Macroeconomic Dynamics, **20**, 2016, 1742–1770. Printed in the United States of America.
doi:10.1017/S1365100515000048

FISCAL POLICY AND THE REAL EXCHANGE RATE

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This paper examines the mechanisms through which government spending affects the dynamics of the real exchange rate. Using a two-sector dependent open economy model with intersectoral mobility costs for private capital, we show that public investment generates (i) a nonmonotonic U-shaped adjustment path for the real exchange rate with sharp intertemporal trade-offs and (ii) a crowding-in of private consumption, consistent with stylized facts. The effects of public consumption, however, are in sharp contrast to those of public investment. The effect of government spending on the real exchange rate depends critically on (i) the sectoral composition of public spending, (ii) the underlying financing policy, (iii) the sectoral intensity of private capital in production, (iv) the relative sectoral productivity of public infrastructure, (v) the elasticity of substitution in production, and (vi) intersectoral mobility costs for capital. In deriving these results, we identify conditions under which the predictions of the neoclassical open economy model can be reconciled with empirical regularities. Our results underscore the importance of decoupling the effects of government investment from those of government consumption in understanding the relationship between fiscal policy and the real exchange rate.

Keywords: Fiscal Policy, Public Investment, Government Spending, Consumption, Real Exchange Rate.

1. INTRODUCTION

Emerging markets have recently embarked on an ambitious expansion of government spending, mainly on public infrastructure such as roads, airports, rail, power supply, water, and telecommunication networks, as a means of sustaining their

This paper has benefited from comments received from S.M. Ali Abbas, Andrew Berg, Salifou Issoufou, William Orie, Stephen Turnovsky, Felix Rioja, Michael Funke, and the Fiscal Affairs and Research Departments of the IMF, and from presentations at the University of Hamburg, Karlsruhe Institute of Technology, Georgia State University, the International Development Workshop at the Federal Reserve Bank of Atlanta, and the Annual Meetings of the Society for Computational Economics in Prague. We are also grateful to an associate editor and two anonymous referees for comments that have improved the paper significantly. Thomas Lebesmuehlbacher provided valuable research assistance for this project. Chatterjee would like to acknowledge a grant from the Sarah H. Moss Foundation that supported the research for this paper. The paper was completed while Chatterjee was visiting the University of Hamburg in Germany, whose hospitality is gratefully acknowledged. Address correspondence to: Santanu Chatterjee, Department of Economics, Terry College of Business, University of Georgia, Athens, GA 30602, USA; e-mail: schatt@uga.edu.

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https://doi.org/10.1017/S1365100515000048 Published online by Cambridge University Press

high economic growth rates from the last two decades. Infrastructure investment is one of the key drivers of economic growth in these markets, with countries such as China and India allocating a growing share of GDP to a variety of infrastructure projects.[1] Globally, the demand for infrastructure will require about $57 trillion in investment by 2030, with about 70% of this demand coming from roads, power, and water [McKinsey Global Institute (2013)]. Over the period 1990–2013, the BRICS countries spent, on the average, about 9% of their GDP on public infrastructure, compared to about 3% for the G-7 countries.[2] In an era of global economic integration, the dynamic effects of these policies on external prices and competitiveness will be of critical importance for both developing and developed countries. Understanding this relationship in the context of a dynamic general equilibrium model is the central objective of this paper.

The dynamic implications of government spending in open economies have been the subject of a growing but inconclusive literature in international macroeconomics. This paper attempts to contribute to three issues in this literature:

(1) The theoretical literature on the link between fiscal policy and the real exchange rate has generally treated government spending as representing public *consumption*, which impinges on the economy as a pure demand shock. An increase in government spending thus raises the demand for nontraded goods and their relative price, causing a real *appreciation* of the exchange rate in the short run. The long-run real exchange rate, on the other hand, remains unaffected, being determined by supply-side factors such as sectoral productivity.[3] In sharp contrast, the recent empirical literature on this issue has documented that government spending generates a short-run real *depreciation* of the exchange rate. The empirical literature, however, does not usually disentangle the relative effects of government consumption and investment, which may impinge on short-run and long-run resource allocation in dramatically different ways.[4] This is a critical issue, because public investment (and its financing) can generate strong supply-side effects by impinging on private-sector productivity. Further, the short-run demand-side effects of governm ent investment spending may also be influenced by the expectations of higher productivity benefits in the long run. A priori, the intertemporal relationship between the *composition* of government spending (investment versus consumption) and the real exchange rate is not clear. We fill an important gap in the literature by providing a systematic analysis of this relationship.

(2) A large empirical literature has documented the strong persistence and nonlinearity in the adjustment of the real exchange rate over time, implying very long periods of *nonmonotonic* adjustment following an underlying shock.[5] In contrast, the predicted deviations of the exchange rate from equilibrium generated by theoretical models are very short-lived and monotonic, with implausibly high speeds of convergence. In this paper, we focus on the dynamic interaction of two factors that may help resolve this discrepancy. First, we introduce government investment that is tied to the stock of public infrastructure, which is accumulated only *gradually* over time (such as roads, ports, and power grids). Therefore, the trade-off between the short-run resource withdrawal effects of public spending

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and the gradual realization of long-run productivity gains will be reflected in the adjustment path of relative prices. Second, it may be costly for investors to reallocate private capital across sectors in response to the long-run productivity benefits of public investment. Indeed, as we will demonstrate in this paper, the interaction between between these two factors can generate both persistence and nonlinearity in the dynamic adjustment of the real exchange rate. Moreover, we also show that changes in government consumption cannot generate either the observed persistence or the nonlinear adjustment of the real exchange rate. This further underscores the importance of decoupling the effects of public investment from those of consumption.

(3) Another contentious issue relates to the short-run correlation between government spending and private consumption in open economies. Theoretical models predict a short-run *negative* correlation: By withdrawing resources from the private sector, government spending raises the marginal utility of wealth, which, in turn, leads agents to reduce the consumption of all normal goods in the short run ("crowding-out" effect). In contrast, recent empirical studies have documented a *positive* correlation between government spending and private consumption in the short run.[6] Again, the question here is whether focusing on government investment rather than consumption may help resolve this issue. Intuitively, an increase in government spending allocated to the creation of public infrastructure that raises the long-run productivity of both private capital and labor might cause private agents to increase private consumption in the short run, by borrowing from their future (higher) expected income.

In this paper, we examine the mechanism through which government spending (both on public infrastructure and on public consumption) and accompanying financing policies affect the dynamics of a two-sector open economy, with a particular focus on the real exchange rate, private consumption, and the sectoral allocation of capital and labor. The model we employ is characterized by the following features: (i) two production sectors, producing traded and nontraded goods, respectively, using private capital and labor, with all private investment being created in the traded goods sector, whereas investment in the nontraded sector takes place only by the transfer of resources from the traded to the nontraded sector; (ii) a gradually accumulating stock of government-provided infrastructure capital (henceforth "public capital") that augments the productivity of the private factors of production through a spillover effect, and a flow of government spending on consumption goods;[7] (iii) the use of both distortionary and nondistortionary sources of financing government spending; and (iv) the presence of convex intersectoral *mobility costs* for private capital—we assume that it is costly for agents to transfer private capital across sectors for investment purposes.

The introduction of sectoral mobility costs for private capital in the analytical model deserves special comment. These costs have been studied extensively in the international trade literature, in the context of the two-sector Heckscher–Ohlin model; see Mayer (1974), Jones (1975), Mussa (1978), and Neary (1982). Morshed and Turnovsky (2004) discuss several examples from post-World War II Western

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Europe to motivate the presence of these costs (they label these intersectoral *adjustment* costs), such as the costly retrofitting of wartime industries to produce consumer goods for the postwar era. Thus, transferring capital across sectors might be associated with nontrivial costs in terms of retrofitting, adapting to a different technology, time, labor, etc. More recently, the importance of these costs in the context of natural resources has also been discussed by van der Ploeg (2011).

The value-added of this paper must be evaluated in the context of two closely related studies, namely Morshed and Turnovsky (2004) and Galstyan and Lane (2009). First, although Morshed and Turnovsky (2004) introduce convex mobility costs for capital in a two-sector dependent economy model, their focus is entirely on government consumption. In contrast, we distinguish the consequences of government investment in the economy's stock of public capital from those of government consumption. Indeed, the combination of a gradually accumulating stock of public capital and intersectoral mobility costs enables us to identify plausible conditions under which the two-sector dependent open economy model yields qualitative predictions that are consistent with stylized facts.[8] Second, although Galstyan and Lane (2009) examine the public investment-real exchange rate link, their analysis is restricted to the (i) steady state, (ii) costless movement of capital across sectors, and (iii) nondistortionary financing of public investment. We conduct a full dynamic analysis that characterizes the intertemporal trade-offs in the adjustment of the real exchange rate in response to government spending shocks, and focus on a broad range of fiscal issues, such as the sectoral composition of government investment spending and the effects of distortionary tax-financing on sectoral income. Third, whereas both Morshed and Turnovsky (2004) and Galstyan and Lane (2009) assume that private investment originates in the nontraded sector, we use the traded sector as the source of investment. We view this as a more plausible assumption, because most developing countries import a large proportion of capital goods for production purposes.

The analytical structure we employ yields a seventh-order nonlinear dynamic system with four state and three jump variables, requiring a numerical solution. The results of our policy experiments can be summarized as follows:

(a) Government spending on infrastructure investment can generate a persistent and *nonmonotonic* U-shaped path for the real exchange rate (following its instantaneous response), thereby generating sharp intertemporal trade-offs in its dynamic adjustment.[9] In contrast, a corresponding increase in government consumption leads to a quick and monotonic adjustment of the real exchange rate, without any intertemporal trade-offs. The result that the real exchange rate depreciates in the short and medium run in response to an increase in government spending is consistent with the recent findings of Corsetti and Muller (2006), Monacelli and Perotti (2010), Enders et al. (2011), Bouakez et al. (2012), and Ravn et al. (2012). However, we show that this behavior is consistent with the presence of government investment, but not consumption.[10]

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(b) The transitional (the length and depth of the U-shaped adjustment), and steady state response of the real exchange rate to an increase in public investment depends critically on (i) the sectoral composition of government spending on infrastructure (i.e., whether the spending increase impinges on traded or nontraded output), (ii) the underlying financing policy (lumpsum tax or sectoral income tax), (iii) the sectoral intensity of private capital, (iv) the sectoral output elasticity of public capital, (v) the elasticity of substitution in production, and (vi) the magnitude of intersectoral mobility costs. We also identify conditions under which an increase in government spending leads to an instantaneous depreciation of the real exchange rate, as has been documented in recent empirical studies.

