

Foreign aid and economic growth: The role of flexible labor supply[☆]

Santanu Chatterjee^a, Stephen J. Turnovsky^{b,*}

^a *Department of Economics, University of Georgia, United States*

^b *Department of Economics, University of Washington, United States*

Received 12 December 2004; received in revised form 2 March 2006; accepted 6 March 2006

Abstract

This paper examines the link between foreign aid, economic growth, and welfare in a small open economy. External transfers impinge on the recipient's macroeconomic performance by affecting resource allocation decisions and relative prices. The endogeneity of the labor–leisure choice plays a crucial role in the propagation of foreign aid shocks. The efficacy of foreign aid also depends on externalities associated with the public good that it helps finance. The impact of tied and untied aid on the recipient government's intertemporal fiscal balance is examined. Finally, the transitional adjustment to a foreign aid shock is shown to be sensitive to the elasticity of substitution in production and the relative importance of the labor–leisure choice in utility.

© 2006 Elsevier B.V. All rights reserved.

JEL classification: E6; F4; O1

Keywords: Foreign aid; International transfers; Endogenous labor; Economic growth; Public investment

[☆] This paper has benefited from presentations at the 2004 MEA meetings in Chicago, the 2004 Annual Conference of the Royal Economic Society in Swansea, the 10th International Conference of the Society of Computational Economics in Amsterdam, the 59th European Meeting of the Econometric Society in Madrid, the 2004 NEUDC conference in Montreal, and the 2005 Fall Meeting of the Midwest International Economics Group at the University of Kansas. The constructive suggestions of an anonymous referee and the Co-Editor, Gordon Hanson, are gratefully acknowledged. Chatterjee acknowledges financial support from the Terry–Sanford Research Grant at the University of Georgia, while Turnovsky's research was supported in part by the Castor endowment at the University of Washington.

* Corresponding author.

E-mail address: sturn@u.washington.edu (S.J. Turnovsky).

1. Introduction

Official development assistance, in the form of foreign aid, represents an important channel through which wealth is transferred from rich, developed nations to poorer, underdeveloped economies. Both the magnitude and the scope of these international transfers have increased significantly over the last four decades. For example, total flows of official development assistance from members of the OECD and OPEC countries have increased from about \$6 million in 1965 to over \$59 billion in 2002. By that time these funds had come to represent between 3% and 5% of the Gross National Income of the recipient low and middle income countries, and to finance between 10% and 20% of their gross capital formation.¹

One issue of concern for both donors and recipients is how foreign aid should be spent in an economy with scarce resources. This has given rise to a long-standing debate, both in academic and policy circles, as to whether international transfers should be “tied” (“productive”) or “untied” (“pure”). As Bhagwati (1967) points out, tied external assistance can take several forms. It may be linked to: (i) a specific investment project, (ii) a specific commodity or service, or (iii) procurement in a specific country. Recent studies by the World Bank point out that over time, a larger proportion of foreign aid has become “untied” with respect to requirements for procuring goods and services from the donor country, but it has become more “tied” in the sense of being linked to investments in public infrastructure projects (telecommunications, energy, transport, water services, etc). Between 1994 and 1999, for example, the proportion of official development assistance that was “untied” in the sense of not being subject to restrictions by donors on procurement sources rose from 66% to about 84%. At the same time, between two-thirds and three-fourths of official development assistance was either fully or partially tied to public infrastructure projects (see footnote 1).

The move toward tying more aid to public investment has been dictated mainly by the growing infrastructure requirements of developing countries. Most economists agree that investment in public infrastructure raises the productivity and efficiency of the private sector and, as a consequence, provides a crucial channel for economic growth, development, and higher living standards.² But financing the required investment in infrastructure has proven to be a challenging task for developing countries. Most such countries have significantly restricted public sector borrowing after the debt-crisis of the early 1980s, while at the same time their infrastructure requirements have increased steadily. Facing binding fiscal constraints, governments in developing countries have turned to external financing, in the form of tied foreign aid programs as a significant source of financing public investment.

The question of what form foreign aid should take has led to a large, but inconclusive, empirical literature on the link between foreign aid, economic growth, and development; see Hansen and Tarp (2000), Burnside and Dollar (2000), and Easterly (2003). Recently, Chatterjee, Sakoulis, and Turnovsky (2003) and Chatterjee and Turnovsky (2004) have developed a general equilibrium-growth framework within which these issues can be analyzed. Their results indicate that the consequences of tied and untied aid programs for economic growth and welfare depend

¹ World Bank (1994, 2004).

² Theoretical and empirical interest in the impact of public capital on macroeconomic performance originated with the work of Arrow and Kurz (1970) and more recently with Aschauer (1989a,b); see Gramlich (1994) for a survey of the early empirical literature. Theoretical contributions include Futagami, Morita, and Shibata (1993), Baxter and King (1993), Fisher and Turnovsky (1998), Devarajan, Xie, and Zou (1998), and Turnovsky (2004).

crucially upon a number of key structural characteristics of the recipient economy. These include: (i) the costs associated with installing the publicly provided capital (intertemporal adjustment costs), (ii) the substitutability between public and private capital in production (intra-temporal adjustment costs), (iii) the degree of access to the world financial market (financial adjustment costs), and (iv) the opportunities for co-financing infrastructure projects using domestic resources.

This paper distinguishes itself from the existing theoretical literature by addressing three critical, but previously neglected, aspects. First, and most importantly, it relaxes the restrictive assumption that labor supply in the recipient economy is inelastic. We show how the endogeneity of labor supply can be a crucial transmission mechanism for foreign aid. This is because the flow of aid alters the marginal valuations of work and leisure, thereby influencing the economy's productive capacity and macroeconomic performance. Second, given that tied aid is used to finance investment in infrastructure or public capital, it is important to identify the channels through which public capital affects production. In this respect, we focus on two externalities generated by the accumulation of public capital: (i) its interaction with "raw" labor in the underlying production function in determining the productivity of private capital,³ and (ii) its effect on aggregate productivity by mitigating congestion associated with the aggregate stock of private capital. We show how the relative merits of tied and untied aid are highly sensitive to the way in which these externalities impact on production, as well as their magnitudes. Finally, motivated by the empirical study of Burnside and Dollar (2000), we employ our model to assess the effects of tied and untied aid programs on the recipient government's fiscal deficit, which is an element of the "good" policy index in the Burnside–Dollar paper. Our analysis highlights the tradeoffs that exist between the impact of foreign aid on consumer welfare, on the one hand, and on the recipient government's financial position, on the other.

Given the complexity of the model, most of the analysis is conducted numerically. The endogeneity of the labor–leisure choice alters many of the results obtained by Chatterjee et al. (2003) and Chatterjee and Turnovsky (2004). These earlier papers show that when labor supply is inelastic, even though a tied aid shock generates a dynamic adjustment, an untied aid shock has no dynamic consequences for the recipient economy, and leads only to instantaneous increases in consumption and welfare. In contrast, we show that with flexible labor supply, both types of aid generate dynamic responses, albeit dramatically different in nature. In the case of untied aid, the dynamic adjustment occurs through the effect of the labor–leisure choice on the marginal rate of substitution between consumption and leisure. By stimulating consumption and encouraging more leisure (reduced work effort), untied aid leads to a decline in the equilibrium growth rate, although the economy's current account and welfare improve in the long run. In contrast, an aid program that is tied to investment in public capital operates in precisely the opposite way. The stimulus to public investment raises the productivity of labor, encouraging additional work effort (less leisure) and substitution away from consumption, thus generating an increase in the growth rate. This adjustment occurs gradually and involves intertemporal tradeoffs in welfare, as agents in the recipient economy forgo short-run consumption for longer run gains due to the enhanced productivity.

