Fiscal Policy and the Real Exchange Rate*

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Abstract

Government spending on infrastructure has recently increased sharply in many emerging-market economies.This paper examines the mechanism through which public infrastructure 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 government spending generates a non-monotonic U-shaped adjustment path for the real exchange rate with sharp intertemporal trade-offs. 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, and (iv) the relative sectoral productivity of public infrastructure. In deriving these results, the model also identifies conditions under which the predictions of the neoclassical open economy model can be reconciled with empirical regularities, namely the intertemporal relationship between government spending, private consumption, and the real exchange rate.

Keywords: Fiscal policy, public investment, consumption, real exchange rates.
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1 Introduction

Emerging markets such as China, India, and Brazil have recently embarked on an ambitious expansion of government spending, mainly on public infrastructure such as roads, airports, rail, power supply, water, telecommunication networks, etc., as a means to sustain their high economic growth rates from the last two decades. Even in OECD countries, where governments have been working on reducing spending, infrastructure spending has remained a potential area for expansion. 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 link between government spending and the real exchange rate has 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 non-traded 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.[1] 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.[2] This is a critical issue, since 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 government investment spending may also be influenced by the expectations of higher productivity benefits in the long-run. *A priori*, it is not clear what the nature of the intertemporal relationship between government investment and the real exchange rate will be. We therefore fill an important gap in the literature by

[1] 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).

[2] See, for example, Corsetti and Muller (2006), Kim and Roubini (2008), Monacelli and Perotti (2010), Caporale et al. (2011), Enders et al. (2011), Bouakez 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.

providing a systematic analysis of this relationship.

(2) A large empirical literature has documented the strong persistence and non-linearity in the adjustment of the real exchange rate over time, implying very long periods of non-monotonic adjustment following an underlying shock.[3] By contrast, the predicted deviations of the exchange rate (from equilibrium) generated by theoretical models are very short-lived and monotonic, with implausibly fast speeds of convergence. In this paper, we focus on the dynamic interaction of two factors that may help resolve this discrepancy. First, public infrastructure is accumulated only *gradually* over time. Therefore, the trade-off between its short-run resource withdrawal effects 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 re-allocate 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 non-linearity in the dynamic adjustment of the real exchange rate.

(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 increase labor supply and reduce the consumption of all normal goods in the short run. By contrast, empirical studies have documented a *positive* correlation between government spending and private consumption in the short run.[4] 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 infrastructure capital 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, specifically on public infrastructure, and accompanying financing policies affect the dynamics of the real exchange rate. We employ a two-sector model of a small open economy with the following features: (i) a gradually accumulating stock of government-provided infrastructure capital (henceforth "public capital") that augments the productivity of private capital and labor in both the traded and non-traded sectors through a spillover effect,[5] (ii) the presence

[3] 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 non-linearities in the adjustment path of the real exchange rate, see Taylor et al. (2001) and, more recently, Cushman and Michael (2011).

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

[5] There is a voluminous literature on the role of public capital in affecting economic growth, starting

of convex intersectoral mobility costs for private capital: we assume that it is costly for agents to transfer private capital from the non-traded to the traded sector for investment purposes. This turns out to be a crucial source of non-monotonicity and persistence in the adjustment of the real exchange rate,[6] (iii) government spending in the form of investment in public infrastructure and a subsidy that reduces the cost of intersectoral capital mobility,[7] and (iv) the use of both distortionary and non-distortionary sources of financing government spending.

Given the framework we have adopted, this paper is closely related to Morshed and Turnovsky (2004) and Galstyan and Lane (2009), albeit with some critical differences. First, while Morshed and Turnovsky (2004) introduce convex mobility costs for capital in a two-sector dependent economy model, their focus is on government consumption. By contrast, we analyze the consequences of government investment in the economy's stock of public capital as well as subsidies to encourage private investment in the traded sector. As we will show, 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. Second, while 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) non-distortionary 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. We also parameterize our model to compare the effects of government consumption with investment. Our analysis thus yields several new results and

with the work of Aschauer (1989) and Barro (1990). Important theoretical contributions include Glomm and Ravikumar (1994), Fisher and Turnovsky (1998), Rioja (2003), and Agenor and Aizenman (2007); see Agenor (2011) for a comprehensive review. Gramlich (1994) and Bom and Ligthart (2010) provide reviews of the corresponding empirical literature.

[6] Intersectoral mobility costs for capital 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) provide several examples from post-World War II Western Europe to motivate the presence of intersectoral mobility costs (they label these as intersectoral *adjustment* costs), such as the costly retro-fitting of war-time industries to produce consumer goods in the post-war era.Thus, transferring capital from the non-traded to the traded sector might be associated with non-trivial costs in terms of retro-fitting, adapting to a different technology, time, labor, etc. More recently, the importance of these costs in the context of natural resources has been discussed by van der Ploeg (2011).

[7] Many developing countries adopt industrial policies that directly or indireclty subsidize private investment in their export sectors. These include the creation of Special Economic Zones (SEZ), subsidies for R&D, tax breaks, etc. This is similar to an investment tax-credit, which has been studied for the one-sector dependent economy model; see, for example, Neary (1982) and Sen and Turnovsky (1990).

insights that characterize this dynamic relationship.[8]

The analytical structure we employ yields a fifth-order non-linear dynamic system with three state and two jump variables and hence requires 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 *non-monotonic* U-shaped path for the real exchange rate (following its instantaneous response), thereby generating sharp intertemporal trade-offs in its dynamic adjustment.[9] The intuition for this result stems from the fact that an increase in public spending on infrastructure and its long-run productivity benefits increase the demand for private investment in the short run in both sectors. Since the transfer of private capital from the non-traded to the traded sector is a costly activity, the non-traded sector accumulates private capital faster than the traded sector to reduce these mobility costs (which are determined by the outflow of resources from the non-traded sector per unit of installed capital in that sector). Consequently, the marginal product of private capital in the non-traded sector increases at a slower rate than the corresponding marginal product in the traded sector (due to diminishing returns), causing a decline in the relative price of non-traded goods and, consequently, a real *depreciation* of the exchange rate in the short and medium term. Over time, as the productivity benefits of the gradually accumulating stock of infrastructure are realized, the transitional depreciation is reversed through the conventional Balassa-Samuelson channel. 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), Ravn et al. (2012), and Bouakez et al. (2012).[10]

(b) The instantaneous, 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 de-

[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 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] Non-linearities in the adjustment path of the real exchange rate have been the subject of focus in models with transaction costs in international arbitrage; see Taylor et al. (2001) for a review of this literature. We also derive a non-linear 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 public investment in government budgets across countries. However, the dynamics of the real exchange rate depend 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.

pends critically on (i) the sectoral composition of government spending on infrastructure (i.e., whether the spending increase impinges on traded or non-traded output), (ii) the underlying financing policy (lumpsum tax or sectoral income tax), (iii) the sectoral intensity of private capital, and (iv) the sectoral output elasticity of public capital. We also identify conditions under which a short-run depreciation of the real exchange rate is reversed into a net real appreciation in the long-run. Given the persistence of the U-shaped adjustment path, we argue that empirical studies that document a long-run real depreciation of the exchange rate in response to an increase in government spending may be picking up only a transitional effect. We also check the sensitivity of the adjustment path of the real exchange rate to (a) the sectoral output elasticity of public capital, (b) the elasticity of substitution between capital and labor in production, and (c) intersectoral mobility costs.

(c) The observed short-run *positive* correlation between government spending and private consumption is generated when (i) public capital is more productive in the traded sector and (ii) the increase in public investment spending is from non-traded output, and (iii) government spending takes the form of an investment tax-credit (subsidy). These results are derived in the absence of a home bias in consumption and indicate that the observed positive correlation between government spending and consumption is not inconsistent with the neoclassical model.

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. These include Kollman (2010), Corsetti et al. (2011), Bouakez and Eyquem (2011), 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 presents the numerical calibration of the model and the policy experiments, Section 4 discusses the sensitivity analysis, and Section 5 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 non-traded good. The agent accumulates wealth over time through an internationally traded bond and faces a perfect world capital market with an exogenous interest rate. There are two production sectors in this economy, namely the traded goods sector and the non-traded goods sector. Each sector uses three factors of production: private capital, labor, and a government-provided economy-wide stock of public capital (infrastructure). The stock of public capital represents a non-excludable and non-rival 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 non-traded output for public investment, and finances this spending using distortionary income taxes (levied on incomes in both sectors) as well as lumpsum taxes (or debt). Finally, we will also assume that all private investment takes place in the non-traded sector, and it is costly for the agent to transfer resources from the non-traded to the traded sector for investment in that sector. The agent receives an investment tax credit (or subsidy) from the government that is targeted towards reducing these intersectoral mobility costs. We treat the traded good as a numeraire, so that the relative price of the non-traded good is the real exchange rate, with an increase denoting a real appreciation and vice-versa.

2.1 Resource Allocation in the Private Sector

The representative agent's intertemporal utility function is given by

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

subject to a flow budget constraint

$$\dot{B} = \left(1 - \tau_T\right) Y_T + rB + p\left[(1 - \tau_N)Y_N - C_N - I_N - (1 - s)\Omega(X, K_N)\right] - C_T - T_L \tag{2}$$

where, C_T and C_N denote the consumption of the traded and non-traded good, respectively. B denotes an internationally traded bond which earns an exogenous world interest rate, r. The agent produces output Y_T in the traded-goods sector and Y_N in the non-traded sector. I_N represents private investment in the non-traded sector and $\Omega(.)$ is the intersectoral mobility cost incurred by the agent to transfer X units of resources from the non-traded sector to the traded sector for investment.[11] The agent pays taxes on output produced in both sectors, with traded output being taxed at the rate τ_T and non-traded output being taxed at the rate τ_N. The agent also pays a lumpsum tax, T_L, and receives an investment subsidy s, targeted towards reducing the cost of converting non-traded output to investment in the traded sector. Finally, the relative price of the non-traded good, i.e., the real exchange rate, is denoted by p.

The rate of accumulation of private capital in each sector is given by

$$\dot{K}_T = X \tag{3a}$$

$$\dot{K}_N = I_N \tag{3b}$$

where K_T is the stock of private capital in the traded sector and K_N is the corresponding stock in the non-traded sector. The cost of transferring X units of non-traded output to the traded sector for investment is given by

$$\Omega(X, K_N) = X\left(1 + \frac{h}{2}\frac{X}{K_N}\right), \ \ h \geq 0 \tag{4}$$

where h is the a parameter that measures the sensitivity of the mobility cost to the resources transferred per unit of installed non-traded capital.[12]

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

$$L_T + L_N = 1 \tag{5}$$

where L_T is the employment in the traded sector and L_N is the corresponding measure in the non-traded sector.