(c) The sectoral composition of government investment, the underlying financing policy, and the output elasticity of public capital are important for generating the observed short-run *positive* correlation between government spending and private consumption. We identify conditions for each of these factors that generate this positive correlation in the absence of a home bias in consumption, underscoring the fact that such an observation is not inconsistent with the neoclassical model. Again, we show that changes in public consumption cannot generate the positive association between government spending and consumption observed in the data.

Finally, we note that our paper is related to a small but growing theoretical literature that attempts to explain the observed short-run depreciation of the real exchange rate in response to an increase in government spending. This includes Kollman (2010), Bouakez and Eyquem (2011), Corsetti et al. (2012), and Ravn et al. (2012). These papers focus on government consumption and factors such as incomplete markets, spending reversals, habit formation, and the aggressiveness of monetary policy. We view our contribution as complementary to this body of work, by focusing instead on government investment, its financing, and a broader range of intertemporal issues and highlighting the importance of an alternative source of friction in the neoclassical model, namely, the interaction between the gradual accumulation of public capital and intersectoral mobility costs for private capital.

The rest of the paper is organized as follows. Section 2 develops a canonical two-sector dependent-economy model with public capital and intersectoral adjustment costs, Section 3 describes the numerical calibration of the model, and Section 4 reports the results of counterfactual policy experiments. Section 5 discusses the sensitivity analysis, and Section 6 concludes.

2. THE ANALYTICAL FRAMEWORK

We consider a small open economy with an infinitely lived representative agent who maximizes utility from the consumption of a traded good and a domestically produced nontraded good. There are two production sectors in this economy, namely the traded goods sector and the nontraded goods sector. Each sector uses three factors of production: private capital, labor, and a government-provided

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economywide stock of public capital (infrastructure). The stock of public capital represents a nonexcludable and nonrival public good that enhances the productivity of private capital and labor in both sectors through a positive spillover effect. The government appropriates fractions of both traded and nontraded output for public investment, and finances this spending using distortionary income taxes (levied on incomes in both sectors) as well as lump sum taxes (or debt). Finally, we will assume that all private investment takes place in the traded sector, and it is costly for the agent to transfer resources from the traded to the nontraded sector for investment in that sector. To close the model, we assume that the agent accumulates debt over time through an internationally traded bond and faces an upward-sloping supply curve of debt, with the interest rate on borrowing being determined as a markup over the world interest rate. We treat the traded good as a numeraire, so that the relative price of the nontraded good is the real exchange rate, with an increase denoting a real appreciation (and a decrease denoting a real depreciation).

2.1. Resource Allocation in the Private Sector

The representative agent's intertemporal utility function is given by

$$U = \int_0^\infty U\left(C_{\mathrm{T}}, C_{\mathrm{N}}\right) e^{-\beta t} dt,\ U_i > 0, U_{ii} < 0,\ i = \mathrm{T}, \mathrm{N}, \tag{1}$$

subject to a flow budget constraint

$$\dot{B} = rB + C_{\mathrm{T}} + I_{\mathrm{T}} + \Omega_{\mathrm{T}} - (1 - \tau_{\mathrm{T}})\, Y_{\mathrm{T}} - p\left[(1 - \tau_{\mathrm{N}}) Y_{\mathrm{N}} - C_{\mathrm{N}} - \Omega_{\mathrm{N}}\right] + T_{\mathrm{L}}, \tag{2}$$

where C_{T} and C_{N} denote the consumption of the traded and nontraded good, respectively, whereas I_{T} denotes private investment in the traded sector. B denotes the agent's current stock of debt (issued through a traded bond), and r denotes the interest rate on borrowing; U_i denotes the first derivative with respect to $i = \mathrm{T}, \mathrm{N}$, and U_{ii} denotes the second derivative with respect to these variables. The agent produces output Y_{T} in the traded-goods sector and Y_{N} in the nontraded-goods sector, and the functions Ω_{T} and Ω_{N} represent convex installation costs for private capital in each sector. The agent pays taxes on output produced in both sectors, with traded output being taxed at the rate τ_{T} and nontraded output being taxed at the rate τ_{N}. The agent also pays a lump sum tax, T_{L}, denominated in terms of the traded good. Finally, the relative price of the nontraded good, i.e., the real exchange rate, is denoted by p, with the traded good being treated as the numeraire.

The interest rate on borrowing is endogenous, and is a mark-up over the exogenous world interest rate:

$$r = r^* + \omega\left(\frac{B}{K}\right),\ \omega' > 0, \tag{3}$$

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where r^* is the world interest rate, K is the economy's aggregate stock of private capital, and the mark-up or premium $\omega(.)$ is a measure of debt-servicing capacity, specifically the aggregate debt-to-capital ratio. However, in making resource allocation decisions, the agent takes the borrowing rate, r, as given, which, in turn, is determined from the macroeconomic equilibrium.[11]

Production of final goods in the traded and nontraded sectors uses a standard neoclassical technology and three factors: sectoral private capital and labor, and the economywide aggregate stock of public capital, provided by the government:

$$Y_i = Y_i(K_i, L_i, K_G), \quad i = T, N. \tag{4}$$

In (4), K_i and L_i represent the employment of private capital and labor in sector i. The stock of public capital, K_G, generates services that are complementary to the private factors in each sector, enhancing their productivity along the transition path and in the long run. The sectoral production functions are characterized by diminishing returns to each factor of production.

Private investment originates in the traded goods sector, but because both sectors use capital as an input in production, some resources must be transferred from the traded to the nontraded goods sector for investment purposes. The rate of accumulation of private capital in the traded goods sector is given by

$$\dot{K}_T = I_T - \Gamma(X) - \delta_T K_T, \tag{5}$$

where I_T denotes the rate of private investment in the traded sector and δ_T is the rate of depreciation of private capital in that sector. X denotes the amount of resources that is transferred from the traded to the nontraded goods sector for investment, with $\Gamma(X)$ capturing the assumption that this transfer is costly:

$$\Gamma(X) = X + \frac{h}{2}X^2, \ h \geq 0. \tag{6}$$

According to (6), transferring X units of output from the traded to the nontraded goods sector for investment incurs a mobility cost given by $\frac{h}{2}X^2$; i.e., the intersectoral transfer requires the use of additional output, the marginal cost of which is given by the parameter h. Note that (i) $X \lesseqgtr 0$, indicating that disinvestment in the nontraded goods sector may lead to resources flowing back to the traded sector; (ii) when $h = 0$, capital is perfectly mobile across the two sectors; and (iii) when $h \to \infty$, capital is fully immobile and specific only to the traded goods sector.[12] Capital accumulation in the nontraded goods sector is then given by

$$\dot{K}_N = X - \delta_N K_N, \tag{7}$$

with δ_N denoting the depreication rate for private capital installed in the nontraded goods sector.

In addition to the cost of transferring capital across sectors, we also assume that *installing* capital in each sector incurs convex installation (adjustment) costs, as

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in Hayashi (1982):

$$\Omega_{\mathrm{T}} = \frac{h_{\mathrm{T}}}{2}\left(\frac{I_{\mathrm{T}}^2}{K_{\mathrm{T}}}\right),\ h_{\mathrm{T}} > 0, \tag{8a}$$

$$\Omega_{\mathrm{N}} = \frac{h_{\mathrm{N}}}{2}\left(\frac{X^2}{K_{\mathrm{N}}}\right)\ h_{\mathrm{N}} > 0, \tag{8b}$$

where h_{T} and h_{N} represent adjustment cost parameters in the traded and nontraded goods sectors, respectively.[13]

The market-clearing condition in the nontraded goods sector is given by

$$Y_{\mathrm{N}} = C_{\mathrm{N}} + \Omega_{\mathrm{N}} + G_{\mathrm{N}}, \tag{9}$$

where G_{N} represents the proportion of nontraded output appropriated by the government for public spending, with

$$G_{\mathrm{N}} = G_{\mathrm{N}}^{\mathrm{I}} + G_{\mathrm{N}}^{\mathrm{C}}, \tag{9a}$$

where $G_{\mathrm{N}}^{\mathrm{I}}$ and $G_{\mathrm{N}}^{\mathrm{C}}$ represent government spending from nontraded output for public investment and consumption, respectively.

