreciation of the nominal exchange rate. As for external developments the major changes relate to a depreciation of the real exchange rate, and a resulting improvement in international competitiveness, which contributes to an improvement in the trade balance despite the further growth of aggregate demand. However the decline in foreign asset stocks continues, with this rate becoming more rapid, indicating further current account deficits.

Over the long run to ultimate steady state the q ratio and real profit decline continuously, although still above their base levels. This further stimulates private sector investment and aggregate demand, whilst the capital stock when in place further stimulates aggregate supply. Additional demand from investment is also enhanced by additional demand from private consumption spending, due to the rise in income as well as increase in private sector wealth. Inflation rises gradually to steady state where it has returned to its base rate, due to aggregate demand catching up with aggregate supply. The nominal interest rate declines continuously to steady state, where it has returned to its base level. External developments are characterised by a continual depreciation of the real exchange rate and improved trade balance, whilst foreign asset stocks continue to decline but at a much slower rate.

Figure 1 **Domestic adjustments—Aggregate demand and supply, private and public investment, inflation and private sector wealth**

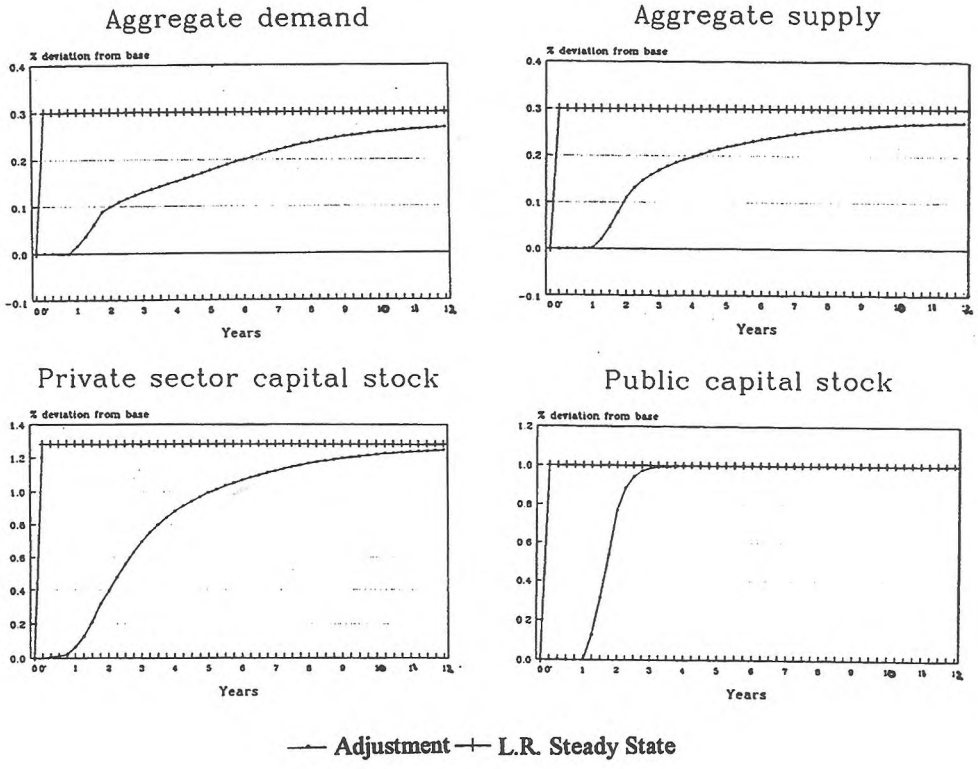


Figure 1 **Domestic adjustments—Aggregate demand and supply, private and public investment, inflation and private sector wealth (cont.)**