Production of final goods in the traded and non-traded sectors uses a standard neoclassical technology and three factors: sectoral private capital and labor, and the economy-wide

[11] The assumption that the non-traded sector is the source of all private investment is consistent with the structure of the dependent ecopnomy model, where the real exchange rate is the relative price of non-traded goods. As we will show below, the relative shadow price of investment in the non-traded sector turns out to be the real exchange rate in equilibrium. Brock and Turnovsky (1994) extend the neoclassical dependent economy model to incorporate investment in both traded and non-traded sectors, but the basic insights of the model remain robust to this extension.

[12] Note that $h = 0$ represents the standard Heckscher-Ohlin specification, where it is costless to transfer capital across sectors. On the other hand, when $h \to \infty$, the model converges to the specific factors model, with capital being immobile across sectors. Though the functional form is similar to the convex installation (adjustment) cost function due to Hayashi (1982), this specification captures the cost of moving resources from one sector to the other for investment, rather than the cost of *installing* capital in a sector. The specification in (4) follows that in Morshed and Turnovsky (2004).

aggregate stock of public capital, K_G, provided by the government:

$$Y_i = Y_i\left(K_i, L_i, K_G\right), \quad i = T, N \tag{6}$$

The stock of public capital 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 market-clearing condition in the non-traded sector is given by

$$Y_N = C_N + I_N + \Omega(X, K_N) + G_N \tag{7}$$

where G_N represents the proportion of non-traded output used by the government for public investment. Private capital in the non-traded sector then evolves according to

$$\dot{K}_N = Y_N - C_N - \Omega(X, K_N) - G_N \tag{7a}$$

The agent chooses the rate of consumption of the two goods, sectoral investment, and the allocation of labor to maximize (1), subject to (2), (3a) and (3b), given (4). 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 $B(0)$, $K_T(0)$, and $K_N(0)$. The current-value Hamiltonian function is

$$\begin{aligned} H \;=\; & U\left(C_T, C_N\right) e^{-\beta t} dt \\ & +\lambda e^{-\beta t}\left[(1-\tau_T) Y_T + rB + p\left\{(1-\tau_N)Y_N - C_N - I_N - (1-s)\Omega(.)\right\} - C_T - T_L - \dot{B}\right] \\ & +q_1^{'} e^{-\beta t}\left[X - \dot{K}_T\right] + q_2^{'} e^{-\beta t}\left[I_N - \dot{K}_N\right] \end{aligned} \tag{8}$$

where λ is the shadow price of wealth held in the traded bond, and $q_1^{'}$ and $q_2^{'}$ are the respective shadow prices for traded and non-traded private capital. The optimality conditions are

$$U_T\left(C_T, C_N\right) = \lambda \tag{8a}$$

$$U_N\left(C_T, C_N\right) = p\lambda \tag{8b}$$

$$\beta = r \Rightarrow \lambda = \bar{\lambda} \tag{8c}$$

$$p = \frac{q_2^{'}}{\bar{\lambda}} = q_2 \tag{8d}$$

$$\frac{\dot{q}_1}{q_1} + \frac{(1-\tau_T)\partial Y_T/\partial K_T}{q_1} = r \tag{8e}$$

$$\frac{\dot{p}}{p}+(1-\tau_N)\frac{\partial Y_N}{\partial K_N}+(1-s)\frac{h}{2}\left(\frac{X}{K_N}\right)^2=r \tag{8f}$$

$$\frac{q_1}{p}=1+(1-s)h\frac{X}{K_N} \tag{8g}$$

$$(1-\tau_T)\frac{\partial Y_T}{\partial L_T}=p(1-\tau_N)\frac{\partial Y_N}{\partial L_N} \tag{8h}$$

$$\underset{t\to\infty}{Lim}\lambda B e^{-\beta t}=\underset{t\to\infty}{Lim} q_1 K_T e^{-\beta t}=\underset{t\to\infty}{Lim} p K_N e^{-\beta t}=0 \tag{8i}$$

The first-order conditions (8a) and (8b) equate the marginal utility of consumption from each sector to the marginal utility of wealth, denominated in terms of the traded bond. (8c) is the standard no-arbitrage condition for a small open economy facing a perfect world capital market: the rate of time preference must equal the world interest rate. This restricts the shadow price of wealth to be a constant over time, and therefore $\lambda=\bar{\lambda}$. (8d) states that the real exchange rate is equal to the shadow price of non-traded capital, denominated in terms of the traded bond. (8e) is the no-arbitrage condition for investment in the traded sector, equating its net after-tax return to the world interest rate. Here, the shadow price of traded-sector private capital is expressed relative to that of the traded bond ($q_1=q_1^{'}/\bar{\lambda}$). (8f) is the corresponding no-arbitrage condition for private investment in the non-traded sector, where from (8d), we note that the shadow price of non-traded sector capital expressed in units of the traded bond is essentially the real exchange rate. (8h) states that the after-tax return to labor in each sector must be the same in equilibrium, and (8i) lists the transversality conditions for the three private assets.

From (8a) and (8b), we can derive the policy functions for sectoral consumption:

$$C_i=C_i\left(p,\bar{\lambda}\right),\quad i=T,N \tag{9a}$$

where,

$$\frac{\partial C_i}{\partial\bar{\lambda}}<0,\ \frac{\partial C_T}{\partial p}>0,\ \frac{\partial C_N}{\partial p}<0,\ i=T,N$$

An increase in the marginal utility of wealth reduces the consumption of both traded and non-traded good, as the agent increases labor supply to offset for the increase in $\bar{\lambda}$. A real appreciation of the exchange rate makes the non-traded good more expensive relative to the traded good, causing the agent to allocate resources away from non-traded consumption towards traded consumption.[13] Further, taking note of (6), we can derive the policy functions

[13]The details of these results are available on request from the authors.

for sectoral labor supply from (8h):

$$L_i = L_i \left(p, K_T, K_N, K_G\right), \; i = T, N \tag{9b}$$

where,

$$\frac{\partial L_T}{\partial p} < 0, \; \frac{\partial L_T}{\partial K_T} > 0, \; \frac{\partial L_T}{\partial K_N} < 0, \; \text{sign}\left(\frac{\partial L_T}{\partial K_G}\right) = \text{sign}\left(\eta - \phi\right)$$

A real appreciation draws resources into the non-traded sector, reducing traded-sector employment. An increase in the stock of private capital in the traded sector raises the marginal product of labor in that sector, raising employment. Exactly the opposite happens when non-traded capital increases. Finally, the effect of a higher stock of public capital on employment in the traded sector is ambiguous and depends on the relative productivity of public capital in the traded sector, $\eta - \phi$. If public capital is more productive in the traded sector, employment in that sector increases, and vice versa.[14]

To obtain the rate of private investment in the traded-goods sector, we differentiate (8g) with respect to time, while taking note of (8e) and (8f):

$$\begin{aligned} \dot{X} \;\; = \;\; & \left[\frac{Y_N - C_N - G_N}{K_N} + (1-\tau_N)\frac{\partial Y_N}{\partial K_N}\right] X - \left[1 + s\left(1 + h\frac{X}{K_N}\right)\right]\frac{X^2}{2K_N} \\ & - \frac{K_N}{(1-s)ph}\left[(1-\tau_T)\frac{\partial Y_T}{\partial K_T} - p(1-s)(1-\tau_N)\frac{\partial Y_N}{\partial K_N}\right] \end{aligned} \tag{9c}$$

2.2 The Public Sector

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

$$G_i = g_i Y_i, \; 0 < g_i < 1, \; i = T, N \tag{10a}$$

where g_i represents the rate of public investment from sector i $(i = T, N)$. As such, g_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 non-traded output is consistent with the findings of Abbas et al. (2011), who report that in developing countries, a significant amount of government spending falls on traded goods.

[14] The details of these results are available on request from the authors.

Public capital accumulates according to

$$\dot{K}_G = G_T + pG_N - \delta_G K_G = g_T Y_T + g_N p Y_N - \delta_G K_G \tag{10b}$$

where δ_G represents the rate of depreciation of public capital.[15] The government maintains a balanced budget at all points of time, using tax revenues to finance spending on infrastructure and the investment subsidy:

$$G_T + p\left[G_N + s\Omega(X, K_N)\right] = \tau_T Y_T + \tau_N p Y_N + T_L \tag{11}$$

The evolution of the current account is obtained by combining (2) with (11):

$$\dot{B} = rB + (1 - g_T)Y_T - C_T \tag{12}$$

2.3 Macroeconomic Equilibrium

The core equilibrium dynamics are represented by a fifth-order non-linear differential equation system with three state variables, K_T, K_N, and K_G and two jump variables, p and X :

$$\dot{K}_T = X \tag{13a}$$

$$\dot{K}_N = Y_N - C_N - G_N - X\left(1 + \frac{h}{2}\frac{X}{K_N}\right) \tag{13b}$$

$$\dot{K}_G = g_T Y_T + p g_N Y_N - \delta_G K_G \tag{13c}$$

$$\dot{p} = p\left[\beta - (1-\tau_N)\frac{\partial Y_N}{\partial K_N} - (1-s)\frac{h}{2}\left(\frac{X}{K_N}\right)^2\right] \tag{13d}$$

$$\begin{aligned}\dot{X} \;=\; & \left[\frac{Y_N - C_N - G_N}{K_N} + (1-\tau_N)\frac{\partial Y_N}{\partial K_N}\right]X - \left[1 + s\left(1 + h\frac{X}{K_N}\right)\right]\frac{X^2}{2K_N} \\ & - \frac{K_N}{(1-s)ph}\left[(1-\tau_T)\frac{\partial Y_T}{\partial K_T} - p(1-s)(1-\tau_N)\frac{\partial Y_N}{\partial K_N}\right]\end{aligned} \tag{13e}$$

The steady-state is attained when

$$\dot{K}_i = \dot{K}_G = \dot{X} = \dot{p} = 0 \quad (i = T, N) \tag{14}$$

[15] Since this is a neoclassical model with a stationary steady-state, and the government is not an optimizing entity, we need a positive rate of depreciation for public capital to close the model. Otherwise, spending on public investment would have to arbitrarily jump to zero at the steady-state, which could not be justified with a passive government.