The agent is endowed with one unit of time for work, which it uses to allocate labor supply to the two sectors. The labor market equilibrium condition is then given by

$$L_{\mathrm{T}} + L_{\mathrm{N}} = 1. \tag{10}$$

The agent chooses the rate of consumption of the two goods, sectoral investment, and the allocation of labor to maximize (1), subject to (2), (5), (7), and (10). The agent takes the government policy variables and the stock of public capital as given, and at the beginning of the planning horizon, is endowed with an initial stock of bonds and private capital, given by $B(0)$, $K_{\mathrm{T}}(0)$, and $K_{\mathrm{N}}(0)$. The current-value Hamiltonian function is

$$\begin{aligned} H = {} & U\left(C_{\mathrm{T}}, C_{\mathrm{N}}\right) e^{-\beta t} dt + \lambda e^{-\beta t}\{\dot{B} - rB - C_{\mathrm{T}} - I_{\mathrm{T}} - \Omega_{\mathrm{T}} + (1-\tau_{\mathrm{T}})\, Y_{\mathrm{T}} \\ & + p\left[(1-\tau_{\mathrm{N}})Y_{\mathrm{N}} - C_{\mathrm{N}} - \Omega_{\mathrm{N}}\right] - T_{\mathrm{L}}\} \\ & + q_{\mathrm{T}}' e^{-\beta t}\left[I_{\mathrm{T}} - \Gamma\left(X\right) - \delta_{\mathrm{T}} K_{\mathrm{T}} - \dot{K}_{\mathrm{T}}\right] + q_{\mathrm{N}}' e^{-\beta t}\left(X - \delta_{\mathrm{N}} K_{\mathrm{N}} - \dot{K}_{\mathrm{N}}\right) \\ & + q_{\mathrm{L}}'\left(1 - L_{\mathrm{T}} - L_{\mathrm{N}}\right), \end{aligned} \tag{11}$$

where λ is the shadow price of the traded bond (debt), q_{T}' and q_{N}' are the respective shadow prices for traded and nontraded private capital, and q_{L}' is the shadow price of sectoral employment. The optimality conditions are

$$U_{\mathrm{T}}\left(C_{\mathrm{T}}, C_{\mathrm{N}}\right) = \lambda, \tag{11a}$$

$$U_{\mathrm{N}}\left(C_{\mathrm{T}}, C_{\mathrm{N}}\right) = p\lambda, \tag{11b}$$

$$\dot{\lambda} = \lambda\left(\beta - r\right), \tag{11c}$$

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$$1 + h_{\mathrm{T}}\left(\frac{I_{\mathrm{T}}}{K_{\mathrm{T}}}\right) = q_{\mathrm{T}}, \tag{11d}$$

$$X = \frac{q_{\mathrm{N}} - q_{\mathrm{T}}}{hq_{\mathrm{T}} + h_{\mathrm{N}}\left(p/K_{\mathrm{N}}\right)}, \tag{11e}$$

$$\frac{\dot{q}_{\mathrm{T}}}{q_{\mathrm{T}}} + \frac{1}{q_{\mathrm{T}}}\left[(1-\tau_{\mathrm{T}})\partial Y_{\mathrm{T}}/\partial K_{\mathrm{T}} + \frac{(q_{\mathrm{T}}-1)^2}{2h_{\mathrm{T}}}\right] - \delta_{\mathrm{T}} = r, \tag{11f}$$

$$\frac{\dot{q}_{\mathrm{N}}}{q_{\mathrm{N}}} + \frac{p}{q_{\mathrm{N}}}\left[(1-\tau_{\mathrm{N}})\frac{\partial Y_{\mathrm{N}}}{\partial K_{\mathrm{N}}} + \frac{h_{\mathrm{N}}}{2}\left(\frac{X}{K_{\mathrm{N}}}\right)^2\right] - \delta_{\mathrm{N}} = r, \tag{11g}$$

$$(1-\tau_{\mathrm{T}})\frac{\partial Y_{\mathrm{T}}}{\partial L_{\mathrm{T}}} = p(1-\tau_{\mathrm{N}})\frac{\partial Y_{\mathrm{N}}}{\partial L_{\mathrm{N}}}, \tag{11h}$$

$$\lim_{t\to\infty} \lambda B e^{-\beta t} = \lim_{t\to\infty} q_{\mathrm{T}} K_{\mathrm{T}} e^{-\beta t} = \lim_{t\to\infty} q_{\mathrm{N}} K_{\mathrm{N}} e^{-\beta t} = 0, \tag{11i}$$

where $q_{\mathrm{T}} = q_{\mathrm{T}}'/\lambda$ and $q_{\mathrm{N}} = q_{\mathrm{N}}'/\lambda$ represent the shadow prices of traded and nontraded capital relative to that of debt.

The first-order conditions (11a) and (11b) equate the marginal utility of consumption from each sector to the marginal utility of wealth, denominated in terms of the traded bond. (11c) is the standard no-arbitrage condition for a small open economy, which states that the evolution of the shadow price of debt is proportional to the difference between the rate of time preference and the interest (borrowing) rate. (11d) represents the optimal choice of investment in the traded goods sector, equating its return to its relative shadow price. (11e) is the corresponding condition for private investment in the nontraded goods sector, which depends on the difference between the sectoral shadow prices of capital: as long as $q_{\mathrm{N}} > q_{\mathrm{T}}$, resources for investment will be transferred to the nontraded goods sector from the traded goods sector. (11f) and (11g) are the no-arbitrage conditions for capital investment in the two sectors, equating their net after-tax return to the interest rate. (11h) states that the after-tax return to labor in each sector must be the same at equilibrium, and finally, (11i) lists the transversality conditions for the three private assets.

From (11a) and (11b), we can derive the policy functions for sectoral consumption:

$$C_i \equiv C_i\left(p, \lambda\right), \; i = \mathrm{T}, \mathrm{N}, \tag{12}$$

where

$$\frac{\partial C_i}{\partial \lambda} < 0, \; \frac{\partial C_{\mathrm{T}}}{\partial p} > 0, \; \frac{\partial C_{\mathrm{N}}}{\partial p} < 0, \; i = \mathrm{T}, \mathrm{N}.$$

An increase in the marginal utility of wealth reduces the consumption of both the traded and the nontraded good, as the agent increases savings to offset the increase in λ. A real appreciation of the exchange rate makes the nontraded good more expensive relative to the traded good, causing the agent to allocate resources away from nontraded consumption toward traded consumption (and vice versa).

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2.2. The Public Sector

The government spends both traded and nontraded output to generate new public investment in public capital. Let sectoral investment by the government be given by G_i^{I} $(i = \mathrm{T}, \mathrm{N})$. The spending rules for each sector are

$$G_i^{\mathrm{I}} = g_i^{\mathrm{I}} Y_i,\ 0 < g_i^{\mathrm{I}} < 1,\ i = \mathrm{T}, \mathrm{N}, \tag{13}$$

where g_i^{I} represents the rate of public investment from sector i $(i = \mathrm{T}, \mathrm{N})$. As such, g_i^{I} represent policy variables for the government, which can be used to alter the rate of sectoral private investment. These can also be thought of as representing the *composition* of government spending on infrastructure. The assumption that government spending impinges on both traded and nontraded output is consistent with the findings of Abbas et al. (2011), who report that in developing countries, a significant amount of government spending is on traded goods.

Public capital accumulates according to

$$\dot{K}_{\mathrm{G}} = G_{\mathrm{T}}^{\mathrm{I}} + G_{\mathrm{N}}^{\mathrm{I}} - \delta_{\mathrm{G}} K_{\mathrm{G}} = g_{\mathrm{T}}^{\mathrm{I}} Y_{\mathrm{T}} + g_{\mathrm{N}}^{\mathrm{I}} p Y_{\mathrm{N}} - \delta_{\mathrm{G}} K_{\mathrm{G}}, \tag{14}$$

where δ_{G} represents the rate of depreciation of public capital. The government maintains a balanced budget at all points of time, using tax revenues to finance spending on infrastructure and the investment subsidy:

$$G_{\mathrm{T}}^{\mathrm{I}} + G_{\mathrm{T}}^{\mathrm{C}} + p\left(G_{\mathrm{N}}^{\mathrm{I}} + G_{\mathrm{N}}^{\mathrm{C}}\right) = \tau_{\mathrm{T}} Y_{\mathrm{T}} + \tau_{\mathrm{N}} p Y_{\mathrm{N}} + T_{\mathrm{L}}, \tag{15}$$

where $G_{\mathrm{T}}^{\mathrm{C}}$ denotes government consumption spending from traded output, with $G_{\mathrm{T}}^{\mathrm{C}} = g_{\mathrm{T}}^{\mathrm{C}} Y_Y$. Similarly, for nontraded public consumption, we assume that $G_{\mathrm{N}}^{\mathrm{C}} = g_{\mathrm{N}}^{\mathrm{C}} Y_{\mathrm{N}}$, where g_i^{C} $(i = \mathrm{T}, \mathrm{N})$ denotes the sectoral rates of public consumption.

The evolution of the current account is obtained by combining (2) with (15):

$$\dot{B} = rB + C_{\mathrm{T}} + I_{\mathrm{T}} + \Omega_{\mathrm{T}} - (1 - g_{\mathrm{T}}) Y_{\mathrm{T}}. \tag{16}$$

2.3. Macroeconomic Equilibrium

The core equilibrium dynamics is represented by a seventh-order nonlinear differential equation system with four state (sluggish) variables, K_{T}, K_{N}, K_{G},and B, and three jump variables, q_{T}, q_{N}, and λ :

$$\dot{K}_{\mathrm{T}} = \left(\frac{q_{\mathrm{T}} - 1}{h_{\mathrm{T}}} - \delta_{\mathrm{T}}\right) K_{\mathrm{T}} - X\left(1 + \frac{h}{2} X\right), \tag{17a}$$

$$\dot{K}_{\mathrm{N}} = X - \delta_{\mathrm{N}} K_{\mathrm{N}}, \tag{17b}$$

$$\dot{K}_{\mathrm{G}} = g_{\mathrm{T}}^{\mathrm{I}} Y_{\mathrm{T}} + g_{\mathrm{N}}^{\mathrm{I}} Y_{\mathrm{N}} - \delta_{\mathrm{G}} K_{\mathrm{G}}, \tag{17c}$$

$$\dot{B} = rB + C_{\mathrm{T}} + I_{\mathrm{T}} + \Omega_{\mathrm{T}} - (1 - g_{\mathrm{T}}^{\mathrm{I}} - g_{\mathrm{T}}^{\mathrm{C}}) Y_{\mathrm{T}}, \tag{17d}$$

$$\dot{q}_{\mathrm{T}} = (r + \delta_{\mathrm{T}})\, q_{\mathrm{T}} - \left[(1 - \tau_{\mathrm{T}}) \partial Y_{\mathrm{T}} / \partial K_{\mathrm{T}} + \frac{(q_{\mathrm{T}} - 1)^2}{2 h_{\mathrm{T}}}\right], \tag{17e}$$