All three aspects being emphasized – the endogeneity of labor supply, the extent of public good–production externalities, and the recipient economy's fiscal deficit – play crucial roles in determining the contrasting effects of tied versus untied aid programs. On the one hand, both the short-run and the long-run welfare gains from an *untied* aid shock are remarkably uniform and relatively insensitive to these characteristics, as well as to the elasticity of substitution in

³ We model this interaction by assuming that labor interacts with public capital to yield "labor efficiency units", which then interacts with private capital in accordance with a constant elasticity of substitution (CES) production function.

production. Intuitively, this is because untied aid impacts directly on the reduction of debt and hence is reflected quickly in enhanced consumption, with relatively little impact on the productive side of the economy and thus on additional future consumption. By contrast, there is a sharp difference between the short-run and long-run welfare effects of *tied* aid, both of which are highly sensitive to the characteristics being addressed. This is because tied aid impacts directly on the productive capacity of the economy, to which these factors primarily relate. Moreover, because the benefits of increased productive capacity take time to reach fruition, the effects of tied transfers on the economy's consumption time profile, and therefore on welfare, occur only gradually.

These differential sensitivities of the welfare gains resulting from these two forms of transfers, mean that their relative merits, from a welfare standpoint, are also sensitive to these same factors. For example, for the benchmark case of a Cobb–Douglas production function, and for what we view as a plausible elasticity of leisure in utility, tied aid is marginally superior to untied aid from a long-run (intertemporal) welfare perspective. But as the elasticity of leisure declines, untied aid becomes superior to tied aid. This is because the less important is leisure in utility, the more tied aid crowds out private consumption, thus decreasing its benefits relative to those of untied aid. But this comparison is also sensitive to the elasticity of substitution in production. If, simultaneously, the elasticity of substitution is reduced, tied aid will encourage more private investment, generating larger increases in output, consumption, and welfare, thus again dominating untied aid. Finally, the relative merits of tied versus untied aid programs are also sensitive to the magnitude of the aggregate public good externality. Since public capital directly mitigates the effects of congestion, the case for tied aid is strengthened when this externality is positive.

The economy's fiscal structure has several interesting consequences for the choice between tied and untied aid. In general, while *untied* aid always improves the government's intertemporal fiscal balance, *tied* aid always leads to a deterioration, thus suggesting a potential tradeoff between consumer welfare and government solvency. The sensitivity of the welfare effects of tied aid to the rate of domestic government investment in the recipient economy has further policy implications. If this public investment is very small, then tied aid is not only superior to untied aid, it is in fact optimal, while the reverse applies if it is high. In contrast, for intermediate rates of domestic public investment, optimality requires that a given flow of foreign aid be *partially* tied to public investment.

The remainder of the paper is structured as follows. Section 2 sets out the analytical framework and summarizes the macro-dynamic equilibrium. Since the basic framework builds on our previous work, our description can be brief. But we hasten to add that the introduction of labor is nontrivial, involving substantial technical details that are relegated to the Appendix. Section 3 conducts numerical simulations and considers the consequences of the elastic labor supply in assessing the relative merits of tied versus untied aid. Section 4 performs some sensitivity analysis, while Section 5 considers the consequences for fiscal balance. Section 6 concludes with some caveats and policy implications.

2. The analytical framework

We begin by spelling out the building blocks of the model.

2.1. Private sector

We consider a small open economy populated by an infinitely lived representative agent who produces and consumes a single traded commodity. The agent has a unit of time, a fraction l of

which can be devoted to leisure, and the balance, $1-l$, to labor supply. Output, Y , is produced using the Constant Elasticity of Substitution (CES) production function

$$Y = \alpha \left(\frac{K_G}{\bar{K}} \right)^\varepsilon [\eta \{(1-l)K_G\}^{-\rho} + (1-\eta)K^{-\rho}]^{-1/\rho} \quad \varepsilon \geq 0 \quad (1a)$$

where K denotes the representative agent's stock of private capital, \bar{K} is the average stock of private capital, and K_G denotes the stock of public capital. The production function comprises two components. In the first, public capital interacts with the agent's labor supply to yield labor measured in efficiency units, $(1-l)K_G$ which in turn combines with private capital.⁴ The second is the externality provided by public capital, incorporated in the term, $(K_G/\bar{K})^\varepsilon$. Here, K_G enhances general productivity by offsetting congestion effects associated with the aggregate private capital stock, \bar{K} ; see Barro and Sala-i-Martin (1992) and Eicher and Turnovsky (2000). The production function has constant returns to scale in both the private factors of production, K and $(1-l)$, and the accumulating factors, K , \bar{K} and K_G , enabling it to support an equilibrium of ongoing (endogenous) growth with both private factors being paid their respective marginal physical products.⁵

The agent consumes this good at the rate C , yielding utility over an infinite horizon represented by the isoelastic utility function:

$$U \equiv \int_0^\infty \frac{1}{\gamma} (Ct^\theta)^\gamma e^{-\beta t} dt \quad (1b)$$

where θ represents the relative importance of leisure in utility. The agent also accumulates physical capital, with expenditure on a given change in the capital stock, I , involving adjustment (installation) costs specified by the quadratic (convex) function

$$\Psi(I, K) = I + h_1 \frac{I^2}{2K} = I \left(1 + h_1 \frac{I}{2K} \right) \quad (1c)$$

Letting δ_K denote the rate of depreciation, the net rate of private capital accumulation is thus

$$\dot{K} = I - \delta_K K \quad (1d)$$

Agents have access to a world capital market, allowing them to borrow internationally. We assume that the creditworthiness of the economy influences its cost of borrowing from abroad. The world capital market assesses the economy's ability to service its debt costs, and views the country's debt–capital (equity) ratio as an indicator of its default risk. Accordingly, the interest rate a country is charged on the world capital market increases with this ratio. This leads to an upward sloping supply schedule for debt, which we express by assuming that the borrowing rate, $r(N/K)$, charged on (national) foreign debt, N , relative to the stock of private capital, K , is of the form:

$$r(N/K) = r^* + \omega(N/K); \quad \omega > 0 \quad (1e)$$

⁴ Thus $s \equiv 1/(1+\rho)$ is the elasticity of substitution between private capital and “efficiency units of labor” in production.

⁵ Chatterjee and Turnovsky (2004) assume $\varepsilon=0$ and we shall treat this as our benchmark case as well. We have also briefly considered the alternative specification: $Y = \alpha (K_G/\bar{K})^\varepsilon [\eta \{(1-l)\bar{K}\}^{-\rho} + (1-\eta)K^{-\rho}]^{-1/\rho}$, which simply augments the Romer (1986) model to include the “congestion-offsetting” externality effect of public capital; see footnote 20.

where r^* is the exogenously given world interest rate, and $\omega(N/K)$ is the country-specific borrowing premium that increases with the nation's debt–capital ratio.⁶ The homogeneity of the relationship is required to sustain a balanced growth equilibrium.

The representative agent chooses consumption, labor supply, and the rates of capital and debt accumulation, to maximize intertemporal utility, Eq. (1b), subject to the flow budget constraint

$$\dot{N} = C + r(N/K)N + \Psi(I, K) - (1-\tau)Y + T \quad (2)$$

where N is the stock of debt held by the private sector, τ is the income tax rate, and T denotes lump-sum taxes.⁷ In performing this optimization, the agent takes the borrowing rate, $r(\cdot)$ as given. This is because the interest rate facing the debtor nation, as reflected in Eq. (1e), is a function of the economy's *aggregate* debt–capital ratio, which the individual agent knows he cannot influence.