At the steady-state equilibrium, the current account is given by

$$\tilde{Y}_T = C_T(\tilde{p}, \bar{\lambda}) + g_T \tilde{Y}_T - r\tilde{B} \tag{15}$$

where the "~" denotes a steady-state quantity for an endogenous variable. To solve the model, we will assume that at the initial pre-shock steady-state, the economy does not hold any debt or credit, i.e., $\tilde{B}_0 = 0$. This only applies to the *initial* equilibrium and will not hold once a shock is realized and absorbed by the economy, as will be shown in the next section. The steady-state condition (14), along with (15) (with $\tilde{B}_0 = 0$), (5) and (8h) yield 8 equations that can be solved for the steady-state quantities $\tilde{K}_T, \tilde{K}_N, \tilde{K}_G, \tilde{X}, \tilde{p}, \bar{\lambda}, \tilde{L}_T$, and $\tilde{L}_N$. Note also from (13a) that at the steady state, there is no new investment in private capital in the traded sector, i.e., $\tilde{X} = 0$.

The linearized dynamics around this initial steady-state can be expressed as

$$\dot{\underline{Z}}' = \Lambda \left(\underline{Z}' - \tilde{\underline{Z}}' \right) \tag{16}$$

where $\underline{Z}' = (K_T, K_N, K_G, p, X)$ is the vector of state and controls, Λ is a 5x5 matrix of linearized coefficients, and $\tilde{\underline{Z}}' = \left(\tilde{K}_T, \tilde{K}_N, \tilde{K}_G, \tilde{p}, \tilde{X}\right)$ is a vector of steady-state quantities. The equilibrium dynamics are characterized by three stable (negative) eigenvalues, denoted by μ_i $(i = 1, 2, 3)$ and two unstable eigenvalues.

2.4 Current Account Dynamics

In this section, we solve for the dynamics of the current account following a shock to the initial steady-state equilibrium in (13)-(15).[16] The optimal (linearized) time paths of the endogenous variables in the vector $\underline{Z}'$takes the following canonical form:

$$Z(t) - \tilde{Z} = A_1 v_{j1} e^{\mu_1 t} + A_2 v_{j2} e^{\mu_2 t} + A_3 v_{j3} e^{\mu_3 t}, \ j = 1, ..., 5, \text{ and } Z = K_T, K_N, K_G, p, X \tag{17}$$

where A_1, A_2, and A_3 represent the constants associated with the stable eigenvalues μ_1, μ_2, and μ_3, respectively, and v_{ji} $(i = 1, 2, 3)$ denote the normalized eigenvectors associated with each stable eigenvalue, where we apply the normalization $v_{1i} = 1$. Linearizing the current

[16] The solution procedure outlined in this section closely follows Turnovsky (1997) and is also similar to the one in Morshed and Turnovsky (2004). More specifically, models of small open economies that face perfect access to world capital markets are characterized by a unit root in the dynamic system, where the steady state equilibrium depends on initial conditions. This hysterisis property, however, is more binding for temporary shocks, which we do not consider in this paper; see Sen and Turnovsky (1990) for a more elaborate discussion.

account equation in (12) around the steady-state equilibrium, we can derive the following (linearized) differential equation for the current account:

$$\dot{B} = r\left(B - \tilde{B}\right) + \Psi_1\left(K_T - \tilde{K}_T\right) + \Psi_2\left(K_N - \tilde{K}_N\right) + \Psi_3\left(K_G - \tilde{K}_G\right) + \Psi_4\left(p - \tilde{p}\right) \quad (18)$$

where,

$$\begin{aligned} \Psi_1 &= (1-g_T)\left(\frac{\partial Y_T}{\partial K_T} + \frac{\partial Y_T}{\partial L_T}\frac{\partial L_T}{\partial K_T}\right), \Psi_2 = \frac{\partial Y_T}{\partial L_T}\frac{\partial L_T}{\partial K_N} \\ \Psi_3 &= \frac{\partial Y_T}{\partial K_G} + \frac{\partial Y_T}{\partial L_T}\frac{\partial L_T}{\partial K_G}, \ \Psi_4 = (1-g_T)\frac{\partial Y_T}{\partial L_T}\frac{\partial L_T}{\partial p} - \frac{\partial C_T}{\partial p} \end{aligned}$$

with all the partial derivatives evaluated at the steady-state. Using (17) in (18), solving the resulting differential equation, and imposing the transversality condition for the traded bond from (8i) leads to the following adjustment path for the current account

$$B(t) = \tilde{B} + \sum_{i=1}^{3}\frac{\Pi_i}{\mu_i - r}e^{\mu_i t} \quad (19)$$

where $\Pi_i = A_i\sum_{j=1}^{4}\Psi_j v_{ji}$, $i = 1, 2, 3$. At $t = 0$, (19) gives

$$B_0 = \tilde{B} + \sum_{i=1}^{3}\frac{\Pi_i}{\mu_i - r} \quad (19a)$$

Under the assumption that $B_0 = 0$, (19a) can be solved for the steady-state level of the current account, $\tilde{B}$ following a shock. Once $\tilde{B}$ is known, (19) then fully characterizes the evolution of the current account and, consequently, the after-shock steady-state equilibrium, using (14).

3 Policy Analysis

The analytical model described in section 2 is too complex for a closed-form solution, and therefore must be evaluated numerically. To solve the model, we propose the following functional forms for the utility and production functions:

$$U(C_T, C_N) = \frac{(C_T^{1-\theta}C_N^{\theta})^{\gamma}}{\gamma}, \ \theta \in [0,1], \ -\infty < \gamma < 1 \quad (20a)$$

$$Y_T = A_T K_G^{\eta} \left[\alpha K_T^{-\rho} + (1-\alpha) L_T^{-\rho} \right]^{-\frac{1}{\rho}}, \ A_T > 0, \ \alpha, \eta \in (0,1), \ \rho \in (-1, \infty) \tag{20b}$$

$$Y_N = A_N K_G^{\phi} \left[\varphi K_N^{-\rho} + (1-\varphi) L_N^{-\rho} \right]^{-\frac{1}{\rho}}, \ A_N > 0, \ \varphi, \phi \in (0,1), \ \rho \in (-1, \infty) \tag{20c}$$

where γ is related to the intertemporal substitution in consumption, $e = 1/(1-\gamma)$ and θ is the relative importance of non-traded consumption in the agent's utility function. The overall productivities of the traded and non-traded sectors are determined by an exogenous component 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 capital intensity in the traded and non-traded sectors, respectively, Finally, 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.

3.1 The Benchmark Equilibrium

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 world interest rate is set at 6 percent. The exogenous productivity parameters A_T and A_N are chosen to yield a plausible benchmark equilibrium. The output elasticity of public capital is set to 0.15 in each sector as a benchmark specification. There is a large empirical literature on the estimation of this elasticity and the range of estimates lie between $0.1 - 0.3$; see Gramlich (1994). In a recent contribution, Bom and Ligthart (2009) review 67 such studies and estimate the long-run elasticity to be 0.146, which is close to our benchmark specification. We will, of course, conduct a sensitivity analysis by differentially varying the sectoral elasticities. 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. We assume a rate of public investment from traded output, $g_T = 0.02$ and from non-traded output, $g_N = 0.07$ to ensure that about 4.6% of aggregate output is spent on infrastructure investment, which is also the long-run average for most OECD countries. Given this specification, about 21 percent of government spending comes from the traded goods sector, while 79 percent comes from the non-traded sector. This is consistent with the findings of Abbas et al. (2011), who document that a non-trivial amount of government purchases in developing countries fall on traded goods.[17] We also assume that there are no distortionary taxes or subsidies in the benchmark equilibrium and all government spending is financed through lumpsum taxes. The benchmark equilibrium is calibrated for the Cobb-Douglas production function.

Table 1B reports the benchmark steady-state equilibrium for two cases: (i) the traded sector is more capital intensive than the non-traded sector ($\alpha = 0.35, \varphi = 0.25$) and (ii) the non-traded sector is more capital intensive than the traded sector ($\alpha = 0.25, \varphi = 0.35$).[18] For example, in the case where the traded sector is more capital intensive, the capital-labor ratio in the traded and non-traded sectors are about 14.26 and 8.83, respectively. The capital-output ratio is 3.05 in the traded sector and 7.97 in the non-traded sector. The allocation of labor to the traded sector is 0.45 and the share of traded output in GDP is about 0.49. The share of consumption of each good in GDP is about 0.48 (since there is no home bias). The steady-state aggregate capital-output ratio is 3.62 and the ratio of public to private capital is 0.25. The long-run real exchange rate is about 1.91.

3.2 Fiscal Policy Shocks

Table 2 reports the long-run effects of three fiscal policy shocks on the macroeconomy and the resultant change in intertemporal welfare. We subject the benchmark equilibrium in Table 1B to the following three government spending shocks:

(a) An increase in public investment from traded output: g_T increases permanently from 0.02 to 0.05.

(b) An increase in public investment from non-traded output: g_N increases permanently from 0.07 to 0.1.

(c) An increase in the investment subsidy to reduce intersectoral adjustment costs in the non-traded sector: s rises permanently from 0 to 0.1.

In policy changes (a) and (b) above, we calibrate the increase in government spending to ensure that in each case total government investment rises from its benchmark rate of 4.6 percent to about 6 percent of GDP. In all three cases, the spending increase is financed by an appropriate adjustment of lumpsum taxes to balance the government's budget. For the benchmark case, using a non-distortionary financing instrument has the advantage of decoupling the effects of spending from revenues. The long-run impact of these fiscal shocks

[17] 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.

[18] It is well known in the dependent open economy models that the dynamics depend critically on the sectoral capital intensities; for a detailed discussion see Turnovsky (1997).

are reported for two alternative scenarios: where the traded sector is more capital intensive and vice versa. The steady-state changes in variables are reported relative to their pre-shock benchmark levels, so that a value greater than one indicates an increase and vice versa. The effect on welfare is reported as a percentage change.[19]

As is evident from Table 2A and 2B, all three government spending shocks, being tied to investment activity, have an expansionary effect on the economy in the long-run, with the capital-labor ratio increasing in both sectors, along with aggregate consumption and GDP. The share of labor employment in the traded sector and traded output in GDP increase in all three cases, indicating that the non-traded sector shrinks relative to the traded sector. Intertemporal welfare improves when government spending is directed towards public investment. However, the investment subsidy generates a net welfare loss for the economy. We also note that the investment subsidy is the least expansionary of the three fiscal spending shocks. The long-run change in the real exchange rate deserves some comment. For the cases where government spending increases public investment, the long-run real exchange rate appreciates when the traded sector is more capital intensive. By contrast, when the non-traded sector is more capital intensive, there is a long-run real depreciation. In the case of the investment subsidy, the real exchange rate appreciates irrespective of the sectoral capital intensity.