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$$\dot{q}_{\mathrm{N}} = (r + \delta_{\mathrm{N}})\, q_{\mathrm{N}} - p\left[(1-\tau_{\mathrm{N}})\frac{\partial Y_{\mathrm{N}}}{\partial K_{\mathrm{N}}} + \frac{h_{\mathrm{N}}}{2}\left(\frac{X}{K_{\mathrm{N}}}\right)^2\right], \tag{17f}$$

$$\dot{\lambda} = \lambda\,(\beta - r)\,. \tag{17g}$$

The steady state is attained when $\dot{K}_{\mathrm{T}} = \dot{K}_{\mathrm{N}} = \dot{K}_{\mathrm{G}} = \dot{B} = \dot{q}_{\mathrm{T}} = \dot{q}_{\mathrm{N}} = \dot{\lambda} = 0$. The corresponding steady-state conditions are

$$\left(\frac{\tilde{q}_{\mathrm{T}} - 1}{h_{\mathrm{T}}} - \delta_{\mathrm{T}}\right)\tilde{K}_{\mathrm{T}} = \tilde{X}\left(1 + \frac{h}{2}\tilde{X}\right), \tag{18a}$$

$$\tilde{X} \equiv \frac{\tilde{q}_{\mathrm{N}} - \tilde{q}_{\mathrm{T}}}{h\tilde{q}_{\mathrm{T}} + h_{\mathrm{N}}\left(\tilde{p}/\tilde{K}_{\mathrm{N}}\right)} = \delta_{\mathrm{N}}\tilde{K}_{\mathrm{N}}, \tag{18b}$$

$$g^{\mathrm{I}}_{\mathrm{T}}\tilde{Y}_{\mathrm{T}} + g^{\mathrm{I}}_{\mathrm{N}}\tilde{Y}_{\mathrm{N}} = \delta_{\mathrm{G}}\tilde{K}_{\mathrm{G}}, \tag{18c}$$

$$\tilde{r}\tilde{B} + \tilde{C}_{\mathrm{T}} + \tilde{I}_{\mathrm{T}} + \tilde{\Omega}_{\mathrm{T}} = (1 - g^{\mathrm{I}}_{\mathrm{T}} - g^{\mathrm{C}}_{\mathrm{T}})\tilde{Y}_{\mathrm{T}}, \tag{18d}$$

$$(1-\tau_{\mathrm{T}})\partial\tilde{Y}_{\mathrm{T}}/\partial K_{\mathrm{T}} + \frac{(\tilde{q}_{\mathrm{T}} - 1)^2}{2h_{\mathrm{T}}} = (\tilde{r} + \delta_{\mathrm{T}})\,\tilde{q}_{\mathrm{T}}, \tag{18e}$$

$$\tilde{p}\left[(1-\tau_{\mathrm{N}})\frac{\partial\tilde{Y}_{\mathrm{N}}}{\partial K_{\mathrm{N}}} + \frac{h_{\mathrm{N}}}{2}\left(\frac{\tilde{X}}{\tilde{K}_{\mathrm{N}}}\right)^2\right] = (\tilde{r} + \delta_{\mathrm{N}})\,\tilde{q}_{\mathrm{N}}, \tag{18f}$$

$$\tilde{r} = \beta. \tag{18g}$$

In addition to (18a)–(18g), we have the market-clearing condition for the nontraded sector,

$$\left(1 - g^{\mathrm{I}}_{\mathrm{N}} - g^{\mathrm{C}}_{\mathrm{N}}\right)\tilde{Y}_{\mathrm{N}} = \tilde{C}_{\mathrm{N}} + \tilde{\Omega}_{\mathrm{N}}, \tag{18h}$$

and the labor market equilibrium conditions

$$(1-\tau_{\mathrm{T}})\frac{\partial\tilde{Y}_{\mathrm{T}}}{\partial L_{\mathrm{T}}} = \tilde{p}(1-\tau_{\mathrm{N}})\frac{\partial\tilde{Y}_{\mathrm{N}}}{\partial L_{\mathrm{N}}}. \tag{18i}$$

$$\tilde{L}_{\mathrm{T}} + \tilde{L}_{\mathrm{N}} = 1. \tag{18j}$$

Noting the policy functions for sectoral consumption in (12), the steady-state conditions (18a)–(18j) yield 10 equations that can be solved for $\tilde{K}_{\mathrm{T}}$, $\tilde{K}_{\mathrm{N}}$, $\tilde{K}_{\mathrm{G}}$, $\tilde{B}$, $\tilde{q}_{\mathrm{T}}$, $\tilde{q}_{\mathrm{N}}$, $\tilde{\lambda}$, $\tilde{p}$, $\tilde{L}_{\mathrm{T}}$, and $\tilde{L}_{\mathrm{N}}$. This completes the characterization of the steady-state equilibrium.[14]

The dynamic system described in (17a)–(17g) is solved by linearization around the steady-state conditions (18a)–(18j):

$$\dot{\underline{Z}}' = \Lambda\left(\underline{Z}' - \tilde{\underline{Z}}'\right), \tag{19}$$

where $\underline{Z}' = (K_{\mathrm{T}}, K_{\mathrm{N}}, K_{\mathrm{G}}, B, q_{\mathrm{T}}, q_{\mathrm{N}}, \lambda)$ is the vector of states and controls, Λ is the 7×7 matrix of linearized coefficients, and $\tilde{Z}' = (\tilde{K}_{\mathrm{T}}, \tilde{K}_{\mathrm{N}}, \tilde{K}_{\mathrm{G}}, \tilde{B}, \tilde{q}_{\mathrm{T}}, \tilde{q}_{\mathrm{N}}, \tilde{\lambda})$ is a vector of the steady-state quantities.

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3. THE BENCHMARK EQUILIBRIUM: CALIBRATION

Closed-form solutions cannot be obtained, given the analytical complexity of the model, and therefore the dynamics is solved and analyzed numerically. To solve the model, we propose the following functional forms for the utility and production functions:

$$U(C_{\mathrm{T}}, C_{\mathrm{N}}) = \frac{(C_{\mathrm{T}}^{1-\theta} C_{\mathrm{N}}^{\theta})^{\gamma}}{\gamma},\ \theta \in [0,1],\ -\infty < \gamma < 1, \tag{20a}$$

$$Y_{\mathrm{T}} = A_{\mathrm{T}} K_{\mathrm{G}}^{\eta} \left[\alpha K_{\mathrm{T}}^{-\rho} + (1-\alpha) L_{\mathrm{T}}^{-\rho}\right]^{-\frac{1}{\rho}},\ A_{\mathrm{T}} > 0,\ \alpha, \eta \in (0,1),\ \rho \in (-1, \infty), \tag{20b}$$

$$Y_{\mathrm{N}} = A_{\mathrm{N}} K_{\mathrm{G}}^{\phi} \left[\varphi K_{\mathrm{N}}^{-\rho} + (1-\varphi) L_{\mathrm{N}}^{-\rho}\right]^{-\frac{1}{\rho}},\ A_{\mathrm{N}} > 0,\ \varphi, \phi \in (0,1),\ \rho \in (-1, \infty), \tag{20c}$$

$$r = r^{*} + e^{a\left(\frac{B}{K}\right)} - 1,\ a \geq 0,\ K = K_{\mathrm{T}} + pK_{\mathrm{N}}. \tag{20d}$$

For the utility function in (20a), γ is related to the intertemporal substitution in consumption, $e = 1/(1-\gamma)$, and θ is the relative importance of nontraded consumption in the agent's utility function. The overall productivities of the traded and nontraded sectors in (20b) and (20c) are determined by exogenous components given by A_{T} and A_{N}, respectively, and the aggregate stock of public capital in the economy, provided by the government. The parameters η and ϕ denote the sectoral output elasticities of public capital. Given the homogeneity of the production functions, α and φ represent the private capital intensity in the traded and nontraded sectors, respectively. ρ is related to the elasticity of substitution between private capital and labor in the production function by $\xi = 1/(1+\rho)$. The case where $\xi = 1$ ($\rho = 0$) approximates the familiar Cobb–Douglas production function. Finally, (20d) specifies the interest rate on debt, where a is a parameter that measures the sensitivity of the borrowing rate to a change in the economy's debt-servicing capacity, given by its aggregate debt–capital ratio. When $a = 0$, we have $r = r^{*}$, and the agent has unrestricted access to world capital markets. The numerical solution for the analytical model is characterized by four stable (negative) eigenvalues and three unstable (positive) eigenvalues, and is robust to variations in the model's deep structural parameters and initial conditions for the state variables.

Table 1A describes the parameterization of the benchmark economy. The preference parameter γ is chosen to yield an intertemporal elasticity of substitution in consumption of 0.4, consistent with the evidence reviewed by Guevenen (2006). The choice of $\theta = 0.5$ ensures that there is no home bias in consumption and each good has the same weight in the utility function. The rate of time preference, β, is set at 0.06, and the world interest rate at 4%, whereas the borrowing premium a is chosen to ensure a plausible debt-to-GDP ratio at equilibrium. The exogenous productivity parameters A_{T} and A_{N} represent scale parameters and are set so that the traded sector is more productive than the nontraded sector. The output elasticity of public capital is set to 0.15 in each sector as a benchmark specification. There

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TABLE 1. Benchmark equilibrium

A. Parameterization

Preference: $\gamma = -1.5$, $\beta = 0.06$, $\theta = 0.5$, $r = 0.04$, $a = 0.08$
Productivity: $\alpha = \varphi = 0.35$, $A_{\mathrm{T}} = 1.5$, $A_{\mathrm{N}} = 1$, $\eta = \phi = 0.15$, $\delta_{\mathrm{T}} = \delta_{\mathrm{N}} = \delta_{\mathrm{G}} = 0.05$, $\xi = 1$
Installation and capital mobility costs: $h_{\mathrm{T}} = h_{\mathrm{N}} = 15$, $h = 30$
Policy: $G_{\mathrm{T}}^{\mathrm{I}}/G = 0.34$, $G_{\mathrm{T}}^{\mathrm{C}}/G = 0.07$, $\tau_{\mathrm{T}} = \tau_{\mathrm{N}} = 0$