The optimality conditions with respect to the individual's choices of C , l , and I are

$$C^{\gamma-1} l^{\theta\gamma} = \lambda \quad (3a)$$

$$\theta C^{\gamma} l^{\theta\gamma-1} = \lambda(1-\tau) \frac{\partial Y}{\partial(1-l)} \quad (3b)$$

$$1 + h_1(I/K) = q \quad (3c)$$

where λ is the shadow value of wealth in the form of internationally traded bonds, q' is the shadow value of the agent's private capital stock, and $q = q'/\mu$ is thus the market price of private capital in terms of the traded bonds. Eq. (3a) equates the marginal utility of consumption to the shadow value of wealth, while Eq. (3b) equates the marginal utility of leisure to the shadow value of after-tax income foregone, where the marginal product of labor, $\partial Y/\partial(1-l)$, equals the equilibrium wage rate. Eq. (3c) equates the marginal cost of an additional unit of investment, inclusive of the marginal installation cost, $h_1 I/K$ to the market value of capital. This equation may be immediately solved to yield the following expression for the growth rate of private capital.

$$\frac{\dot{K}}{K} \equiv \psi_K = \psi_K(q) = \frac{q-1}{h_1} - \delta_K \quad (3c')$$

Applying the standard optimality conditions with respect to N and K leads to the usual arbitrage relationships, equating the rates of return on consumption and investment in private capital to the costs of borrowing from abroad

$$\beta - \frac{\dot{\lambda}}{\lambda} = r(N/K) \quad (4a)$$

$$\frac{\alpha^{-\rho} (K_G/\bar{K})^{-\varepsilon\rho} (1-\tau)(1-\eta)(Y/K)^{1+\rho}}{q} + \frac{\dot{q}}{q} + \frac{(q-1)^2}{2h_1 q} - \delta_K = r(N/K) \quad (4b)$$

⁶ The original formulation of this type of borrowing cost relationship is due to Bardhan (1967). Further discussion and rationalization of it, including variants of the specification and some empirical support, are discussed in our earlier work.

⁷ Since we are focusing on debtor nations, we assume $N > 0$. However, it is possible for $N < 0$ in which case the agent accumulates credit by lending abroad. For simplicity, interest income is assumed to be untaxed.

Finally, in order to ensure that the agent's intertemporal budget constraint is met, the following transversality conditions must hold:

$$\lim_{t \rightarrow \infty} \lambda N e^{-\beta t} = 0; \quad \lim_{t \rightarrow \infty} q' K e^{-\beta t} = 0. \quad (4c)$$

2.2. Public capital, foreign aid, and national debt

The resources for the accumulation of public capital come from two sources: domestically financed government expenditure on public capital, \bar{G} , and a program of capital transfers or foreign aid, TR , from the rest of the world. We therefore postulate⁸

$$G \equiv \bar{G} + \phi TR \quad 0 \leq \phi \leq 1 \quad (5)$$

where ϕ represents the degree to which the foreign aid is tied to investment in public infrastructure. If $\phi=1$, the aid is completely tied to public investment and is therefore “productive”; if $\phi=0$, aid is completely unrestricted and thus represents a “pure” transfer, of the traditional Keynes–Ohlin type.

Analogous to private capital, we assume that the gross accumulation of public capital, G , is also subject to convex costs of adjustment:

$$\Gamma(G, K_G) = G(1 + (h_2/2)(G/K_G)).$$

Public capital stock depreciates at the rate, δ_G , so that its net rate of accumulation is

$$\dot{K}_G = G - \delta_G K_G. \quad (6)$$

To sustain an equilibrium of on-going growth, both domestic government expenditure on infrastructure, \bar{G} , and the flow of aid from abroad, TR , must be tied to the scale of the recipient economy. We do this by specifying them as a fraction of that country's level of income

$$\bar{G} = \bar{g}Y, \quad \text{and} \quad TR = \sigma Y, \quad 0 < \bar{g} < 1, \quad \sigma > 0, \quad 0 < \bar{g} + \sigma < 1$$

Substituting \bar{G} and TR into Eq. (5) and then into Eq. (6), we can express the growth rate of public capital by

$$\frac{\dot{K}_G}{K_G} \equiv \psi_G = (\bar{g} + \sigma\phi) \frac{Y}{K_G} - \delta_G. \quad (6')$$

⁸ Note that there are different ways of specifying how aid is tied. The specification (5) relates aid to the accumulation of new public capital. An alternative formulation is to tie the aid to total investment costs, inclusive of installation costs. As noted by Chatterjee et al. (2003), the differences between these specifications are minor, and since there is no compelling evidence favoring one formulation over the other, we adopt Eq. (5), which turns out to be marginally simpler.

The government sets its tax and expenditure parameters to maintain a balanced budget. Expressing this in the form⁹

$$T = \Gamma(G, K_G) - \tau Y - TR \tag{7}$$

T determines the lump-sum taxes necessary to balance the current budget, given by the right hand side of Eq. (7). The national budget constraint, (current account) is obtained by combining Eqs. (7) and (2),

$$\dot{N} = r(N/K)N + C + \Psi(I, K) + \Gamma(G, K_G) - Y - TR. \tag{8}$$

That is, the economy accumulates debt to finance its total expenditures on public capital, private capital, consumption, and interest payments net of output produced and transfers received.

2.3. Macroeconomic equilibrium

The steady-state equilibrium of the economy has the characteristic that all real aggregate quantities grow at the same constant rate, and that the labor allocation, l , and the relative price of capital, q , are constant. We show in the Appendix how the equilibrium dynamics of the system can be conveniently expressed in terms of the following stationary variables, $z \equiv K_G/K$, $n \equiv N/K$, l and q . Assuming a symmetric equilibrium in which $K = \bar{K}$, we get:

$$\frac{\dot{z}}{z} = (\bar{g} + \sigma\phi) \frac{y}{z} \delta_G - \left(\frac{(q-1)}{h_1} - \delta_K \right) \tag{9a}$$

$$\frac{\dot{n}}{n} = r(n) + \frac{1}{n} \left[c + \frac{q^2 - 1}{2h_1} + \{(\bar{g} + \sigma\phi) - (1 + \sigma)\}y + \frac{h_2}{2} (\bar{g} + \sigma\phi)^2 \frac{y^2}{z} \right] - \left(\frac{(q-1)}{h_1} - \delta_K \right) \tag{9b}$$

$$\dot{q} = r(n)q - \frac{1}{\alpha^\rho z^{\epsilon\rho}} \alpha(1-\tau)(1-\eta)y^{1+\rho} - \frac{(q-1)^2}{2h_1} + \delta_K q \tag{9c}$$

$$i = \left(\frac{\{1 + \Omega\}\{\beta - r(n)\} + (i-\gamma)\{[\Omega(1 + \rho) - (1 + \Omega)\epsilon]\psi_K + [1 + \rho + (\epsilon - \rho)(1 + \Omega)]\psi_G\}}{[\{\gamma(1 + \theta) - 1\}\{1 + \Omega\} - (1 - \gamma)(1 + \rho)\Omega(\frac{l}{1-\tau})]} \right) l \tag{9d}$$

⁹ We should point out that in analyzing the effect of foreign aid, we assume that the recipient government acts passively, keeping its tax and expenditure policies unchanged. In reality, aid programs may call for co-financing by the government of the recipient economy, whereby it is required to match the foreign aid to some degree. It is also possible for the government, by choosing an appropriate mix of taxes and expenditure, to ensure that the equilibrium path is independent of any constraints imposed by the donor country. This may be important since the effects of tied aid are sensitive to the recipient economy's economic structure and may have undesirable effects. These issues have been addressed in some detail in our previous work, where we also consider growth-maximizing and welfare-maximizing government responses. Since their main consequences are only marginally affected by the elasticity of labor supply, we do not address them further here.