The intuition behind the above results can be better understood by a depiction of the dynamic response of the economy to these shocks. This is illustrated in Figure 1, which plots the time paths of labor employment in the traded sector, the share of traded output in GDP, aggregate consumption, and the real exchange rate, all relative to their pre-shock benchmark levels.

a. *An increase in public investment from traded output:* labor employment in the traded sector, as well as the share of traded output in GDP increase instantaneously on impact of the shock, while aggregate consumption declines. This happens because in the short run, with all private and public capital stocks fixed instantaneously, the higher government spending on traded output creates an increase in demand in that sector. As a result, the relative price of traded goods increase instantaneously, causing a real depreciation of the exchange rate, consistent with the findings of Monacelli and Perotti (2006) and Ravn et al. (2012), albeit in the context of government consumption. This draws labor into the traded sector from the non-traded sector, increasing the flow of traded output in the short run. On the other hand, even though the government spending will lead to a higher stock

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

of public capital in the future, in the short run it represents a resource withdrawal from the economy. The resultant increase in the marginal utility of wealth causes the agent to instantaneously reduce consumption. Over time, as public investment leads to the gradual accumulation of the stock of public capital, the productivity of labor and capital improve in both sectors. Given the initial expansion of employment and output in the traded sector, the higher productivity along the transition path ensures that it is sustained over time. The higher output along the transition path also ensures that consumption increases in transition above its pre-shock level after its initial decline.

We also see from Figure 1 that the government spending increase generates a transitional behavior of the real exchange rate that is *non-monotonic* in nature, represented by an U-shaped adjustment path. Following its initial depreciation, the real exchange rate continues to depreciate in the short run but this trend is eventually reversed into a net long-run appreciation. This happens because, following the shock, the full productivity benefits of the higher stock of public capital are not realized in the short run, given the slow convergence speeds of the state variables. However, the expectation of higher productivity in the future requires that non-traded output be transferred to the traded sector for private investment. Given intersectoral mobility costs, this is a costly activity. Therefore, to reduce these costs, the non-traded sector accumulates capital faster than the traded sector. The marginal product of non-traded capital therefore increases at a slower rate than that of traded capital (complemented by the transfer of labor to the traded sector as well), causing the real exchange rate to depreciate in the short run. Over time, as enough public capital is accumulated, and its productivity benefits are realized, the conventional Balassa-Samuelson effect kicks in, and the real exchange rate appreciates.[20]

b. *An increase in public investment from non-traded output:* The short-run response of the economy to this shock is exactly the opposite of the corresponding response for the increase in spending from traded output. The higher public spending in the non-traded sector increases the relative demand for non-traded goods, causing an instantaneous real appreciation and reduction in labor employment in the traded sector. As resources get drawn into the non-traded sector, the share of traded output in GDP also declines on impact of the spending shock. Given the instantaneous transfer of labor to the non-traded sector, the real exchange rate must over-shoot its long run equilibrium to equate the real return on labor in both sectors. In contrast to the case of spending on traded output, aggregate consumption now increases instantaneously, generating the observed short-run positive correlation between government spending and consumption that is observed in the data. Even though the

[20]Indeed, as we will see in section 4.3, when there are no intersectoral mobility costs ($h = 0$), this non-monotonicity is absent from the path of the real exchange rate.

spending shock generates a resource withdrawal effect in the short run, the real appreciation of the exchange rate increases the domestic consumption of the traded good relative to the non-traded good, which has a net positive effect on aggregate consumption.[21] In transition, for reasons noted above, the real exchange rate depreciates following its initial appreciation. This draws resources back to the traded sector over time, increasing both labor employment in that sector as well as its share of output in GDP. The time path of the real exchange rate is again non-monotonic and has an U-shape, as the Balassa-Samuelson productivity effect from the higher stock of public capital eventually takes over. This causes a long-run real appreciation of the exchange rate.

c. *An increase in the investment subsidy:* The qualitative effects of subsidizing the cost of transferring non-traded output to the traded sector for investment are similar to that of an increase in public investment from the non-traded sector. The only difference now is that since the cost of the transfer of resources to the traded sector is subsidized, the adjustment of the real exchange rate is less non-monotonic, with the short-run real appreciation being sustained over time. The investment subsidy also generates a positive short-run response of aggregate consumption.

When the non-traded sector is more capital intensive, the dynamic responses to the three fiscal shocks are qualitatively similar, except for the long-run adjustment of the real exchange rate. In this case, in sharp contrast to the case when the traded sector is more capital intensive, the long-run real exchange rate *depreciates* for the two public investment shocks, underscoring the sensitivity of the real exchange rate dynamics to the sectoral intensity of private capital.

3.3 Exchange Rate Dynamics: Sensitivity to Financing Policies

In this section, we examine how sensitive the dynamic adjustment of the real exchange rate is to the three fiscal spending shocks, when different financing policies are used to balance the government's budget. Specifically, we consider three types of financing policies:

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 non-traded output

The short-run (instantaneous) and long-run responses of the real exchange rate (relative to its pre-shock equilibrium) are reported in Table 3 and Figure 2. As we can see from these results, the underlying mode of financing matters critically for both the short-run and long-run response of the real exchange rate. Since we have already discussed the response of the

[21] We will return to the issue of the short-run correlation between government spending and aggregate consumption in section 3.5.

real exchange rate when spending increases are financed by lumpsum taxes, we will focus on the cases of distortionary tax-financing in this section. When public investment is financed by a tax on traded output, irrespective of which sector's output the spending impinges on, the real exchange rate depreciates both in the short run as well as the long run. By contrast, the response is exactly the opposite when the same increase in public investment is financed by a tax on non-traded output: a real appreciation in both the short run and long run. These results remain robust to the sectoral capital intensity. The intuition behind these contrasting responses lie in the effect of the sectoral income taxes on the relative demand for sectoral output. A higher tax on traded (non-traded) output, lowers the after-tax return from that sector's output and discourages private investment. On the other hand, to the extent that the higher government spending it finances creates an augmented stock of public capital, it increases the long-run demand for private investment. If the second effect dominates the first, a tax on traded (non-traded) output increases the long-run relative demand for traded (non-traded) output for investment purposes. Therefore, the real exchange rate depreciates (appreciates) as the relative price of non-traded goods falls (rises).

In the case of an increase in government spending on the investment subsidy, the real exchange rate appreciates both in the short run as well as in the long-run, irrespective of the mode of financing. This indicates that the expansionary effect of the subsidy dominates the distortionary effects of the underlying tax policies, thereby generating a net increase in demand for non-traded goods (since the subsidy is directed towards non-traded output).

3.4 The Persistence of the Real Exchange Rate

Figure 3 takes up the issue of the persistence of the real exchange rate's dynamic adjustment (in terms of its deviations from the steady-state) and its implications for empirical analyses with relatively short time-series data. Most empirical studies of the real exchange rate use at most 25-30 years of data to study its dynamics. On the other hand, the empirical literature has also documented the strong persistence of real exchange rate deviations from PPP. This leads to the possibility that in a relatively short time-series, what might look like a non-stationary process is actually stationary with a lot of persistence. However, this may also lead to misleading predictions of the behavior of the real exchange rate in response to underlying shocks.

Figure 3 plots the dynamic response of the real exchange rate for increases in public investment from traded output (figure 3A) and non-traded output (figure 3B) with each increase being financed by lumpsum taxes. The dynamic responses are plotted for two scenarios: when the time period of analysis is (i) $T = 40$ periods and (ii) $T = 400$ periods. As we can see, in the case where $T = 40$ periods , the time-path of the real exchange rate suggests that after its initial response (discussed above), the real exchange rate *depreciates* towards an "equilibrium," thus implying that government spending shocks lead to a depreciation of the real exchange rate (as in Galstyan and Lane, 2009, or Ravn et al., 2011). However, once one considers the entire adjustment path ($T = 400$), it is clear that the long-run response is actually a real *appreciation*. The discrepancy is due to the non-monotonicity of the relationship between government spending and the real exchange rate.

3.5 The Short-run Correlation between Government Spending and Private Consumption

The correlation between government spending and consumption in the short run has been the subject of much debate in the open economy macro literature. The neoclassical dependent economy model typically predicts a negative correlation between government spending and aggregate consumption, due to the short-run resource withdrawal effect and the consequent rise in the marginal utility of wealth. On the other hand, recent empirical studies have documented the presence of a positive short-run correlation (see Ravn, et al., 2012). We consider this issue in Table 4 and Figure 4, and focus on the sensitivity of this predicted correlation with (i) the relative sectoral output elasticity of public capital, and (ii) the sectoral composition of government spending.

The spending increases correspond to the benchmark policy exercises we considered in section 3. The main difference now is that we focus on three cases with respect to the sectoral output elasticity of public capital: (i) public capital is more productive in the traded sector ($\eta = 0.15, \phi = 0.05$), (ii) public capital is more productive in the non-traded sector ($\eta = 0.05, \phi = 0.15$), and (iii) public capital has no productivity benefits in either sector ($\eta = \phi = 0$), so that an increase in government spending approximates the case of government consumption. Table 4 reports the instantaneous response of aggregate consumption relative to its pre-shock benchmark, and Figure 4 plots the entire dynamic adjustment of consumption relative to its pre-shock level.

As we can see, these experiments throw up both negative and positive correlations between the short-run response of consumption and the underlying spending shock. Specifically, the results indicate that the following conditions for a positive correlation between government spending and short-run consumption that is observed in the data:

(a) public investment in infrastructure must impinge on non-traded output, *and*

(b) public capital must be at least as productive in the traded sector as it is in the non-traded sector ($\eta \geq \phi$).