B. Benchmark steady-state quantities

L_{T}	$\frac{K_{\mathrm{T}}}{K}$	$\frac{Y_{\mathrm{T}}}{Y}$	$\frac{C}{Y}$	$\frac{K}{Y}$	$\frac{B}{Y}$	$\frac{K_{\mathrm{G}}}{K}$	$\frac{G^{\mathrm{I}}}{Y}$	$\frac{G^{\mathrm{C}}}{Y}$	p
0.431	0.534	0.431	0.698	1.454	0.359	0.354	0.049	0.182	2.332

Note: $i = \mathrm{T}, \mathrm{N}$.

is a large empirical literature on the estimation of this elasticity and the range of estimates lie between 0.1 and 0.3; see Gramlich (1994). In a recent contribution, Bom and Ligthart (2014) reviewed 67 such studies and estimated the long-run elasticity to be 0.146, which is close to our benchmark specification. The sectoral intensities of private capital, α and φ, are set equal to each other in the baseline specification. We will, of course, conduct a sensitivity analysis by differentially varying these sectoral elasticities and intensities. The intersectoral mobility cost parameter is set at $h = 30$, following the calculations of Morshed and Turnovsky (2004). Again, this parameter will be subject to a sensitivity analysis. The adjustment costs for both traded and nontraded capital, h_{T} and h_{N} respectively, are both set to 15, consistent with the findings of Auerbach and Kotlikoff (1987), Barro and Sala-i-Martin (1995), and Ortiguera and Santos (1997). We assume a rate of public investment from traded output, $g_{\mathrm{T}}^{\mathrm{I}} = 0.02$, and from nontraded output, $g_{\mathrm{N}}^{\mathrm{I}} = 0.07$, to ensure that about 4.5% of aggregate output is spent on infrastructure investment, which is consistent with the corresponding long-run average for both OECD and developing countries. Given this specification, about a third of government investment comes from the traded goods sector, with the rest coming from the nontraded sector. The public consumption parameters $g_{\mathrm{T}}^{\mathrm{C}}$ and $g_{\mathrm{N}}^{\mathrm{C}}$ have been calibrated so that aggregate public consumption represents about 18% of GDP, with 7% of public consumption originating in the traded sector. These values are consistent with the findings of Abbas et al. (2011), who document that a nontrivial amount of government purchases in developing countries falls on traded goods.[15] We also assume that there are no distortionary taxes in the benchmark equilibrium and all government spending is financed through lump sum taxes. The benchmark equilibrium is calibrated for the Cobb–Douglas production function.

Table 1B reports the benchmark steady-state equilibrium for the key macroeconomic variables of the model. For example, the share of employment and output of the traded goods sector is about 43%. About 53% of private capital is employed

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in the traded good sector, whereas the capital–output ratio is 1.45. The share of aggregate private consumption in GDP is about 70%, with both sectors contributing equally to total consumption (because there is no home bias). The steady-state share of private debt in GDP is about 36%, and the ratio of public to private capital is 0.35. The long-run real exchange rate is about 2.33.

4. POLICY ANALYSIS: FISCAL SHOCKS

In this section, we analyze the model's dynamic implications for changes in fiscal policy. Specifically, we focus on the following types of permanent government spending shocks:

(a) an increase in government spending from traded output,
(b) an increase in government spending from nontraded output, and
(c) an increase in aggregate government spending, with an equal and proportionate increase in government spending from each sector.

For each of these three cases, we compare the effects of an increase in government investment with those of an equivalent increase in government consumption. We calibrate the increase in sectoral government spending (investment or consumption) to ensure that in each case the share of government expenditure in GDP (investment or consumption) rises by one percentage point from its baseline specification.

4.1. Public Investment

Table 2A reports the steady-state effects of an increase in public investment, corresponding to the three cases (a)–(c), with the dynamic adjustment of the key macroeconomic variables illustrated in Figure 1. In all three cases, the spending increase is financed by an appropriate adjustment of lump sum taxes to balance the government's budget. Using a nondistortionary financing instrument has the advantage of decoupling the effects of public spending from those of revenues. The steady-state changes in variables are reported as percentage deviations relative to their preshock benchmark levels.[16]

As is evident from Table 2A, all three government spending shocks, being tied to investment activity, have an expansionary effect on the aggregate economy in the long run, with aggregate consumption and GDP increasing from their steady-state levels. The economy's net indebtedness increases, and the long-run real exchange rate appreciates at equilibrium. Long-run welfare also increases in each case. For the aggregate variables, an increase in public investment from traded output has the most expansionary effect on the economy in the long run. For the sectoral variables, however, the effects of public investment are asymmetric, depending on the sectoral source of government investment. The shares of capital, labor, and output for the traded sector increase when the increase in public investment impinges on the traded sector, whereas the shares of labor and output in the traded sector decline when the nontraded sector is the source of the spending increase.

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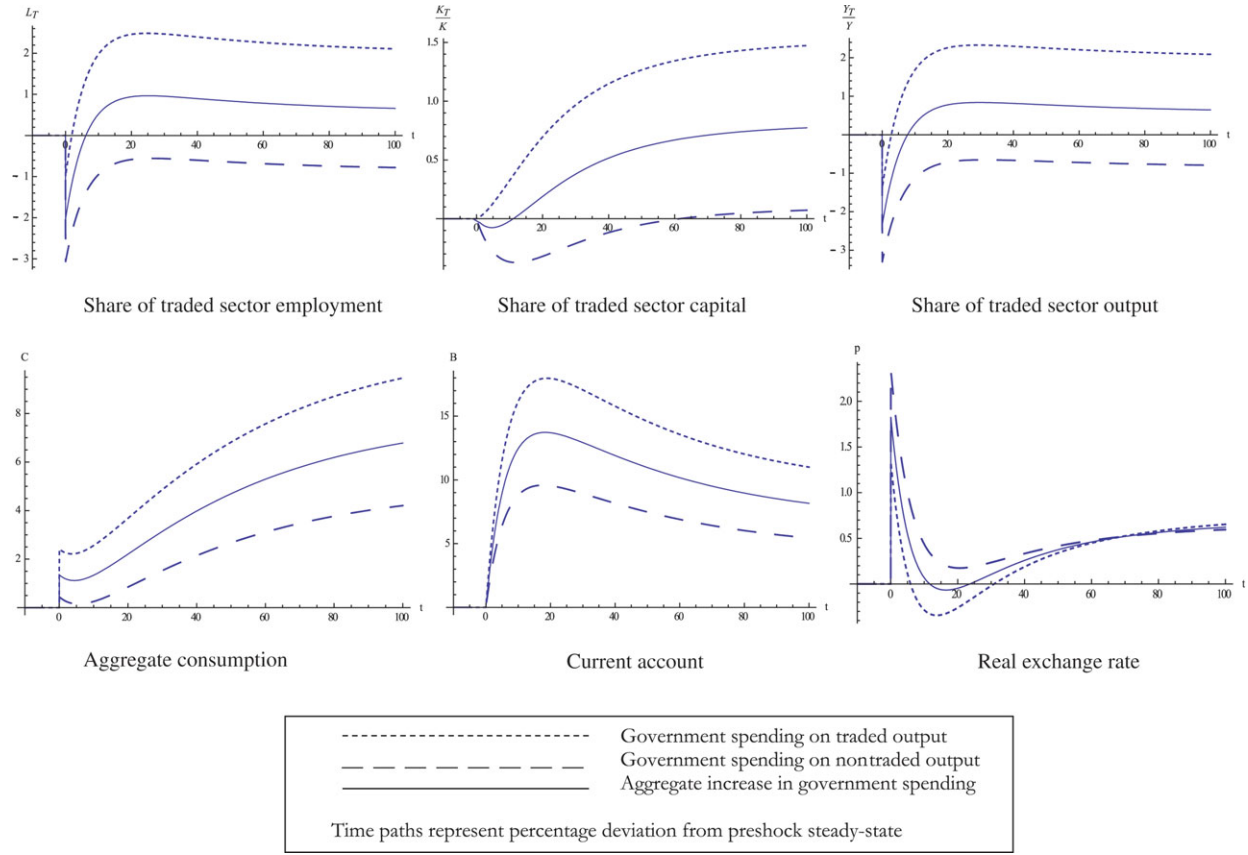


FIGURE 1. Increase in public investment (lump sum tax-financed).

TABLE 2. Government spending shocks: long-run effects

	L_T	K_T/K	Y_T/Y	C	Y	B	p	Welfare
				A. Increase in public investment				
Δg_T	2.001	1.528	2.001	10.846	9.197	9.157	0.759	3.345
Δg_N	-0.846	0.105	-0.847	5.001	5.218	4.378	0.657	0.416
$\Delta g = \Delta g_T + \Delta g_N$	0.574	0.817	0.573	7.872	7.156	6.709	0.705	1.816
				B. Increase in public consumption				
Δg_T	1.312	0.519	1.313	-1.329	0.061	0.559	-0.136	-1.383
Δg_N	-1.021	-0.409	-1.021	-1.370	-0.048	-0.436	0.106	-1.323
$\Delta g = \Delta g_T + \Delta g_N$	0.146	0.058	0.146	-1.348	0.007	0.062	-0.015	-1.354

Note: All results are reported as percentage deviations relative to their preshock equilibrium levels.

When aggregate spending increases across both sectors, the magnitude of the long-run responses represents an intermediate case between the increases in traded and nontraded government spending.

The intuition behind these results can be better understood by a depiction of the dynamic response of the economy to these shocks, which displays some interesting transitional characteristics not evident from the long-run responses. This is illustrated in Figure 1, which plots the time paths (in terms of percentage deviations from the steady state) of the shares of labor, capital, and output in the traded sector, aggregate consumption, the current account (debt), and the real exchange rate.