where

$$\Omega \equiv \Omega(z, l) \equiv ((1-\eta)/\eta)[(1-l)z]^{\rho} \quad (10a)$$

$$\frac{Y}{K} \equiv y = y(z, l) = \alpha z^{\varepsilon} [(1-\eta) + \eta\{(1-l)z\}^{-\rho}]^{-1/\rho} \quad (10b)$$

$$\frac{C}{K} \equiv c = c(z, l) = \frac{(1-\tau)}{\theta} \left(\frac{l}{1-l} \right) \left(\frac{1}{1+\Omega} \right) y \quad (10c)$$

$$r(n) = r^* + \omega(n) \quad (10d)$$

and the growth rates of the two types of capital are

$$\frac{\dot{K}}{K} \equiv \psi_K = \frac{q-1}{h_1} - \delta_K \quad (11a)$$

$$\frac{\dot{K}_G}{K_G} \equiv \psi_G = (\bar{g} + \sigma\phi) \frac{y}{z} - \delta_G. \quad (11b)$$

Eq. (9a) expresses the equilibrium growth rate of the ratio of public to private capital (z) in terms of the difference between the growth rate of public capital (K_G) and that of private capital (K), while Eq. (9b) expresses the equilibrium growth rate of the debt to private capital ratio (n), analogously. Eq. (9c) describes the evolution of the shadow price of private capital (q), necessary to ensure that the rate of return on investment equals the borrowing cost, while Eq. (9d) determines the dynamics of leisure (l). This last relationship is a reduced form equilibrium condition, reflecting how leisure must evolve in order for the consumer optimality conditions (3a) and (3b) to be maintained as the rates of return on both labor and capital change. Taken together, Eqs. (9a)–(9d) provide an autonomous set of dynamic equations in z , n , l , and q of which, two are state variables (k and n), while the remaining two are “jump” variables (q and l), and are free to respond instantaneously to new information as it becomes available. Once z and l are known, the output–capital ratio and the consumption–output ratio are determined by Eqs. (10b) and (10c).

The economy reaches steady state when $\dot{z} = \dot{n} = \dot{l} = \dot{q} = 0$. Applying these conditions to Eqs. (9a)–(9d) we can solve for the steady-state values, \tilde{z} , \tilde{q} , \tilde{n} and \tilde{l} . Given these quantities, Eqs. (10b)–(10d) and either Eq. (11a) or (11b) determine \tilde{y} , \tilde{c} , the steady-state interest rate \tilde{r} , and the long-run growth rate $\tilde{\psi}$, respectively.¹⁰ Linearizing Eqs. (9a)–(9d) around the steady-state yields an approximation to the underlying dynamic system. This system (not reported) forms the basis for our dynamic simulations. To be saddlepoint-stable, there must be two unstable roots to match the two jump variables. For all plausible sets of parameter values our simulations yield the required pattern of eigenvalues, namely two positive (unstable) and two negative (stable) roots, the latter being denoted by μ_1 and μ_2 , with $\mu_2 < \mu_1 < 0$.

¹⁰ The solution for the steady-state equilibrium is set out in the Appendix. Because this system is highly non-linear, it need not be consistent with a well-defined steady-state equilibrium with $\tilde{z} > 0$, $\tilde{c} > 0$. Our numerical simulations, however, yield well-defined steady-state values for all plausible specifications of all the structural and policy parameters.

Eqs. (9a), (9b), (9c), (9d) and (10a), (10b), (10c), (10d) represent “core” dynamic equations from which other key variables, in particular the various growth rates, may be derived. In addition to the growth rates of the two capital goods reported in Eqs. (11a) and (11b), the growth rates of consumption and output are given by

$$\frac{\dot{C}}{C} \equiv \psi_C = \frac{r(n) - \beta + \gamma\theta(1/l)[F(z, n, q, l)/G(z, l)]}{1 - \gamma} \quad (11c)$$

$$\frac{\dot{Y}}{Y} \equiv \psi_Y = \frac{1}{1 + \Omega(z, l)} \left[\Omega(z, l)\psi_K + \psi_G - \frac{\dot{i}}{1-l} \right] + \varepsilon[\psi_G - \psi_K] \quad (11d)$$

where $F(\cdot)$, $G(\cdot)$ are defined in the Appendix. Although the growth rates diverge during the transition, they ultimately converge to the common equilibrium rate $\tilde{\psi}_K = \tilde{\psi}_G = \tilde{\psi}_C = \tilde{\psi}$.

3. The dynamic effects of foreign aid: a numerical analysis

Due to the complexity of the model, we will examine the dynamic effects of a foreign aid or a transfer shock using numerical simulations. We begin by calibrating a benchmark economy, using the following parameters representative of a small open economy, which starts out from an equilibrium without any transfers or aid from abroad.

The Benchmark Economy

Preference parameters:	$\gamma = -1.5, \beta = 0.04, \theta = 1$
Production parameters:	$\alpha = 0.6, \eta = 0.2, \varepsilon = 0, h_1 = 15, h_2 = 15$
Elasticity of substitution in production:	$s = 1$
Depreciation rates:	$\delta_K = 0.05, \delta_G = 0.05$
World interest rate:	$r^* = 0.06,$
Premium on borrowing:	$a = 0.15^a$
Policy parameters:	$\tau = 0.15, \bar{g} = 0.05$
Transfers:	$\sigma = 0, \phi = 0$

^a The functional specification of the upward sloping supply curve that we use is: $r(n) = r^{*+} e^{an} - 1$. Thus, in the case of a perfect world capital market, when $a = 0$, $r = r^*$, the world interest rate.

Our choices of preference parameters β , γ , depreciation rates, δ_K , δ_G , and the world interest rate, r^* are standard, while α is a scale variable.¹¹ The productive elasticity of public capital $\eta = 0.2$ is consistent with the empirical evidence (see Gramlich, 1994). But given the introduction of labor in efficiency units, this implies that the productive elasticity of labor is also 0.2, while that of private capital is 0.8.¹² Setting $s = 1$ yields the Cobb–Douglas technology, which serves as a

¹¹ For example, an annual rate of time preference of 4% and physical depreciation rates of 5% are conventional in the real business cycle literature; see Cooley (1995). The choice of $\gamma = -1.5$ implies an intertemporal elasticity of substitution of 0.4, well within the conventional range of estimates; see e.g. Guvenen (in press).

¹² An inevitable feature of calibrating a Romer (1986)-type AK model is that keeping the size of the externality plausible, while maintaining the assumption of constant returns to scale in the private factors, imposes constraints on the elasticities on labor and private capital. In order to reconcile these elasticities with the empirical evidence on the income shares of labor and private capital, it is necessary to interpret K as an amalgam of physical and human capital, with $(1-l)$ describing “raw” unskilled labor; see Rebelo (1991).

reasonable benchmark.¹³ The borrowing premium $a=0.15$ is chosen to ensure a plausible equilibrium debt–output ratio. The elasticity on leisure, θ , is the key determinant of the equilibrium labor–leisure allocation and has been set to ensure that this is empirically plausible.¹⁴ The tax rate is set at $\tau=0.15$, while the rate of domestic government expenditure on public investment is assumed to be $\bar{g}=0.05$. The choice of adjustment costs is less obvious and $h_1=15$ lies in the consensus range of 10 to 16.¹⁵ Note also that the equality of adjustment costs between the two types of capital serves as a plausible benchmark. The public good externality parameter is set at $\varepsilon=0$.