The intuition is drawn from our discussion in Section 3.2 above. An increase in public spending from non-traded output generates a short-run resource withdrawal effect in that sector, which in turn causes an instantaneous real appreciation of the exchange rate. As non-traded goods become more expensive on the margin, the agent substitutes away from non-traded consumption towards consumption of the traded good. In addition, if public capital is at least or more productive in the traded sector, then the long-run productivity benefits of public investment for the traded sector and its eventual expansion (through the Balassa-Samuelson effect) causes a large instantaneous increase in consumption of traded output, which more than offsets the short-run decline in non-traded consumption. As a result, aggregate consumption increases in the short run.

We also find that when government spending takes the form of an investment subsidy targeted towards lowering intersectoral adjustment costs, aggregate consumption increases in the short run. In this particular case, we observe a positive correlation irrespective of the sectoral output elasticity of public capital. The above results are also robust to the sectoral capital intensity in production (Table 4B, Figure 4B).

4 Sensitivity Analysis

This section conducts a sensitivity analysis of the dynamic response of the real exchange rate to government spending shocks to variations in three deep structural parameters of the model: (i) the sectoral output elasticities of public capital, η 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, h.

4.1 Sectoral Output Elasticity of Public Capital

As in the previous section, we consider three cases: (i) $\eta = 0.15, \phi = 0.05$, (ii) $\eta = 0.05, \phi = 0.15$, and (iii) $\eta = \phi = 0$. Figure 5 depicts the adjustment path of the real exchange rate relative to its pre-shock equilibrium. The relative sectoral output elasticity of public capital is a critical determinant of the dynamics of the real exchange rate. When public investment impinges on traded output, the short-run exchange rate appreciates (depreciates) both in the short run as well as the long run when public capital is more (less) productive in the traded sector. When public capital is not productive, the increase in spending from traded output represents government consumption. Since this is a pure demand shock, the real exchange rate depreciates in the short run, but returns to its pre-shock equilibrium in the long-run. In this case, government spending has no impact on the long-run real exchange rate, which is a well-known result in the literature.

When public investment draws on non-traded output, the short run exchange rate appreciates, irrespective of the relative sectoral elasticity of public capital, with the appreciation being the largest when public capital is more productive in the traded sector. In the long-run however, the sectoral elasticity matters. When public capital is more productive for the traded sector, the short run appreciation is sustained in the long-run. By contrast, when the non-traded sector benefits more from public capital, the short run appreciation is reversed over time into a long-run depreciation. When government spending is not productive for either sector and represents public consumption, the real exchange rate converges back to its pre-shock equilibrium following the initial appreciation.

When government spending takes form of an investment subsidy, the time path of the real exchange rate is more robust, with a short-run and long-run appreciation of the real exchange rate, with the short-run rate under-shooting the long-run equilibrium. All the above results are robust to variations in the sectoral capital intensity in production.

4.2 Elasticity of Substitution in Production

Figure 6 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) $\xi = 1.25$.

We see from figure 6 that the larger is the elasticity of substitution in production, larger is the short-run and long-run response of the real exchange rate to a government spending shock, but the qualitative responses remain robust to the benchmark cases discussed in section 3. Further, the higher the elasticity of substitution in production, the more persistent is the adjustment of the real exchange rate.

4.3 Intersectoral Mobility Costs

Figure 7 illustrates the sensitivity of the real exchange rate dynamics generated by the three fiscal spending shocks to the magnitude of intersectoral mobility costs. We consider three cases: (i) $h = 0$ (costless transfer of capital across sectors), (ii) $h = 30$ (benchmark specification), and (iii) $h = 60$. As is evident from the plots, the intersectoral costs do not affect the steady-state response of the real exchange rate. This is because, in the steady-state, there is no new investment in private capital in the traded sector, i.e., $\tilde{X} = 0$ and therefore adjustment costs are not incurred. However, these costs play an important role in determining the short run and transitional response of the real exchange rate. First of all, higher the cost of mobility of capital, more persistent and non-monotonic is the dynamic adjustment of the real exchange rate; following the initial response to a shock, the transitional depreciation takes place for a longer period of time before it is reversed, the higher is h. Second, it is interesting to note that when $h = 0$, i.e., it is costless to transfer private capital across sectors, the relationship between government spending and the real exchange rate is *monotonic* after the initial adjustment. This points to the importance of positive intersectoral mobility costs in generating the non-monotonic relationship between government spending and the real exchange rate.

5 Conclusions

In this paper, we have analyzed the mechanism through which government spending policies, specifically on public infrastructure, affect the dynamics of the real exchange rate. While much of the literature has previously focused on the effects of government consumption, government investment and financing policies have received far less attention. An important feature of our analysis is the presence of convex mobility costs for transferring private capital from the non-traded to the traded sector. Given that our underlying framework is a variant of the flexible-price neoclassical model, this specification acts as a source of friction and persistence for the dynamics and the real exchange rate. In this context, we introduce government spending in in the form of (i) a gradually accumulating stock of productivity-augmenting infrastructure capital, and (ii) an investment subsidy that reduces the cost of transferring capital from the non-traded to the traded goods sector. We further assume that the government can finance this spending on investment by a range of distortionary and non-distortionary tax instruments.

Our results indicate that in the presence of intersectoral mobility costs for private capital, government spending shocks generate a non-monotonic 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. Whether government spending leads to a short-run (long-run) depreciation or appreciation depends critically on (i) the sectoral composition of the spending, (ii) the underlying financing policy, (iii) the sectoral capital-intensity in production, and (iv) the sectoral output elasticities of public capital. Robustness checks are conducted for the elasticity of substitution in production and the intersectoral mobility costs. Our model is also able to predict the observed positive short-run correlation between government spending and private consumption when (i) public capital is at least as productive in the traded sector as it is in the non-traded sector, and (ii) government investment impinges on non-traded output. An investment subsidy also generates this positive correlation in the short run.

While we have focused on the link between government investment and the real exchange rate, the framework can be easily extended to incorporate other types of government spending, such as those on education, 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.

TABLE 1. BENCHMARK EQUILIBRIUM

A. PARAMETERIZATION

Preference:
$\gamma = -1.5, \beta = r = 0.06, \theta = 0.5$
Productivity:
$A_T = 1.5,\ A_N = 1, \eta = \phi = 0.15, h = 30, \delta_G = 0.05,\ \xi = 1$
Policy:
$g_T = 0.02, g_N = 0.07, \tau_T = \tau_N = 0, s = 0$

B. PRE-SHOCK STEADY-STATE QUANTITIES

	$\frac{K_T}{L_T}$	$\frac{K_N}{L_N}$	$\frac{K_T}{Y_T}$	$\frac{K_N}{Y_N}$	L_T	$\frac{Y_T}{Y}$	$\frac{C_i}{Y}$	$\frac{G_T}{G}$	$\frac{K}{Y}$	$\frac{K_G}{K}$	$\frac{G}{Y}$	p
Traded Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$	14.258	8.827	3.051	7.965	0.451	0.487	0.477	0.213	3.624	0.252	0.046	1.912
Non-Traded Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$	12.286	19.847	3.659	6.642	0.523	0.487	0.477	0.213	4.775	0.191	0.046	1.139

Note: $K = K_T + pK_N,\ Y = Y_T + pY_N,\ G = G_T + pG_N$
$i = T, N$

TABLE 2. GOVERNMENT SPENDING SHOCKS: LONG-RUN EFFECTS

NOTE: *All results are reported relative to their pre-shock equilibrium levels*

A. TRADED SECTOR MORE CAPITAL-INTENSIVE

	K_T / L_T	pK_N / L_N	L_T	Y_T / Y	C	Y	p	$\Delta W(\%)$
a. Δg_T	1.072	1.079	1.087	1.081	1.002	1.085	1.010	+ 0.122
b. Δg_N	1.071	1.078	1.044	1.041	1.005	1.081	1.010	+ 0.217
c. Δs	1.117	1.044	1.036	1.034	1.013	1.046	1.038	- 0.063

B. NON-TRADED SECTOR MORE CAPITAL-INTENSIVE

	K_T / L_T	pK_N / L_N	L_T	Y_T / Y	C	Y	p	$\Delta W(\%)$
a. Δg_T	1.079	1.071	1.063	1.068	0.998	1.066	0.992	+ 0.126
b. Δg_N	1.080	1.072	1.033	1.035	1.001	1.069	0.992	+ 0.197
c. Δs	1.116	1.031	1.018	1.019	1.010	1.029	1.026	- 0.011

Note: $C = C_T + pC_N$, and $Y = Y_T + pY_N$

TABLE 3. GOVERNMENT SPENDING AND THE REAL EXCHANGE RATE
Sensitivity to Financing Policies

NOTE: *All results are reported relative to their pre-shock equilibrium levels*

A. TRADED SECTOR MORE CAPITAL INTENSIVE

	$p(0)$	$\tilde{p}$
I. a. Δg_T (Lumpsum tax-financing)	0.998	1.007
b. Δg_T (tax on traded output)	0.978	0.976
c. Δg_T (tax on non-traded output)	1.007	1.041
II. a. Δg_N (Lumpsum tax-financing)	1.022	1.007
b. Δg_N (tax on traded output)	1.001	0.976
c. Δg_N (tax on non-traded output)	1.030	1.039
III. a. Δs (Lumpsum tax-financing)	1.012	1.038
b. Δs (tax on traded output)	1.008	1.033
c. Δs (tax on non-traded output)	1.013	1.043

B. NON-TRADED SECTOR MORE CAPITAL INTENSIVE

	$p(0)$	$\tilde{p}$
I. a. Δg_T (Lumpsum tax-financing)	0.999	0.992
b. Δg_T (tax on traded output)	0.979	0.963
c. Δg_T (tax on non-traded output)	1.004	1.037
II. a. Δg_N (Lumpsum tax-financing)	1.022	0.992
b. Δg_N (tax on traded output)	1.0004	0.963
c. Δg_N (tax on non-traded output)	1.029	1.034
III. a. Δs (Lumpsum tax-financing)	1.013	1.026
b. Δs (tax on traded output)	1.011	1.022
c. Δs (tax on non-traded output)	1.014	1.031

TABLE 4. GOVERNMENT SPENDING AND SHORT-RUN CONSUMPTION:
Sensitivity to the Sectoral Output Elasticity of Public Capital

Instantaneous response of total consumption relative to its pre-shock equilibrium level: $C(0)/\tilde{C}_0$