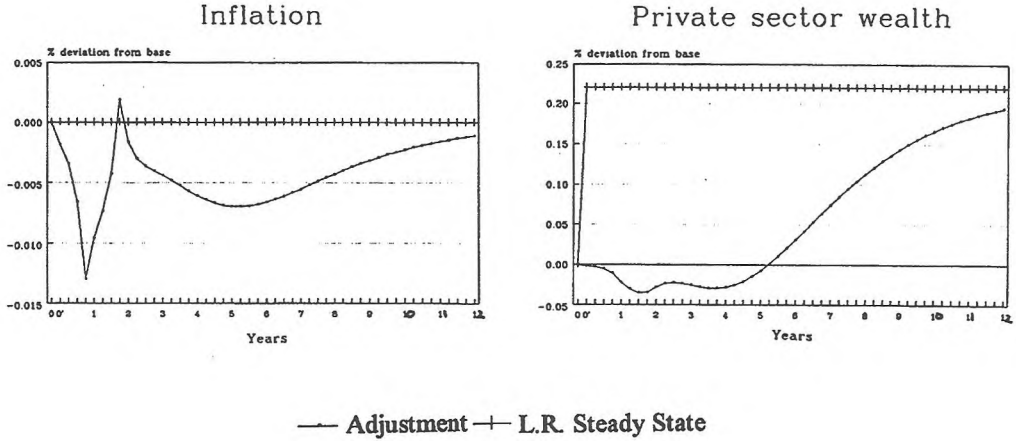


Figure 2 Domestic adjustments—Private investment factors

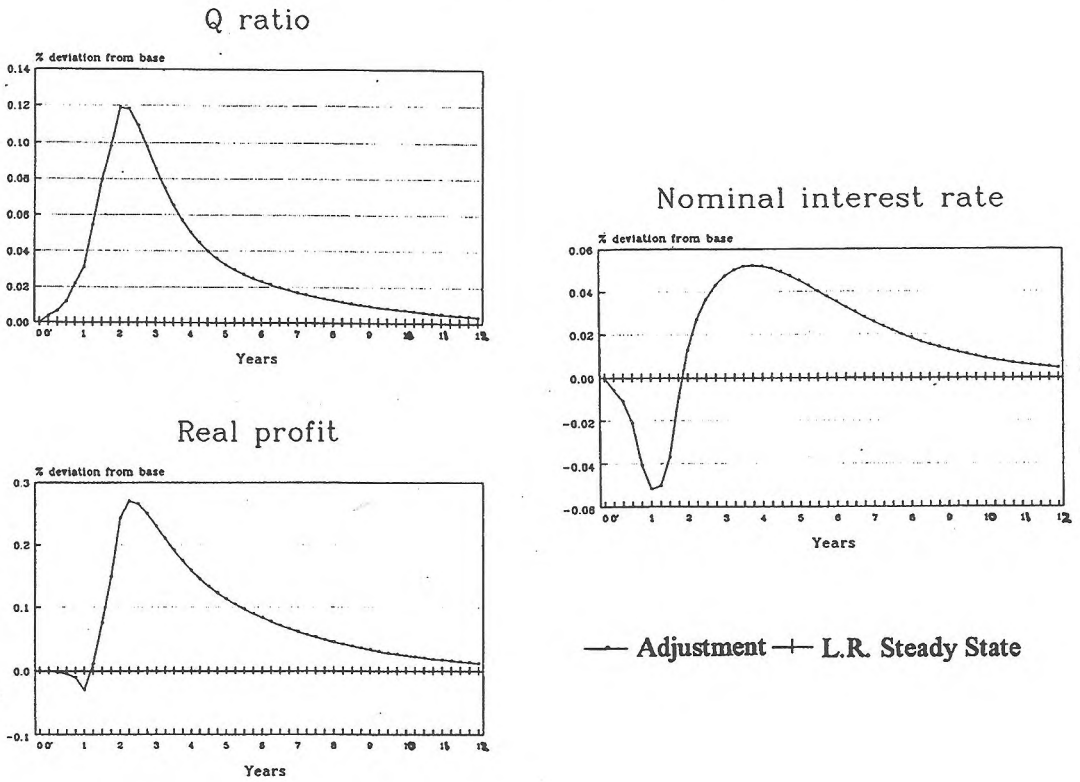
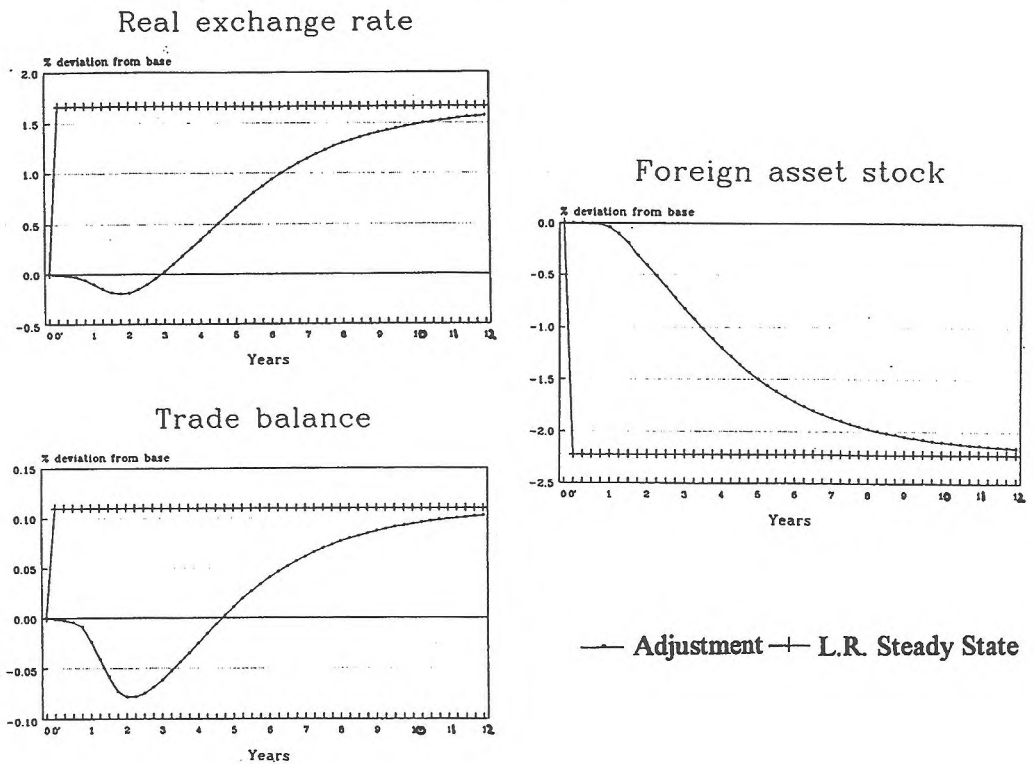