Substituting these base parameters into the steady state Eqs. (A.7a)–(A.7f), described in the Appendix, and noting the functional form for Eq. (10d) (see footnote 11), yields the benchmark equilibrium, summarized in Row 1 of Table 1. The steady-state ratio of public to private capital is 0.25, the consumption–output ratio is 0.60, and the debt–output ratio is 0.42, yielding an equilibrium borrowing premium of 2.13% over the world rate of 6%. The capital–output ratio is 2.97, and 78% of the agent’s time is allocated to leisure, consistent with empirical evidence, yielding a long-run growth rate of 1.65%. This equilibrium is a reasonable characterization of a small–medium indebted economy, experiencing a modest steady growth rate and having a relatively small stock of public capital.

This equilibrium is based on several specific assumptions and therefore it is important to conduct some sensitivity analysis. The critical parameters upon which we focus are: (i) the elasticity of substitution in production, s , (ii) the elasticity of leisure in utility, θ , (iii) the externality parameter, ε , and (iv) the domestic fiscal policy parameters, \bar{g} , τ .

3.1. A permanent increase in the flow of foreign aid: long run effects

We now introduce a permanent foreign aid flow to the above benchmark economy. Specifically, the inflow of foreign aid is tied to the scale of the recipient economy, and increases from 0% of GDP in the initial steady-state to 5% of GDP in the new steady-state (an increase in σ from 0 to 0.05).¹⁶ This aid may be tied to new investment in public capital ($\phi=1$), representing a “productive” transfer, or it may be untied ($\phi=0$), in which case it is a “pure” transfer. The long-run and short-run responses of key variables in the recipient economy are reported in Rows 2 and

¹³ The Cobb–Douglas production function is the standard specification throughout the contemporary endogenous growth literature, starting with the pioneering work of Romer (1986), Lucas (1988), and Barro (1990). Historically, estimates of the elasticity of substitution have typically ranged between 0.8 and 1.2 for many economies and supported the Cobb–Douglas case as a reasonable benchmark; see Berndt (1976) for early evidence. Recent evidence suggests that s tends to be somewhat smaller for developing economies, and somewhat larger for developed countries; see Duffy and Papageorgiou (2000). Moreover, macro-dynamic adjustments tend to be quite sensitive to small deviations in s from unity, thus supporting the sensitivity analysis being undertaken in this paper; see Turnovsky (2002).

¹⁴ The allocation of time between leisure and work is particularly sensitive to θ , and this has been set so as to yield an equilibrium fraction of time devoted to leisure of around 0.76, consistent with the empirical evidence.

¹⁵ Although it is impractical to obtain direct empirical estimates of h_1 , it is possible to derive estimates indirectly. For example, Origueira and Santos (1997) show that the speed of convergence is sensitive to h_1 , and choose $h_1=16$ on the grounds that it generates a speed of convergence of around 2% per annum, consistent with much empirical evidence. Auerbach and Kotlikoff (1987) and Barro and Sala-i-Martin (1995) infer h_1 from empirical estimates of the Tobin q . These generally imply a slightly lower value for h_1 , suggesting a tradeoff between these two sources of information. In Chatterjee et al. (2003) we have conducted extensive sensitivity analysis with respect to adjustment costs.

¹⁶ While $\sigma=0.05$ is arbitrary, it is approximately the average rate of foreign aid, in terms of the recipients’ GDP, offered by the European Union under its aid program to prospective members in the early 1990s and thus serves as a reasonable benchmark.

Table 1
Permanent foreign aid shock

a. Long-run effects								
	\tilde{K}_G/\tilde{K}	\tilde{r} %	\tilde{l}	\tilde{C}/Y	\tilde{K}/Y	\tilde{N}/Y	$\tilde{\psi}$ %	$\Delta(W)$ %
Benchmark equilibrium $\sigma=0, \phi=0, \bar{g}=0.05, \tau=0.15$	0.253	8.13	0.780	0.602	2.969	0.416	1.65	–
Tied aid $\sigma=0.05, \phi=1, \bar{g}=0.05, \tau=0.15$	0.542	9.77	0.768	0.563	2.523	0.622	2.31	7.96
Untied aid $\sigma=0.05, \phi=0, \bar{g}=0.05, \tau=0.15$	0.252	7.99	0.793	0.653	3.011	0.396	1.60	7.71

b. Short-run effects								
	$l(0)$	$\frac{C(0)}{Y(0)}$	ψ_K (0) %	ψ_G (0) %	ψ_Y (0) %	ψ_C (0) %	$\Delta(W)$ (0) %	
Benchmark equilibrium $\sigma=0, \phi=0, \bar{g}=0.05, \tau=0.15$	0.780	0.602	1.65	1.65	1.65	1.65	–	
Tied aid $\sigma=0.05, \phi=1, \bar{g}=0.05, \tau=0.15$	0.777	0.594	1.95	8.33	3.48	1.87	– 1.53	
Untied aid $\sigma=0.05, \phi=0, \bar{g}=0.05, \tau=0.15$	0.7925	0.650	1.55	1.57	1.54	1.64	8.32	

Benchmark equilibrium: Cobb–Douglas production function ($s=1$).

3 in Table 1a and b. In addition, the final columns in the table summarize the effects on long-run welfare, $[\Delta W]$, and short-run welfare, $[\Delta W(0)]$, both measured by the optimized utility of the representative agent where C and l are evaluated along the equilibrium path. These welfare changes are measures of equivalent variation, calculated as the percentage change in the initial stock of capital necessary to maintain the level of welfare unchanged following the particular shock. The differences between the effects of the two types of transfer are dramatic.

We first consider the long-run effects of an increase in foreign aid (Table 1a) and then discuss the short-run transitional dynamics generated by this shock (Table 1b and Fig. 1).

3.1.1. Tied aid

The long-run impact of a tied foreign aid shock is reported in Row 2 of Table 1a. Since the aid is tied directly to public investment, in the new steady state the ratio of public to private capital more than doubles, increasing from 0.25 to 0.54, as a consequence of the investment boom in infrastructure. The larger stock of public capital increases the marginal productivity of private capital and labor, leading to a positive, though lesser, accumulation of private capital, and increasing employment time from 0.220 to 0.232. Although the transfer stimulates consumption through a wealth effect, the enhanced productive capacity has a greater impact on output, leading to a decline in the long-run consumption–output ratio from 0.60 to 0.563. The higher productivity raises the long-run growth rate to 2.31%, while long-run welfare improves by 7.96%. The increased accumulation of both private and public capital lead to a higher demand for external borrowing as a means of financing the new investment in private capital and the installation costs of public capital. This results in an increase in the steady state debt–output ratio from 0.42 to 0.62, raising the borrowing premium to nearly 3.8%. However, since this increased borrowing is used to finance additional investment (rather than consumption), leading to a long-run increase in the economy's productive capacity, ensures that the higher debt–output ratio is sustainable.