A. TRADED SECTOR MORE CAPITAL INTENSIVE

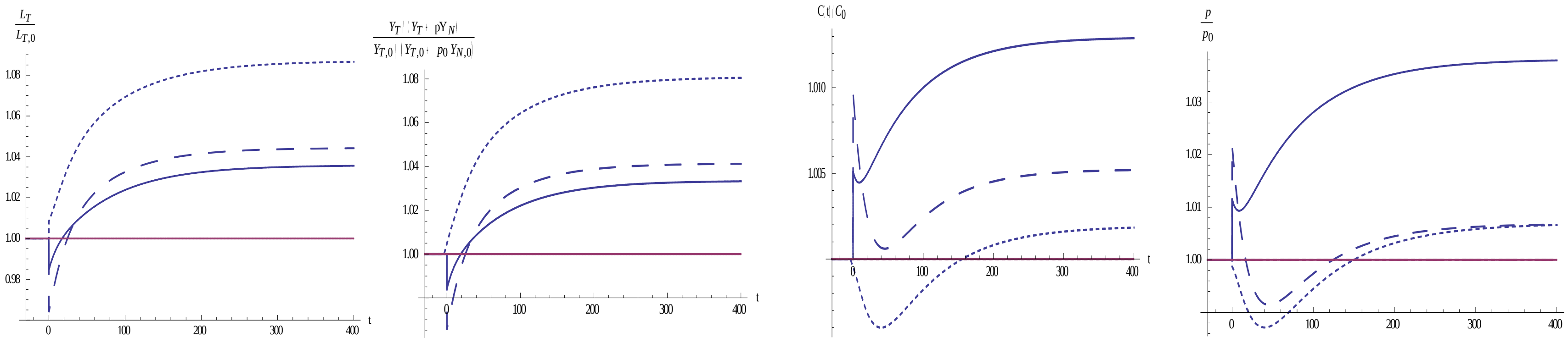
	$\eta = \phi = 0$	$\eta = 0.15, \phi = 0.05$	$\eta = 0.05, \phi = 0.15$
Δg_T (Lumpsum tax-financing)	0.980	0.998	0.987
Δg_N (Lumpsum tax-financing)	0.985	**1.008**	0.996
Δs (Lumpsum tax-financing)	**1.004**	**1.005**	**1.004**

B. NON-TRADED SECTOR MORE CAPITAL INTENSIVE

	$\eta = \phi = 0$	$\eta = 0.15, \phi = 0.05$	$\eta = 0.05, \phi = 0.15$
Δg_T (Lumpsum tax-financing)	0.981	0.997	0.986
Δg_N (Lumpsum tax-financing)	0.987	**1.008**	0.995
Δs (Lumpsum tax-financing)	**1.005**	**1.006**	**1.006**

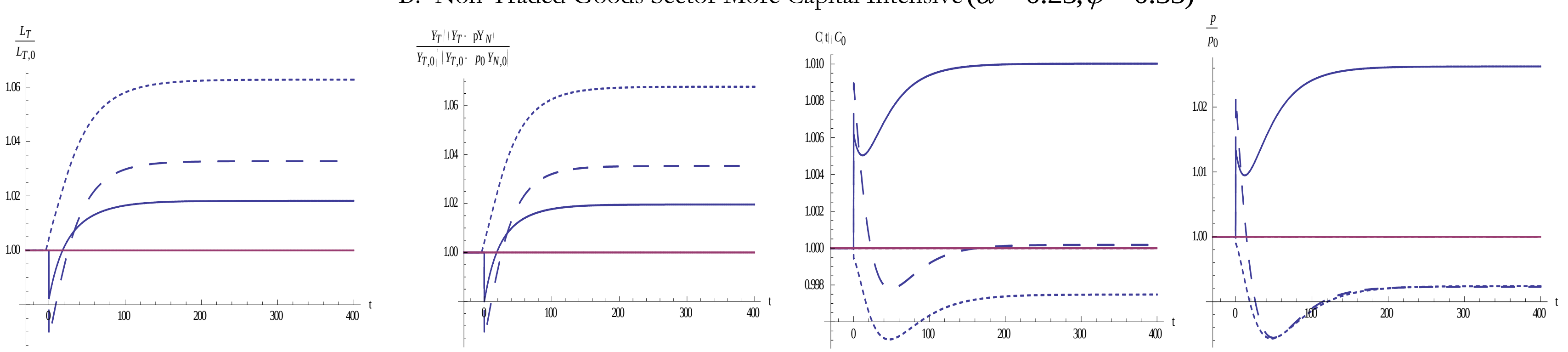
FIGURE 1. Government Spending Shocks (Lumpsum Tax-financed)

A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$



i. Traded sector employment | ii. Traded sector output (relative to GDP) | iii. Total consumption | iv. Real exchange rate

B. Non-Traded Goods Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$



i. Traded sector employment | ii. Traded sector output (relative to GDP) | iii. Total consumption | iv. Real exchange rate

Government spending on traded output
Government spending on non-traded output
Investment subsidy
Normalized pre-shock equilibrium = 1

FIGURE 2. Government Spending and the Real Exchange Rate: Sensitivity to Financing Policies

A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$

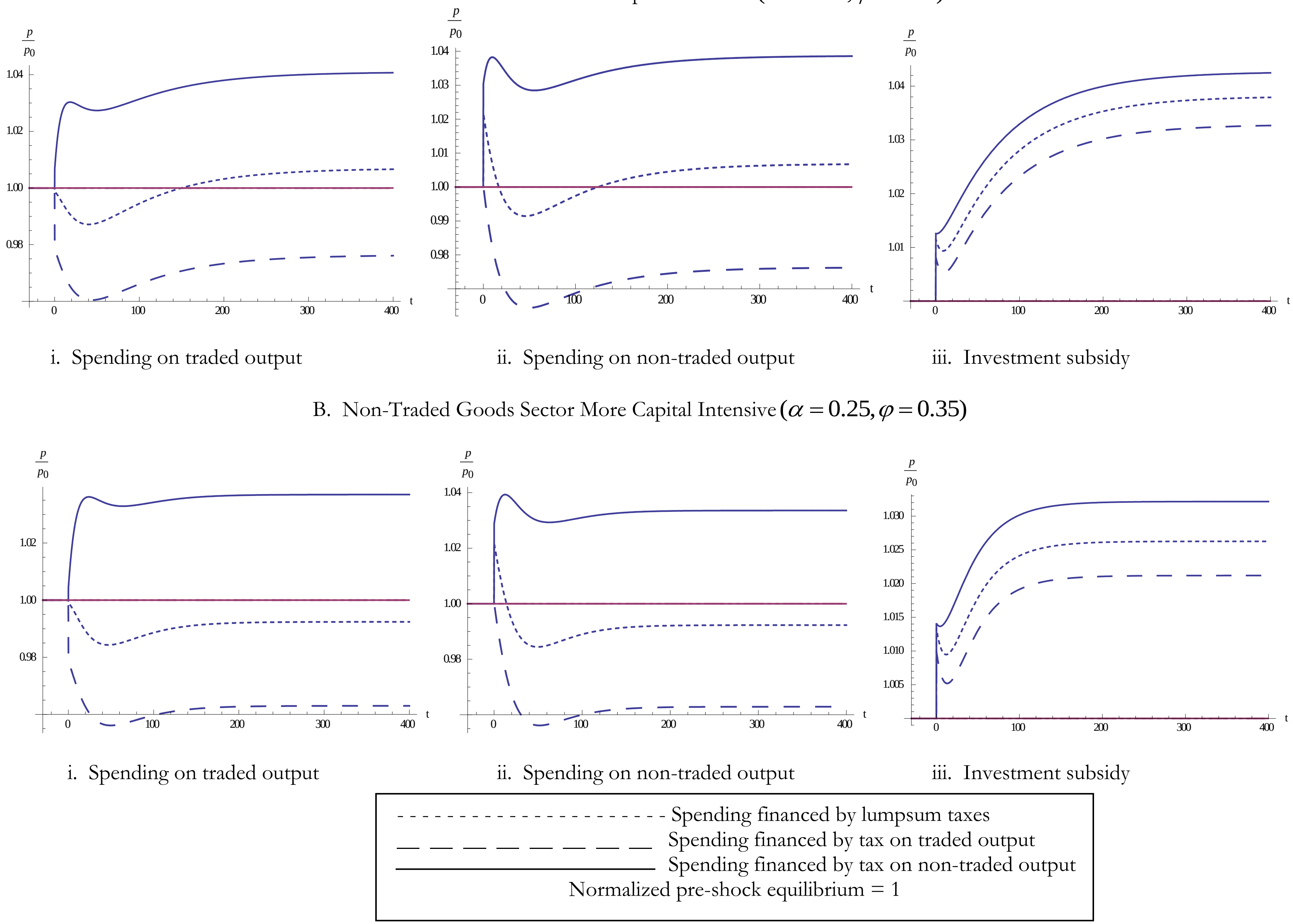
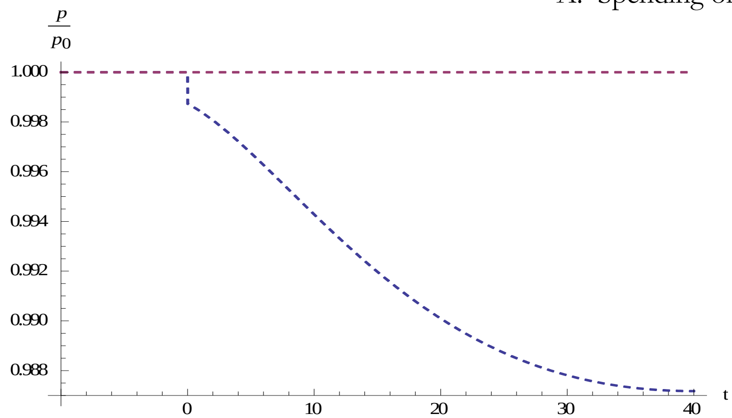


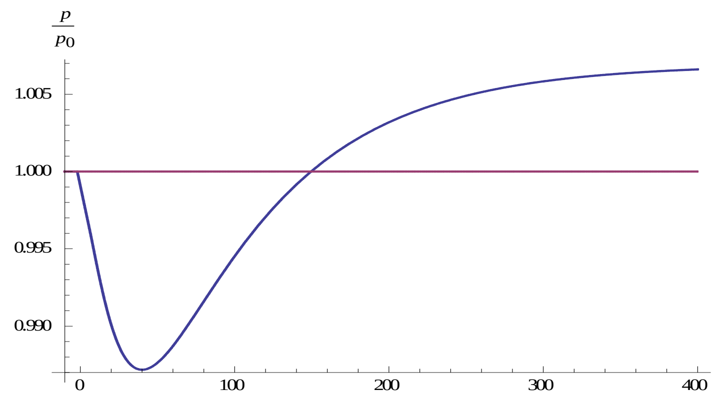
FIGURE 3. Government Spending, the Persistence of the Real Exchange Rate, and the Time Horizon