Figure 3 Domestic adjustments—Real exchange rate, trade balance and foreign asset stocks



The simulation scenario presented suggests that public capital spending can 'crowd in' private investment and lead to an improved performance for a number of key macroeconomic variables. Asset market variables have a key role to play in the process of transmitting the effects of such a change in policy to the macroeconomy. The traditional crowding out effect arising from government spending pushing up the interest rate is apparent during the adjustment process, once this spending eventuates. However as is clear from the simulation results public capital spending directly enhances the supply capacity of the economy as well as aggregate demand. It also indirectly enhances aggregate supply, on balance, through its improvement of real profit earned on the private capital stock. This pushes up equity prices and the q ratio, providing a further stimulus to private investment. Such an effect offsets the traditional decline in investment from a higher interest rate. Inflation outcomes can also be improved with this policy particularly over the medium and long run. A sizeable response of aggregate supply can produce an increase in supply in excess of demand, contributing to downward pressure on domestic costs and prices. Finally developments in the external sector are somewhat mixed. In the context of a country such as Australia, which has a major problem on current account, an expansion in public capital spending could exacerbate difficulties on the current account, as indicated by declining foreign asset stocks. However, the trade balance can be improved as a result of a weakening of the real exchange rate.

CONCLUSIONS

The importance of govenment capital (infrastructure) spending for private investment has been the primary focus of this paper.

Traditional macroeconomic theory emphasises the demand consequences of such spending and the importance of the crowding out effect operative through a higher interest rate. This paper has focused upon the contribution which public capital spending can make to enhancing the profitability of private sector investment, and the role which such spending can make to the supply side of the economy. The issue was discussed within the context of a dynamic rational expectations macroeconomic framework, and the simulation results derived from it suggest that for the parameter values utilised public capital spending could lead to an overall "crowding in" effect of private investment and increase in productive capital stock. This would have a positive effect upon the long run productive potential of the economy. A policy of fiscal restraint, on the other hand, which focuses upon reducing public capital spending, could have potentially adverse effects upon the economy's infrastructure and impede future economic performance based upon these results.

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