On impact of the increase in public investment, the real exchange rate appreciates to clear the goods market, because sectoral private capital is instantaneously fixed. Consequently, the instantaneous rise in the relative price of nontraded goods leads to a decrease in the share of employment and output in the traded sector. Because the increase in public spending is tied to infrastructure (public capital), the implied long-run increase in private productivity leads to an increase in short-run consumption, even though the increase in government spending represents a resource withdrawal from the private sector in the short run. These instantaneous responses are robust to all three types of government investment (traded, nontraded, or aggregate). However, following these responses, the transition paths of the key macroeconomic variables depend critically on the sectoral origin of government spending. For example, when government investment increases from traded output, the higher demand for goods in this sector tends to increase its share of both employment and capital over time. Consequently, the share of the traded sector in total output also increases in transition. The higher relative demand emanating from the traded sector reduces the relative price of nontraded goods, leading to a sharp *depreciation* of the real exchange rate in transition. Over time, as the higher government spending increases the economy's stock of public capital, its positive spillover effects for private productivity generate a Balassa–Samuelson effect, leading to a net appreciation of the real exchange rate in the long run. An

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interesting aspect of the macroeconomic adjustment is that the transitional path of the real exchange rate is *nonmonotonic* in nature, represented by an U-shaped adjustment path. The fact that government spending does not immediately translate into a higher stock of public capital, but does so only gradually over time, is key to the nonmonotonic adjustment of the real exchange rate. As such, the short-run behavior of the real exchange rate is determined by demand-side factors, whereas in the long run the supply side dominates.

An increase in public investment from the nontraded sector generates exactly the opposite dynamic response from the case where government spending impinges on traded goods. In this case, the higher demand for nontraded goods generated by the government leads to a flow of both labor and capital into the nontraded sector, thereby reducing their corresponding shares in the traded sector. Consequently, the decline in the relative price of the nontraded good is much smaller than in the previous case, and even though the real exchange rate again displays a U-shaped adjustment path, the real exchange rate is always above its preshock equilibrium level.

In both these examples of an increase in public investment, private consumption increases monotonically in transition to its long-run steady state.[17] The economic expansion also increases borrowing by the private agent, thereby worsening the current account, both in transition and in the long run. The case where there is an aggregate increase in public investment is intermediate between the polar examples of the increases in traded and nontraded public investment.

4.2. Public Consumption

In this section, we compare the dynamic effects of an increase in public investment with those of a corresponding increase in public consumption. As before, we consider three cases, where the increase in public consumption spending impinges on the traded or nontraded sector, or equally on both sectors. Table 2B reports the steady-state changes, whereas Figure 2 illustrates the transitional adjustment of the economy.

Comparing Tables 2A and 2B, we see that the aggregate effects of an increase in public consumption, irrespective of the sector of origin, are much smaller than those for public investment. Further, the increase in public consumption always crowds out private consumption in the long run, in sharp contrast to the case of public investment. Aggregate welfare also declines in this case, as opposed to the welfare increase reported under an increase in public investment. Public consumption from nontraded output leads to a permanent economic contraction and a net real appreciation of the exchange rate. On the other hand, public consumption from traded output has exactly the opposite effect.

Figure 2 shows that when the government spending increase takes the form of consumption, the economy's adjustment is very quick and monotonic, in sharp contrast to the case of public investment. Because government spending is not tied to investment, it has only demand-side implications in both the short and the

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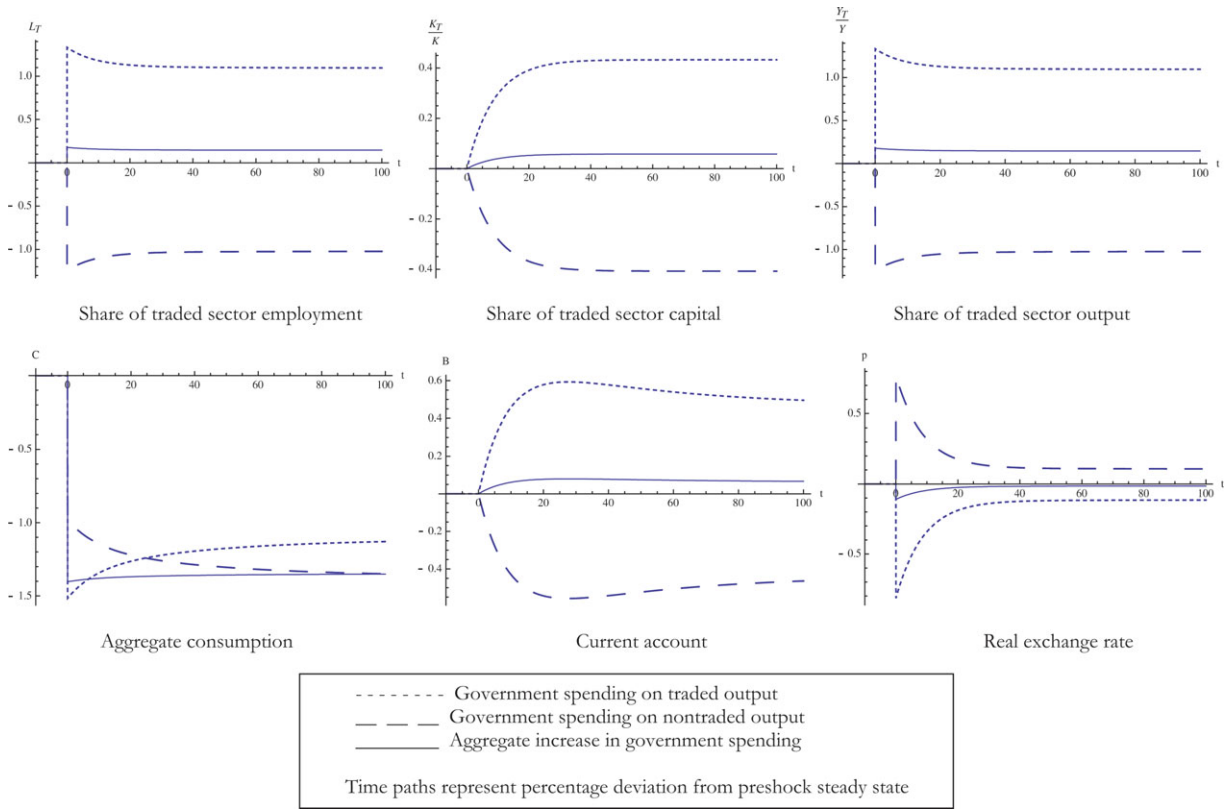


FIGURE 2. Increase in public consumption (lump sum tax-financed).

long run. Therefore, the trade-offs observed in the dynamic adjustment of sectoral labor, output, and the real exchange rate in Figure 1 are now absent. Further, public consumption also crowds out private consumption, both in the short run and the long run. The time path of the real exchange rate also does not display the U-shaped trajectory observed in Figure 1, thereby pointing to the importance of disentangling the effects of government investment from consumption.

4.3. Public Investment, the Real Exchange Rate, and Private Consumption

In this section, we explore the short-run relationship of public investment, the real exchange rate, and private consumption to variations in (i) the underlying financing policy and (ii) the relative sectoral output elasticity of public capital. With respect to financing policies, we consider three cases:

a. spending increase financed by lumpsum taxes (benchmark case);
b. spending increase financed by a tax on traded output;
c. spending increase financed by a tax on nontraded output.

For the sectoral elasticity of public capital, we also consider three possibilities:

a. Public capital is more important in the traded sector, i.e., $\eta > \phi$ ($\eta = 0.15, \phi = 0.05$).

b. Public capital is equally important for both sectors, i.e., $\eta = \phi$ ($\eta = \phi = 0.15$).

c. Public capital is more important for the nontraded sector, i.e., $\eta < \phi$ ($\eta = 0.05, \phi = 0.15$).

Figure 3 depicts the public investment–real exchange rate relationship for these cases, and Figure 4 depicts the public investment–private consumption relationship. Our discussion will focus only on the instantaneous responses of the real exchange rate and private consumption following an increase in government spending, to be consistent with the corresponding empirical literature. Essentially, we are looking for conditions under which we observe the following empirical regularities: (i) a *negative* short-run correlation between government spending and the real exchange rate, i.e., an instantaneous real depreciation of the exchange rate, and (ii) a *positive* short-run correlation between government spending and consumption, i.e., an instantaneous increase in private consumption.[18]

From Figure 3A, we see that both the underlying financing policy and the sectoral elasticity of public capital play an important role in determining the instantaneous correlation between government spending and the real exchange rate. Qualitatively, the empirically observed real depreciation of the exchange rate occurs when government spending is financed by a tax on the output of the traded sector. This is especially important for developing countries, where the nontraded sector often represents the informal economy, which is outside of the tax collection radar of the government [see La Porta and Schleifer (2014)]. The implication here is that if the traded goods sector bears the tax burden of financing an increase in government spending, the real exchange rate depreciates in the short run. This happens because the long-run implied productivity benefit from a higher stock of