$(\alpha = 0.35, \varphi = 0.25)$

A. Spending on Traded Sector Output

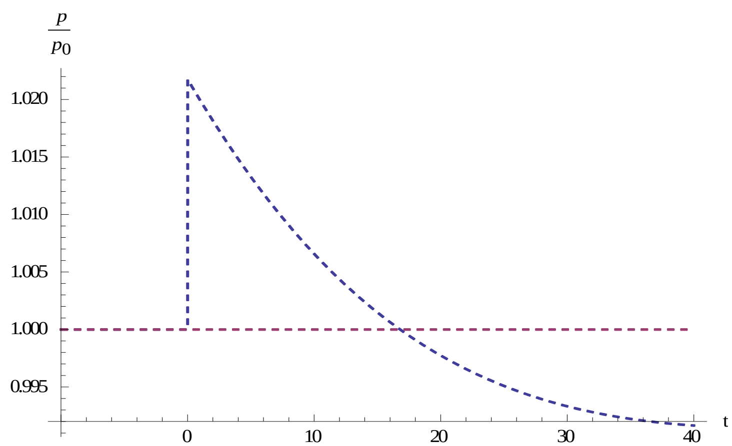


i. T = 40

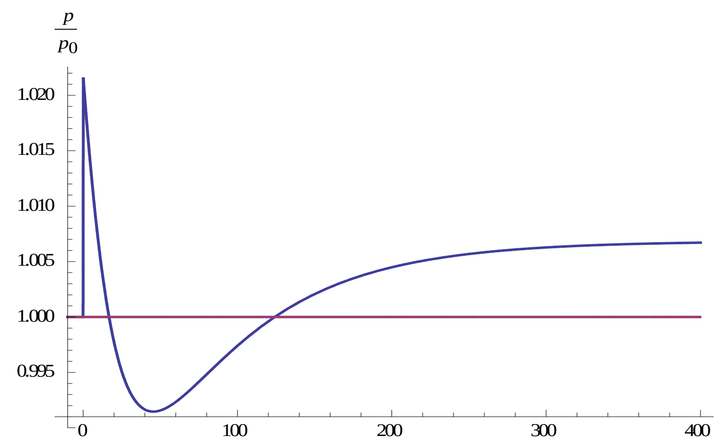


ii. T=400

B. Spending on Non-Traded Sector Output



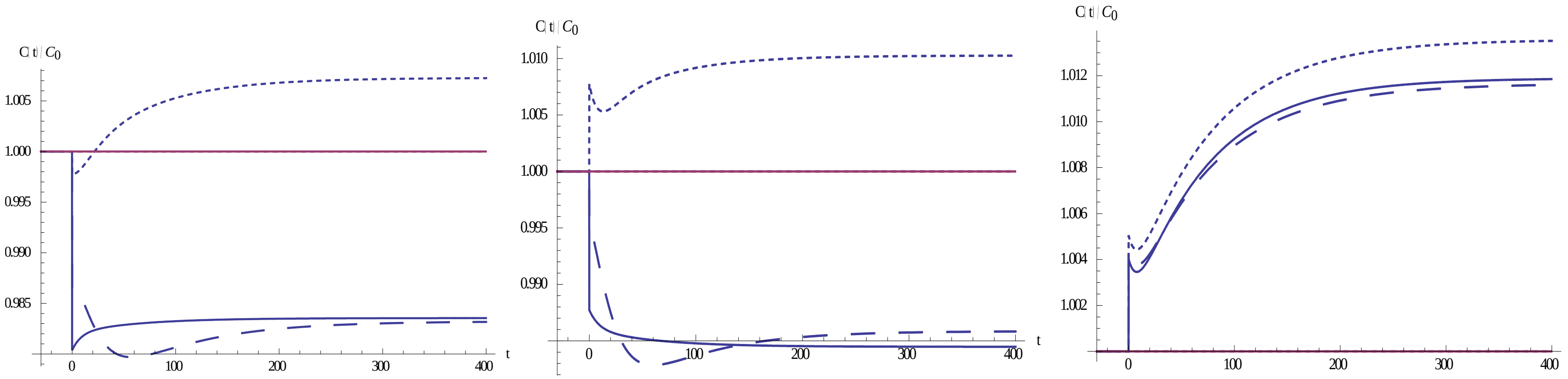
i. T = 40



ii. T=400

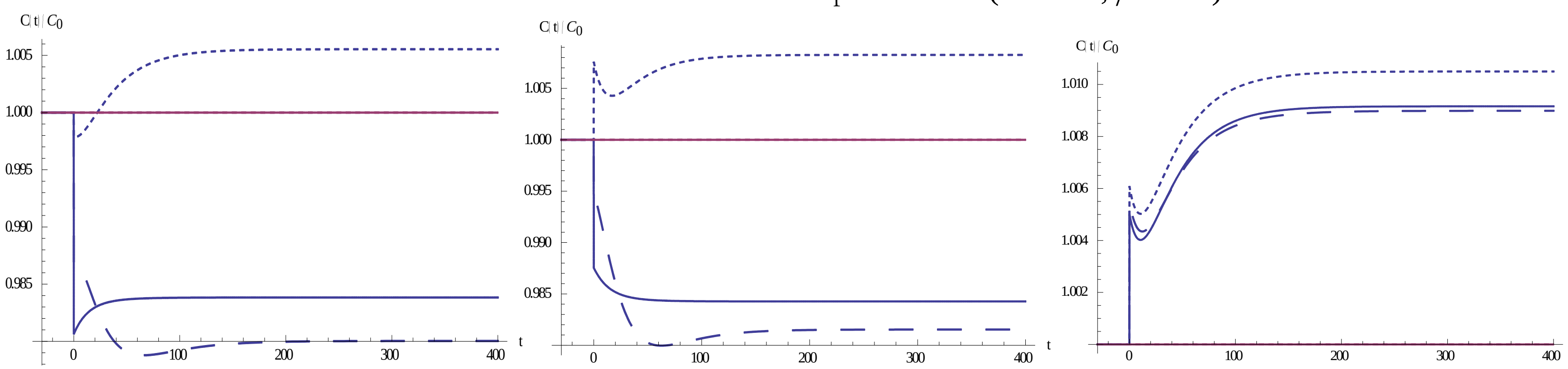
FIGURE 4. Government Spending and Consumption: Sensitivity to the Sectoral Elasticity of Public Capital

A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$



i. Spending on traded output ii. Spending on non-traded output iii. Investment subsidy

B. Non-Traded Goods Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$



i. Spending on traded output ii. Spending on non-traded output iii. Investment subsidy

- $\eta = 0.15, \phi = 0.05$

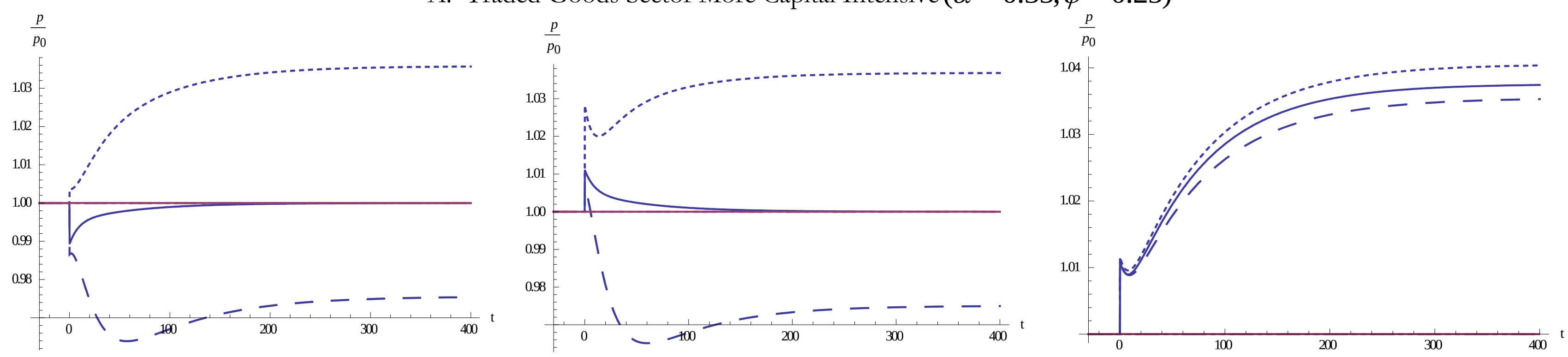
— — — — — — — — $\eta = 0.05, \phi = 0.15$

———————— $\eta = \phi = 0$

Normalized pre-shock equilibrium = 1

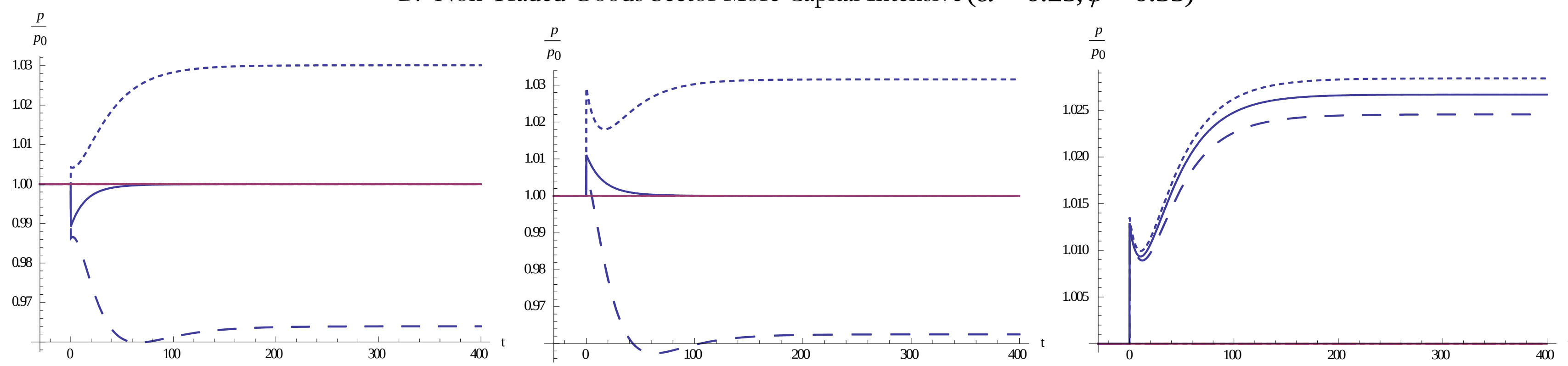
FIGURE 5. Government Spending and the Real Exchange Rate: Sensitivity to the Sectoral Elasticity of Public Capital