3.1.2. Untied aid

A permanent untied aid shock, i.e., an aid flow not tied to any investment activity, has precisely the opposite qualitative effects, as illustrated in Row 3 of Table 1a. Apart from consumption and

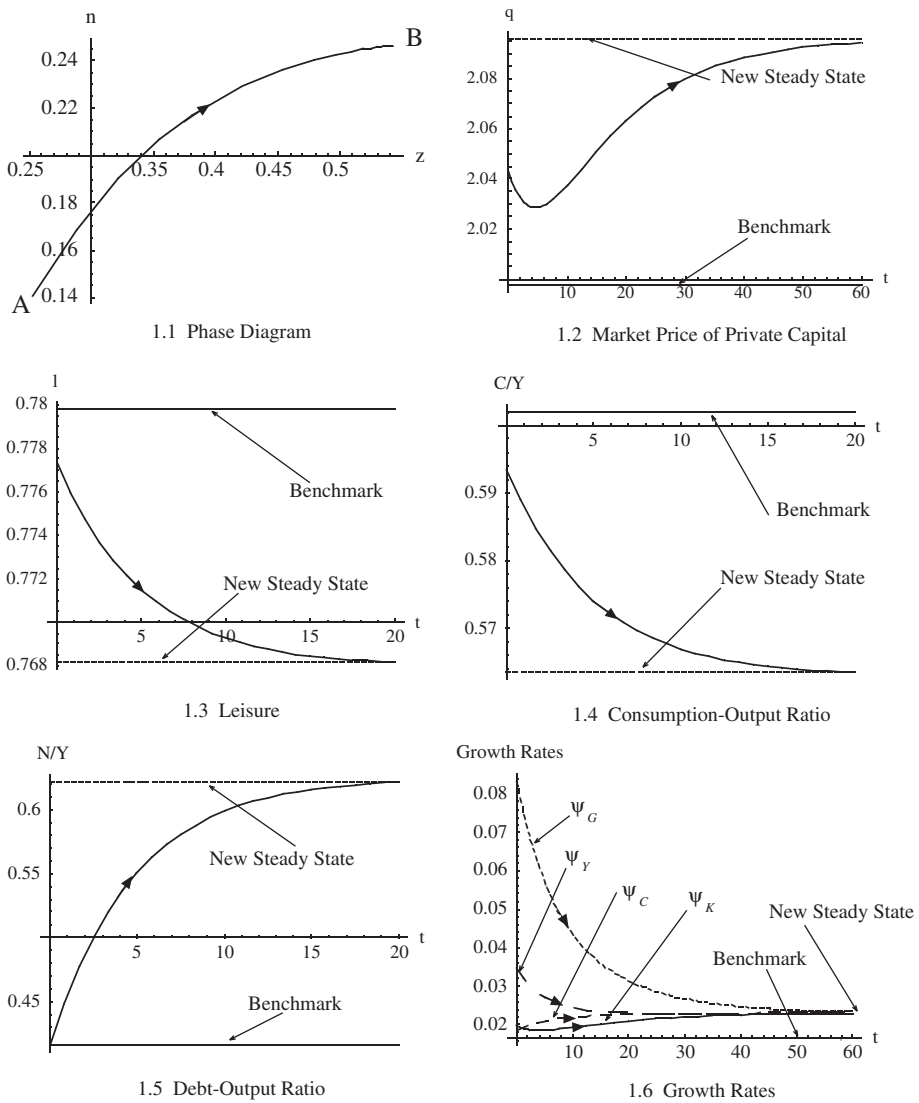


Fig. 1. Dynamic responses to tied aid shock (Cobb–Douglas case).

leisure, the changes are much smaller. Being untied, the transfer is devoted to debt reduction, thereby allowing an increase in consumption. The debt–output ratio declines to 0.396 and the consumption–output ratio rises to around 0.65. The increase in consumption raises the marginal utility of leisure, increasing the fraction of leisure time from 0.78 to 0.793. Since the aid no longer favors public investment, the ratio of public to private capital remains virtually unchanged. With the shift toward more consumption and leisure, productivity of both types of capital decline and the equilibrium growth rate is reduced from 1.65% to 1.60%, leading to an overall increase in welfare of around 7.71%, marginally less than for the tied aid shock.

3.2. Transitional dynamics

3.2.1. Tied aid

The transitional adjustment paths following the increase in tied aid in the benchmark economy are illustrated in Fig. 1. Fig. 1.1 illustrates the stable adjustment locus in z – n space, indicating how z and n both generally increase together during the transition. The immediate effect of the tied aid shock is to raise the growth rate of public capital, thereby raising the productivity of both private capital and labor; see Table 1b, Row 2. Given the cost of borrowing, the higher return to capital causes an instantaneous upward jump in the shadow price of private capital (q), thereby inducing a corresponding increase in private investment. At the same time, the higher productivity of labor induces an immediate, but slight, decline in the time devoted to leisure. While the upward jump in q reduces the rate of return on private capital, the increase in labor supply raises its return, and on balance, the latter effect slightly dominates. Thus, immediately after its initial increase, q begins to decline slightly, in order to maintain equality between the rate of return to capital and the borrowing costs, which initially remain unchanged [see Fig. 1.2].

The introduction of tied aid leads to an initial short-run decline in the consumption–output ratio. This is because the short-run substitution from leisure to labor both increases output and reduces the marginal utility of consumption. Thereafter, as the larger capital stocks are reflected in more output, the consumption–output ratio continues to decline monotonically toward its new steady-state value. Because of the complementarity of consumption and leisure in utility, the decline in the consumption–output ratio induces a steady decline in leisure toward its new equilibrium level of 0.768 [see Fig. 1.3 and 1.4].

The short-run increase in output leads to a slight initial decline in the debt–output ratio, after which it increases monotonically through time [see Fig. 1.5]. This is because the accumulation of public capital raises the average productivity of private capital, while the accumulation of both types of capital increases the need to borrow from abroad to finance new investment and installation costs. The higher debt raises borrowing costs. While, the short-run reduction in q , decrease in leisure, and accumulation of public capital all serve to raise the return on private capital, this is insufficient to equal the higher borrowing costs and thus after a few periods q must begin to rise monotonically (i.e. $\dot{q} > 0$) in order to generate the appropriate equilibrium return to capital.

The contrasting time paths of the four growth rates, ψ_K , ψ_G , ψ_Y , and ψ_C during the transition toward their common long-run growth rate of 2.31% are illustrated in Fig. 1.6. With public capital being directly stimulated by the transfer, its growth rate jumps initially to over 8.3% before gradually declining. By contrast, private capital increases only very gradually from 1.95% to 2.31% during transition, as the accumulation of public capital enhances its productivity. As a result, the ratio of public to private capital increases at a steady monotonic rate. The growth rate of output is a weighted average of the growth rates of the two capital stocks plus the temporary growth of labor and therefore immediately increases to 3.5% with the aid shock. On the other hand, the only influence on the initial growth rate of consumption is the effect that operates through the labor supply and the labor–leisure choice, raising its growth rate from 1.65% to 1.87%. Thereafter it responds only gradually, in response to the accumulation of assets in the economy. It always lies below the growth rate of output, so that C/Y is falling, as noted in Fig. 1.4. However, the level of consumption is still growing, albeit at a modest rate.