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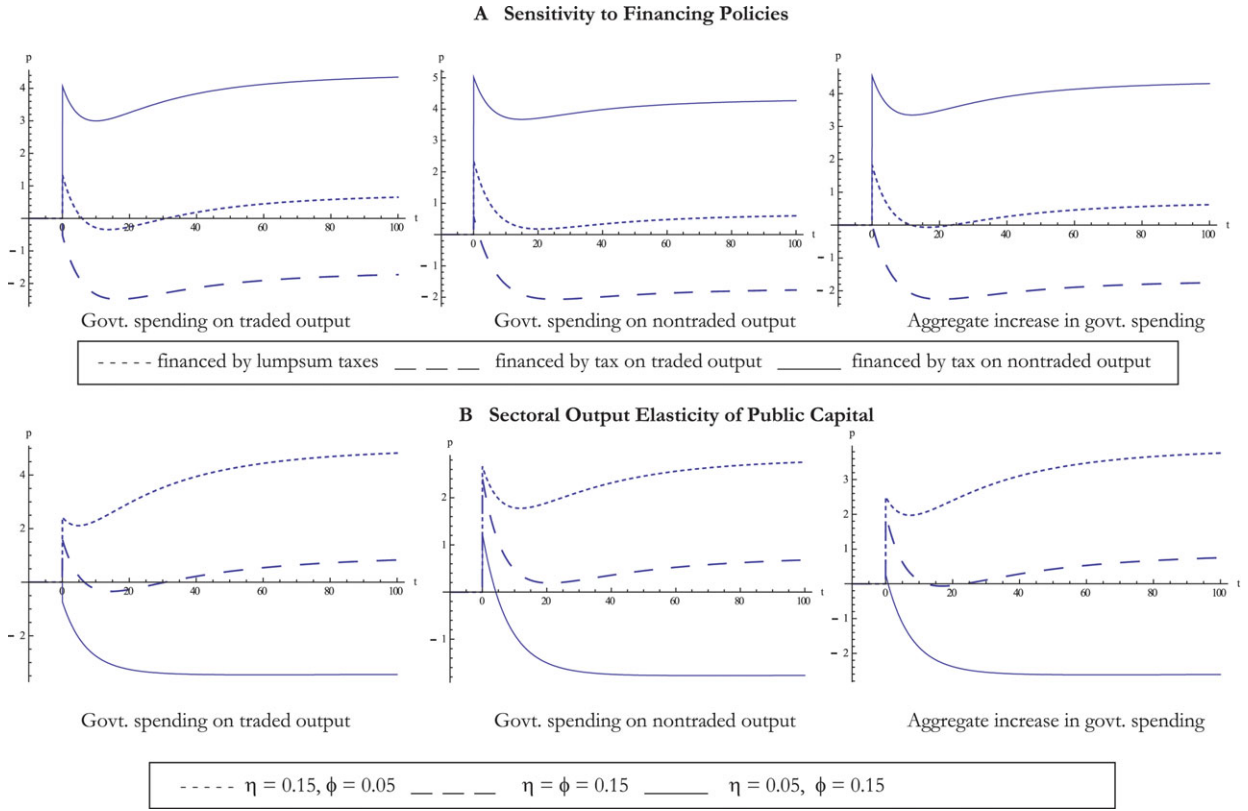


FIGURE 3. Public investment and the real exchange rate. Time paths represent percentage deviation from preshock steady state.

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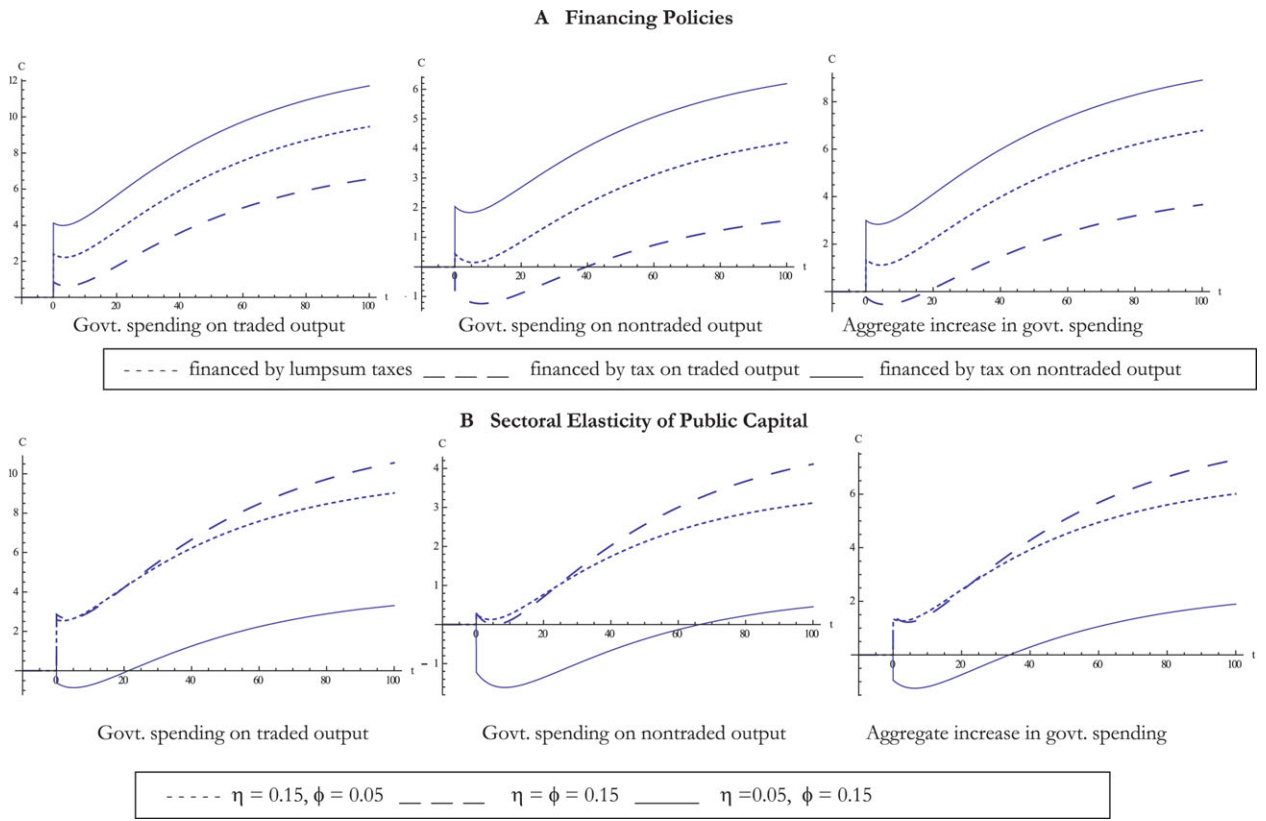


FIGURE 4. Public investment and private consumption. Time paths represent percentage deviation from preshock steady state.

public capital is more than offset by a decline in the after-tax return on private capital (in the short run).

Figure 3B suggests that when the output elasticity of public capital is greater in the nontraded sector than in the traded sector, an increase in government investment can lead to a real depreciation of the exchange rate when government spending impinges either on traded output or equally on both sectors. When public capital is more productive for the nontraded sector, any additional increase in government spending generates diminishing returns in that sector, leading to a fall in the relative price of nontraded goods.

Figure 4 considers the relationship between government spending and private consumption. With respect to financing policies (Figure 4A), the results suggest that when government spending increases on traded goods, the short-run response of consumption is positive, irrespective of the underlying financing policy. The financing policy matters when government spending increases in the nontraded sector or when there is an aggregate increase in spending. Here, lump sum tax financing or a tax on nontraded output generates an instantaneous increase in private consumption. On the other hand, from Figure 4B, we see that the short-run correlation between government spending and consumption is positive when public capital is relatively equally or more productive for the traded goods sector.

5. REAL EXCHANGE RATE DYNAMICS: SENSITIVITY ANALYSIS

This section conducts a sensitivity analysis of the dynamic response of the real exchange rate to public investment shocks for variations in three deep structural parameters of the model: (i) the sectoral intensities of private capital, α and φ, (ii) the elasticity of substitution between private capital and labor in production, $\xi = 1/(1 + \rho)$, and (iii) the intersectoral mobility cost parameter for private capital, h. The results are reported in Figures 5A–5C.

5.1. Relative Sectoral Intensity of Private Capital

We consider three cases: the traded sector is (i) more capital-intensive, i.e., $\alpha > \varphi$ ($\alpha = 0.35, \varphi = 0.25$); (ii) equally capital-intensive, i.e., $\alpha = \varphi = 0.35$; or (iii) less capital-intensive, i.e., $\alpha < \varphi$ ($\alpha = 0.25, \varphi = 0.35$), relative to the nontraded sector. Figure 5A depicts the adjustment path of the real exchange rate following the three types of government investment shocks we have considered before (traded, nontraded, and aggregate) for these three cases. As the capital intensity in the traded sector increases relative to that in the nontraded sector, (i) the long-run real appreciation of the real exchange rate increases in magnitude, and (ii) the nonmonotonicity (U-shape) of the transitional adjustment of the real exchange rate is preserved, but is more pronounced when the traded sector is relatively more capital-intensive. These results are robust to the origin of government spending, i.e., traded, nontraded, or aggregate.

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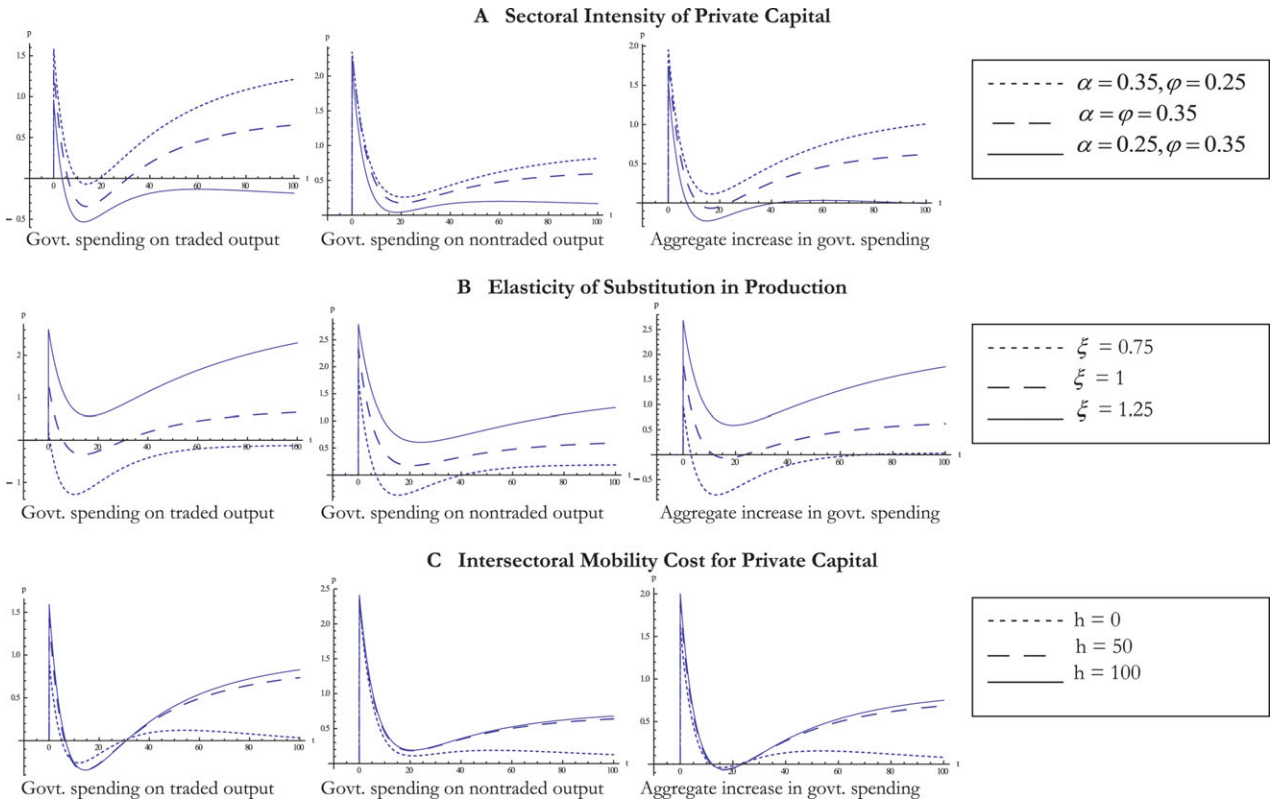


FIGURE 5. Real exchange rate dynamics: sensitivity analysis. Time paths represent percentage deviation from preshock steady state.