A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$



i. Spending on traded output   ii. Spending on non-traded output   iii. Investment subsidy

B. Non-Traded Goods Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$



i. Spending on traded output   ii. Spending on non-traded output   iii. Investment subsidy

- - - - - - - - - - $\eta = 0.15, \phi = 0.05$

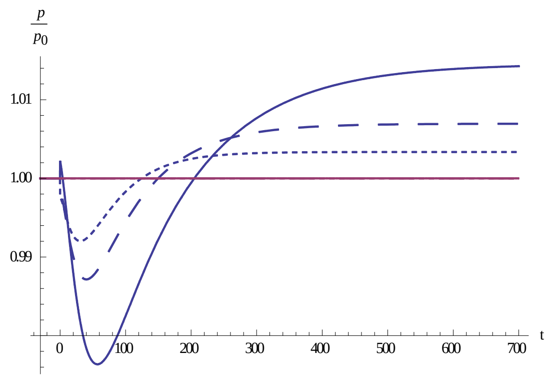
— — — — — $\eta = 0.05, \phi = 0.15$

———— $\eta = \phi = 0$

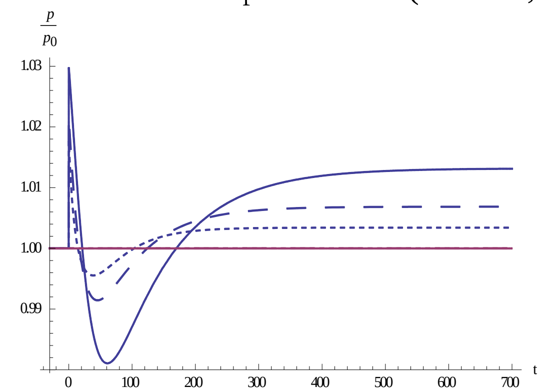
Normalized pre-shock equilibrium = 1

FIGURE 6. Government Spending and the Real Exchange Rate: Sensitivity to the Elasticity of Substitution in Production

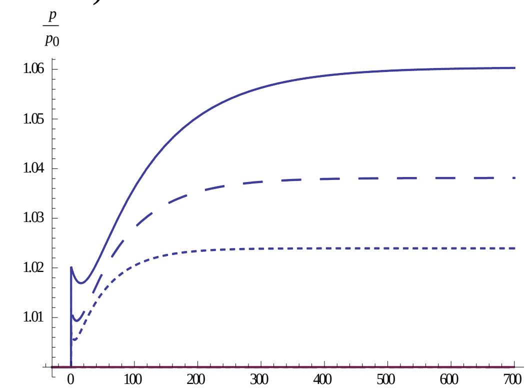
A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$



i. Spending on traded output

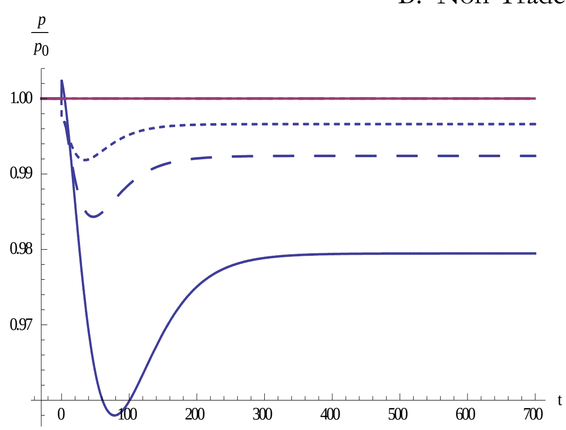


ii. Spending on non-traded output

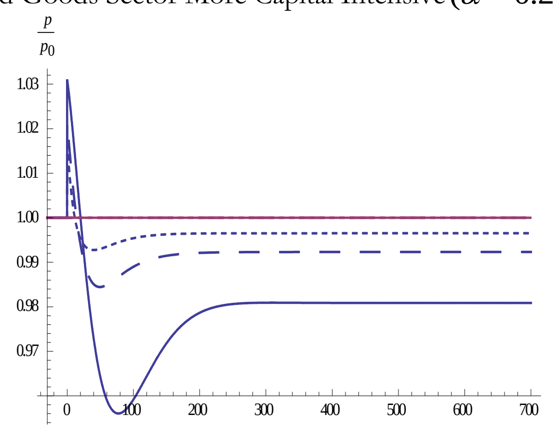


iii. Investment subsidy

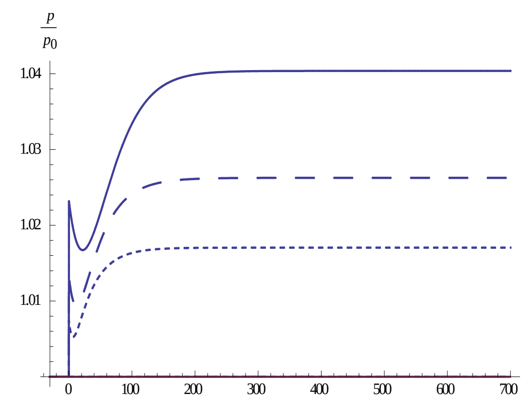
B. Non-Traded Goods Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$



i. Spending on traded output



ii. Spending on non-traded output



iii. Investment subsidy

- - - - - - - - - - $\xi = 0.75$

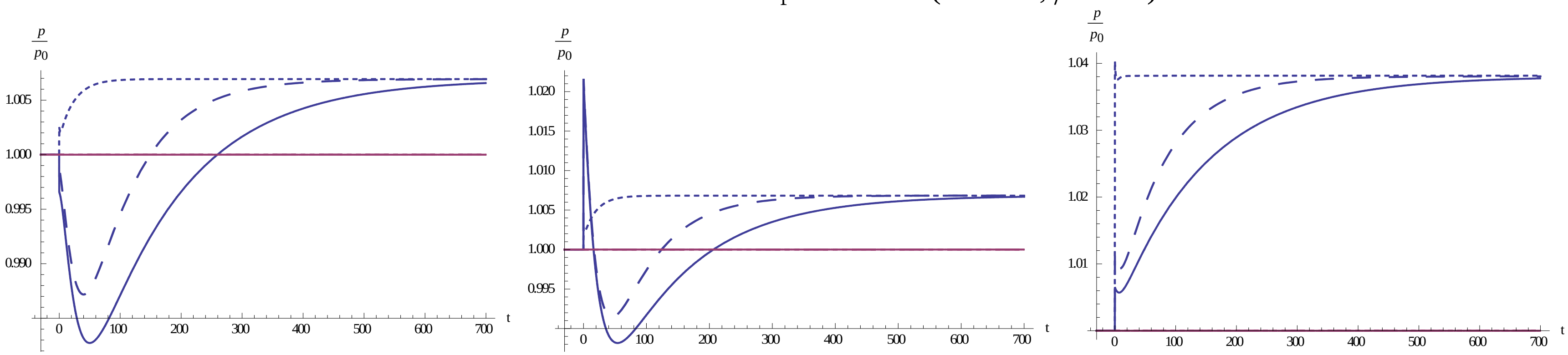
— — — — — — $\xi = 1$

———————— $\xi = 1.25$

Normalized pre-shock equilibrium = 1

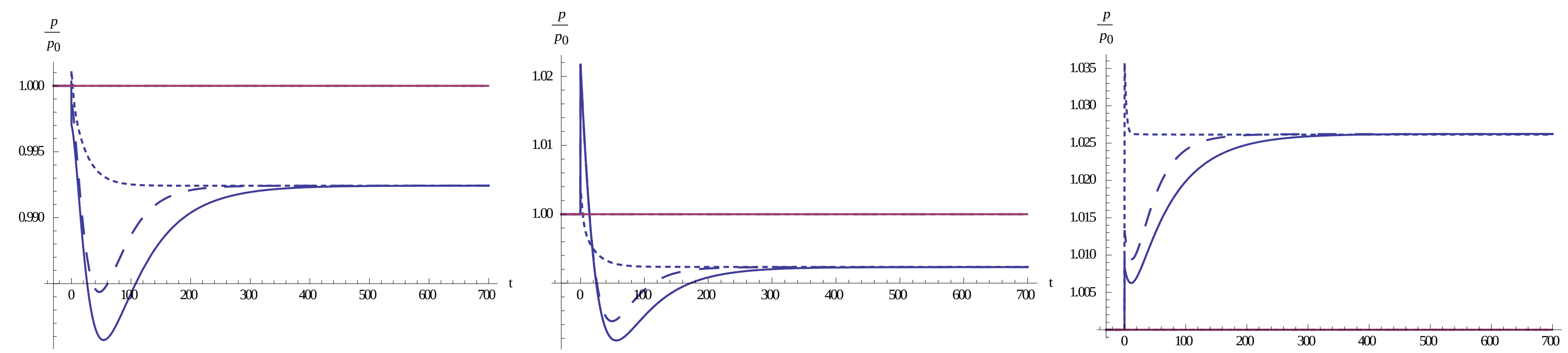
FIGURE 7. Government Spending and the Real Exchange Rate: Sensitivity to Intersectoral Mobility Costs

A. Traded Goods Sector More Capital Intensive $(\alpha = 0.35, \varphi = 0.25)$

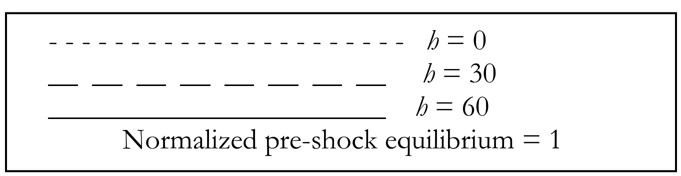


i. Spending on traded output   ii. Spending on non-traded output   iii. Investment subsidy

B. Non-Traded Goods Sector More Capital Intensive $(\alpha = 0.25, \varphi = 0.35)$



i. Spending on traded output   ii. Spending on non-traded output   iii. Investment subsidy



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