3.2.2. Untied aid

The transitional dynamics following an untied aid shock are illustrated in Fig. 2 and the following three observations should be made, highlighting how our results differ from earlier

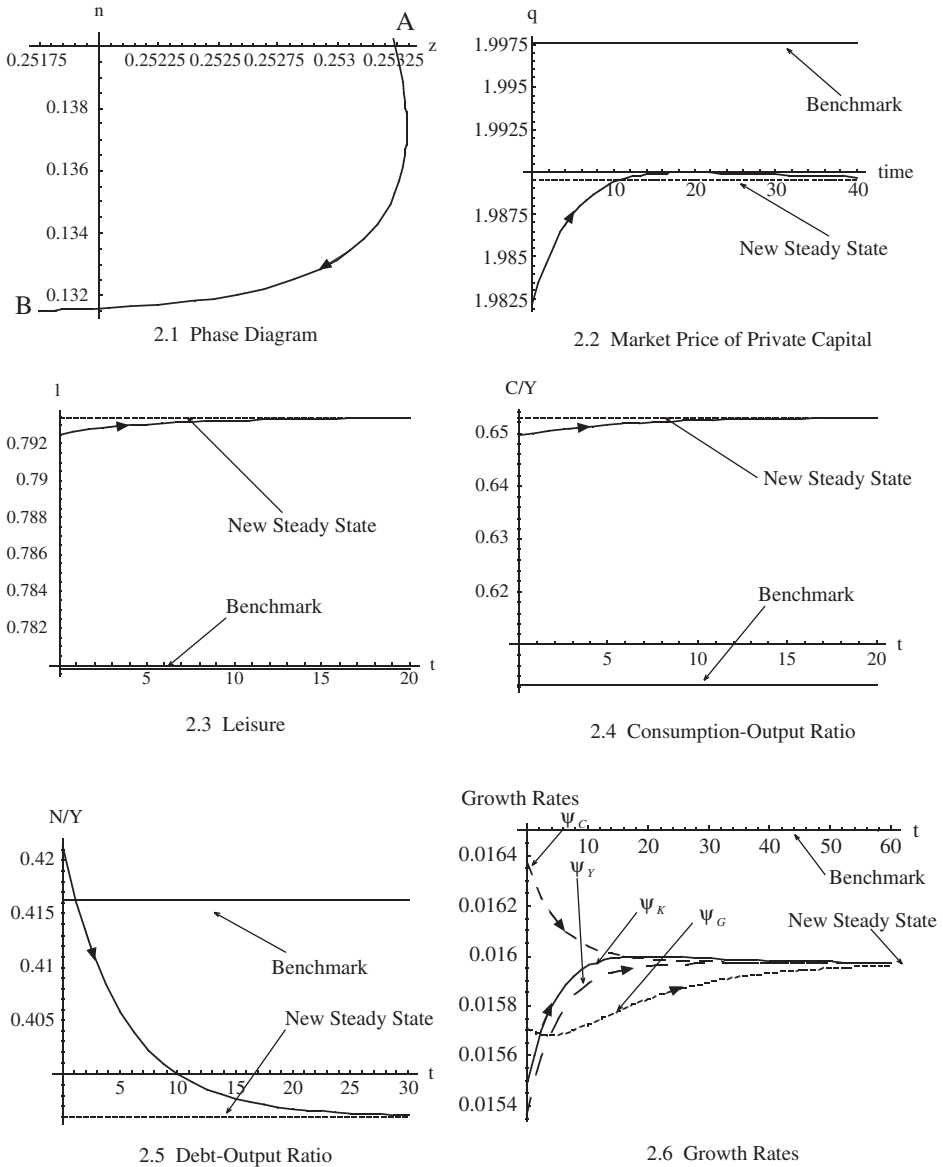


Fig. 2. Dynamic responses to untied aid shock (Cobb–Douglas case).

findings. First, the existence of transitional dynamics following an untied aid shock depends crucially upon the endogeneity of labor supply. If labor supply is inelastic, then untied aid has no dynamic or growth effects and the economy moves instantaneously to its new steady-state via a once-and-for-all increase in the consumption–output ratio; see Chatterjee et al. (2003). Second, the dynamics in response to untied aid are in sharp contrast to those generated by tied aid, being more or less the reverse. This reflects the fact, noted in Table 2 that the long-run responses of the economy to the two types of aid are generally opposite in nature. Third, the dynamic adjustment generally occurs much more rapidly than in response to the tied aid shock.

Table 2
Sensitivity of permanent responses to the elasticities of substitution (s) and leisure (θ)

N/Y	$s=1$			$s=1.2$			$s=1.6$										
	$d\bar{l}$	$d(\bar{C}/Y)$	$d(\bar{N}/Y)$	$d\bar{l}$	$d(\bar{C}/Y)$	$d(\bar{N}/Y)$	$d\bar{l}$	$d(\bar{C}/Y)$	$d(\bar{N}/Y)$								
$\theta=0$	0	-0.065	0.194	-0.35	1.03	0	0.741	0	-0.036	0.053	-0.266	0.566	0	-0.024	0.003	-0.227	0.375
$\theta=1$	0.009	-0.054	0.419	-0.630	0.984	-0.012	0.657	-0.026	-0.029	0.101	-0.327	0.446	-0.041	-0.024	0.019	-0.192	0.223
$\theta=2$	0.007	-0.046	0.572	-0.814	0.939	-0.007	0.608	-0.015	-0.028	0.111	-0.327	0.385	-0.017	-0.025	0.017	-0.147	0.158
<i>(i) Tied Aid Shock: σ increases from 0 to 0.05, $\phi=1$</i>																	
$\theta=0$	0	0.05	0	0	0.05	0	0	0	0.05	0	0	0	0	0.05	0	0	0
$\theta=1$	0.014	0.052	-0.038	0.055	-0.069	0.014	0.051	0.013	0.05	-0.011	0.032	-0.039	0.010	0.049	-0.002	0.018	-0.020
$\theta=2$	0.009	0.052	-0.058	0.080	-0.073	0.008	0.051	0.007	0.05	-0.012	0.034	-0.037	0.004	0.050	-0.002	0.014	-0.015
<i>(ii) Untied Aid Shock: σ increases from 0 to 0.05, $\phi=0$</i>																	

Fig. 2.1 illustrates the transitional adjustment paths for the two state variables, the ratios of debt to private capital and public capital to private capital, respectively. On receipt of the aid, these move in opposite directions, implying that on impact the debt–capital ratio begins to decline, while the public–private capital ratio begins to increase. The untied transfer is initially applied primarily to debt reduction, which allows an immediate substantial increase in consumption, increasing the marginal utility of leisure, and thus inducing an immediate sharp reduction in labor supply.

The main impact of an untied aid shock is on consumption, leisure, and debt reduction, as illustrated in Figs. 2.3–2.5. Its initial impact is to raise the marginal utility of leisure causing a reduction in labor supply, and hence in the productivity of private and public capital, and in q . The receipt of the untied aid has a slightly less adverse short-run effect on the growth rate of public capital, reducing it to 1.57%, slightly above that of private capital. As z increases, the productivity of public capital declines relative to private capital, causing their relative growth rates to reverse. After just over two periods the growth rate of private capital exceeds that of public capital and z begins to decline with n . The decline in q is partially reversed during the subsequent transition as the relative stock of public to private capital declines.

4. Sensitivity analysis

The contrast between the effects of tied and untied foreign aid is striking. It is therefore important to determine how sensitive this comparison is to the chosen parameter values for the benchmark economy. This is explored in Tables 2–5, along the various dimensions noted earlier.¹⁷

4.1. Elasticity of substitution in production (s) versus flexibility in labor supply (θ)

Table 2 presents a grid summarizing the changes in key variables in response to equal amounts of tied aid and untied aid, respectively, as the elasticity of substitution in production, s , varies between 0.8 and 1.6, while θ varies between 0 and 2.¹⁸ One interesting feature is that the effect of tied aid on the equilibrium growth rate is highly sensitive to even minor deviations from the benchmark ark value of $s=1$ (Cobb–Douglas). Thus, for example, if a researcher estimates $s=1$ with a standard error of 0.1 – a tight estimate – and if $\theta=1$, then, with 95% probability, the implied increase of 0.66 percentage points in the growth rate could be as high as 0.98 or as low as 0.45. A sustained difference in the growth rate of half a percentage point accumulates to a substantial difference in economic performance. This is seen from the spread on the implied welfare gain of 7.96%, which is even larger, ranging as high as 21.1% and as low as 0.53%.

Looking though the two panels of Table 2, the following observations can be made.