5.2. Elasticity of Substitution in Production

Figure 5B plots the response of the real exchange rate to the three underlying government spending shocks for three values of the elasticity of substitution in production between private capital and labor: (i) $\xi = 0.75$, (ii) $\xi = 1$, and (iii) $\xi = 1.25$. The larger the elasticity of substitution in production, the larger are the short-run and long-run response of the real exchange rate to a government spending shock. Further, the higher the elasticity of substitution in production, the more persistent is the adjustment of the real exchange rate. Though variations in the elasticity of substitution in production do not affect the nonmonotonic transitional path of the real exchange rate, low values of the elasticity generate more nonmonotonicity in the adjustment of the real exchange rate.

5.3. Intersectoral Mobility Costs

Figure 5C illustrates the sensitivity of the real exchange rate dynamics generated by the three fiscal spending shocks to variations in the magnitude of intersectoral mobility costs for private capital. We consider three cases: (i) $h = 0$ (costless transfer of capital across sectors), (ii) $h = 50$, and (iii) $h = 100$. As is evident from the plots, the intersectoral mobility cost does not affect the instantaneous response of the real exchange rate. However, it does affect the long-run and transitional behavior of the real exchange rate. The higher the cost of mobility of capital, the more persistent and nonmonotonic is the adjustment of the real exchange rate. Further, a higher mobility cost also translates into a larger real appreciation in the long run.

6. CONCLUSIONS

In this paper, we have analyzed the mechanism through which government spending affects the dynamic adjustment of a small open economy. Much of the literature has previously focused on the effects of government consumption; government investment and financing policies have received far less attention. In this context, we introduce government investment in the form of a gradually accumulating stock of productivity-augmenting infrastructure capital, which in turn can be financed by a range of distortionary and nondistortionary tax instruments. Another important feature of our analysis is the presence of convex mobility costs for transferring private capital across sectors.

Our results indicate that government spending, when it leads to the accumulation of public capital, generates a nonmonotonic U-shaped adjustment path for the real exchange rate. Given the persistence of this adjustment path, a transitional depreciation that lasts for several periods after the incidence of the shock can be more than reversed over time, as the resource-withdrawal effects of government spending in the short run are dominated by its productivity impact over time. In contrast, government consumption leads to a much quicker and monotonic

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adjustment of the real exchange rate, devoid of any intertemporal trade-offs. Whether government spending leads to a short-run (long-run) depreciation or appreciation of the real exchange rate depends critically on (i) the sectoral composition of the spending, (ii) the underlying financing policy, (iii) the sectoral capital intensity in production, (iv) the sectoral output elasticities of public capital, (v) the elasticity of substitution in production, and (vi) intersectoral mobility costs. Our model is also able to identify conditions under which the model generates the observed positive short-run correlation between government spending and private consumption. In this context, we show that the presence of public investment is crucial to generating this positive correlation.

Although we have focused on the link between government investment and the real exchange rate, the framework can easily be extended to incorporate other types of government spending, such as that on education or healthcare, and alternative sources of financing such as foreign aid. In this context, another important consideration is the consequence of capital-market imperfections or constraints on government borrowing to finance spending. All these represent promising areas for future research.

NOTES

1. According to a recent report by the Urban Land Institute and Ernst & Young (2013), China has fast-tracked work on more than 60 infrastructure projects and 82 new airports in 2013 alone, with a price tag of $158 billion. India plans to increase investment in infrastructure (mainly roads and telecommunications) from 5.2% of GDP in the period 2003–2007 to 10% during 2013–2017.

2. The global average for infrastructure investment was about 6.7% of GDP during this period [source: WDI (2014)].

3. The theoretical literature has been built on either the flexible-price neoclassical dependent economy model, with prominent early contributions including Obstfeld (1989), van Wincoop (1993), and Brock and Turnovsky (1994), or the sticky-price Keynesian open economy framework based on the Mundell–Fleming model, dating back to Dornbusch (1976) and, more recently, Obstfeld and Rogoff (1995).

4. See, for example, Corsetti and Muller (2006), Kim and Roubini (2008), Monacelli and Perotti (2010), Bouakez et al. (2011), Caporale et al. (2011), Enders et al. (2011), and Ravn et al. (2012). Abbas et al. (2011) provide an exhaustive review of both the theoretical and empirical literature that links government spending to the real exchange rate.

5. See Engel (1993, 1999), Knetter (1993), Froot and Rogoff (1995), Taylor (1995), Edwards and Savastano (1999), and Cheung and Lai (2000) for some early contributions. For nonlinearities in the adjustment path of the real exchange rate, see Taylor et al. (2001) and, more recently, Cushman and Michael (2011) and Ahmad et al. (2013).

6. See, for example, Fatas and Mihov (2001), Blanchard and Perotti (2002), and Ravn et al. (2012).

7. There is a voluminous literature on the role of public capital in affecting economic growth, starting with the work of Aschauer (1989) and Barro (1990). Important theoretical contributions include Glomm and Ravikumar (1994), Turnovsky (1997), Fisher and Turnovsky (1998), Rioja (2003), Agenor and Aizenman (2007), Chatterjee (2007), and Chatterjee and Morshed (2011); see Agenor (2012) for a comprehensive review. Gramlich (1994) and Bom and Ligthart (2014) provide reviews of the corresponding empirical literature.

8. A recent contribution by Cerra et al.(2010) also examines the effects of financing public investment by foreign aid. However, they model the *flow* of public investment as being relevant for production rather than the accumulated *stock* of public capital, along with a costless transfer of capital

https://doi.org/10.1017/S1365100515000048 Published online by Cambridge University Press

across sectors. The distinction between the stock and flow specifications turns out to be crucial for the predictions of the model. Berg et al. (2010) also develop an open economy DSGE model with public investment and the real exchange rate, but their focus is on the consequences of scaling-up of foreign aid and the Dutch Disease for cyclical fluctuations in low-income countries.

9. Nonlinearities in the adjustment path of the real exchange rate have been the focus of models with transaction costs in international arbitrage; see Taylor et al. (2001) for a review of this literature. We also derive a nonlinear adjustment path, albeit from a very different source (intersectoral mobility costs and a gradually accumulating stock of public capital).

10. In general, the share of public consumption is larger than that of public investment in government budgets across countries. However, the dynamics of the real exchange rate depends on *shocks* or innovations to the different categories of government spending, rather than the existing *levels* or shares of spending. Therefore, shocks to public investment will affect a country's relative prices, irrespective of its share in total spending.

11. In small open-economy models with a fixed world interest rate and discount factor, the marginal utility of wealth must be a constant along the transition path, with the consequence that foreign asset holdings can become indeterminate. Introducing an endogenous world interest rate that depends on the stock of debt or some measure of debt-servicing capacity is a common way to close these models; see, for example, Eaton and Gersovitz (1981), Turnovsky (1997), and Uribe and Schmitt-Grohe (2003).

12. The case where $h = 0$ is identical to the two-sector Heckscher–Ohlin model with costless movement of factors of production across sectors, whereas the case where $h \to \infty$ approximates the specific factors model, with capital being specific only to the traded goods sector. The specification in (6) is similar to the one adopted by Morshed and Turnovsky (2004), with two important differences: first, whereas Morshed and Turnovsky (2004) assume that the transfer cost depends on the ratio of the output transfer (X) to the stock of installed capital in the nontraded goods sector, i.e., $\frac{h}{2}\left(\frac{X^2}{K_N}\right)$, we simply assume that the transfer cost depends on X itself. Second, in their specification, investment originates in the nontraded goods sector, whereas in ours its origin is in the traded goods sector.

13. It is important to distinguish between the *intersectoral* mobility cost for capital, given in (6), and the *within-sector* installation or adjustment costs, given by (8a). In other words, whereas (6) captures the cost of moving output from the traded to the nontraded goods sector for investment, (8a) and (8b) capture the *within-sector* cost of installing capital, once sectoral investment decisions have been made by the agent.

14. Note that the steady-state borrowing rate on debt, $\tilde{r}$, is determined by (3): $\tilde{r} = r^* + \omega\left(\tilde{B}/\tilde{K}\right)$.

15. As mentioned earlier (in Section 1), even though the share of public investment is smaller than that of public consumption in total government spending across countries, what matters for the dynamics of the real exchange rate is the shock or innovation to a particular type of public spending, and not its share in total spending.

16. Changes in welfare levels are computed by an equivalent variation in consumption across steady states; i.e., we determine the required change (in percentage terms) in the initial consumption level (and therefore in the consumption flow over the entire adjustment path) such that the agent is indifferent between the intial welfare level and that following the policy change.

17. We will return to the issue of the short-run correlation between government spending, the real exchange rate and aggregate consumption in Section 4.3.

18. See, for example, Fatas and Mihov (2001), Blanchard and Perotti (2002), Corsetti and Muller (2006), Kim and Roubini (2008), Monacelli and Perotti (2010), and Ravn et al. (2012).

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