- (i) The tendency for tied and untied aid to have opposite long-run effects on economic activity is robust to variations in s and θ .
- (ii) Tied aid has substantially greater long-run effects on variables involving asset accumulation [capital stocks and foreign debt], than does untied aid. The effects on consumption and leisure are comparable in magnitude (though opposite in direction).

¹⁷ In our earlier work, with fixed labor supply, we conducted sensitivity analysis with respect to the adjustment costs of public capital as well as the degree of capital market imperfections. We have also addressed these aspects here, but since the conclusions are basically unchanged from those obtained previously, we omit them from our discussion.

¹⁸ We have extended the sensitivity analysis to include $\theta=5$, but the pattern remains unchanged.

Table 3

Sensitivity of short-run and long-run welfare responses to the elasticities of substitution (s) and leisure (θ)

	$s=0.8$		$s=1$		$s=1.2$		$s=1.6$	
	$\Delta[W(0)]$	$\Delta(W)$	$\Delta[W(0)]$	$\Delta(W)$	$\Delta[W(0)]$	$\Delta(W)$	$\Delta[W(0)]$	$\Delta(W)$
<i>(i) Tied aid: σ increases from 0 to 0.05, $\phi=1$</i>								
$\theta=0$	0.71	10.18	-3.97	6.00	-7.76	1.06	-13.04	-3.14
$\theta=1$	5.14	21.08	-1.53	7.96	-6.71	0.53	-12.56	-6.82
$\theta=2$	7.03	26.46	-0.69	9.15	-6.55	0.16	-12.52	-7.68
<i>(ii) Untied aid: σ increases from 0 to 0.05, $\phi=0$</i>								
$\theta=0$	8.24	8.24	8.66	8.66	8.94	8.94	9.28	9.28
$\theta=1$	7.49	6.47	8.32	7.71	8.94	8.55	9.70	9.52
$\theta=2$	7.22	5.89	8.21	7.50	8.94	8.54	9.78	9.64

- (iii) Increasing the elasticity of substitution, s , reduces the positive effect of tied aid on the growth rate, while reducing the negative effect on the consumption–output and capital–output ratios. On the other hand, a higher s primarily reduces the adverse effect of an untied aid shock on the debt–output ratio, while decreasing the positive effects on the capital–output and consumption–output ratios, the latter only mildly. The net effect is to reduce the adverse effect on the growth rate.

Intuitively, the larger the elasticity of substitution, the larger is the increase in productivity of private capital resulting from tied aid, and this induces a substitution towards private capital. As a result, the Y/K ratio rises less, so that the increased productivity of private capital is reduced, thus lowering its rate of accumulation, and mitigating the fall in consumption. For untied aid, a higher elasticity of substitution means that the reduction in the productivity of private capital resulting from the reduction in labor supply is mitigated, so that the fall in the growth rate is moderated. Slower growth means less borrowing, lower borrowing costs, and thus a decline in the debt–output ratio.

- (iv) As the importance of leisure in utility (θ) increases, the positive effect of tied aid on the growth rate declines, and so do the adverse effects on the consumption–output and capital–output ratios. In contrast, the adverse effect of untied aid on the growth rate increases, while its positive effect on the capital–output ratio and the adverse effect on the debt–output ratio also diminishes.

The intuition is as follows. The more the agent values leisure in utility, the less they are willing to reduce it in response to an increase in tied aid, the less the reduction in consumption, and the less the positive effect on the growth rate. In the case of untied aid, as θ increases, and agents enjoy more leisure, the productivity of capital and the return on capital decline, so the adverse effect on the growth rate increases. However, there are some offsetting effects. As leisure increases, because of its diminishing marginal utility, agents increase their leisure at a diminishing rate. This mitigates the adverse effect of untied aid on the growth rate, for a sufficiently large θ .¹⁹

¹⁹ One result in Table 2 worth noting is the contrast in the response of leisure to an increase in tied aid as s increases from 0.8 to 1.6. As already noted, if $s=1$, a tied transfer, by increasing labor productivity, encourages more work effort, an effect that is exacerbated as the elasticity of substitution increases beyond 1. For low s , however, this response is reversed. The intuition is seen most clearly by focusing on the polar case of the fixed coefficient production function, $s=0$. In this case, private capital, K , and labor in efficiency units, $(1-l)K_g$, need to change proportionately. Since tied aid leads to an increase in the relative stock, $z \equiv K_g/K$, this must be accompanied by a decrease in labor for $(1-l)z$ to remain constant and for production to remain efficient.

Table 4

Sensitivity of long-run welfare responses to the elasticities of substitution (s), leisure (θ), and the public capital externality (ε) (percentage changes in welfare, σ increases from 0 to 0.05)

	$s=0.8$		$s=1$		$s=1.2$		$s=1.6$	
	$\phi=0$	$\phi=1$	$\phi=0$	$\phi=1$	$\phi=0$	$\phi=1$	$\phi=0$	$\phi=1$
<i>(i) $\varepsilon=0.02$</i>								
$\theta=0$	8.21	12.10	8.63	6.33	8.91	2.68	9.25	-1.68
$\theta=1$	6.44	23.46	7.67	9.89	8.51	2.24	9.47	-5.31
$\theta=2$	5.86	29.11	7.46	11.16	8.50	1.88	9.59	-6.16
<i>(ii) $\varepsilon=0.05$</i>								
$\theta=0$	8.16	15.12	8.58	9.05	8.86	5.20	9.19	0.60
$\theta=1$	6.39	27.84	7.61	12.94	8.43	4.91	9.39	-2.93
$\theta=2$	5.82	33.34	7.40	14.34	8.42	4.57	9.50	-3.78
<i>(iii) $\varepsilon=0.1$</i>								
$\theta=0$	8.08	20.57	8.49	13.93	8.77	9.70	9.09	4.65
$\theta=1$	6.30	34.21	7.51	18.50	8.32	9.73	9.25	1.33
$\theta=2$	5.75	41.17	7.31	20.18	8.32	9.46	9.37	0.51
<i>(iv) $\varepsilon=0.2$</i>								
$\theta=0$	7.94	33.43	8.33	25.31	8.59	20.11	8.90	13.89
$\theta=1$	6.15	51.30	7.31	31.90	8.10	21.19	8.99	11.32
$\theta=2$	6.37	60.63	7.14	34.36	8.12	21.11	9.12	10.59

4.2. Welfare comparisons

The comparison of the overall intertemporal welfare gains for the two types of aid is particularly striking. Table 3 indicates that for the benchmark case ($s=1$, $\theta=1$), the net effects of the two types of aid on intertemporal welfare are more or less comparable; the gains from tied aid are 7.96%, while those from untied aid are 7.71%. But despite this similarity in the overall intertemporal welfare gains for the two forms of aid, the contrasting dynamic adjustments in the economy lead to sharp differences in the time-profiles of the benefits they provide. For tied aid, the commitment toward public investment involves initial consumption losses and less leisure, leading to a short-run welfare loss of 1.53%. Over time, as the economy becomes more productive, consumption increases rapidly. Welfare rises sharply, with subsequent gains dominating the initial losses, resulting in an overall intertemporal welfare gain. In contrast, the response to untied aid does not

Table 5

Sensitivity of Foreign aid shocks to domestic fiscal structure (Cobb–Douglas production function, σ increases from 0 to 0.05, $\varepsilon=0$)

	$\bar{g}=0.02$				$\bar{g}=0.05$				$\bar{g}=0.10$						
	Tied aid ($\phi=1$ is opt)		Untied aid ($\phi=0$)		Tied aid ($\phi=1$)		Untied aid ($\phi=0$)		Interior optimal mix		Tied aid ($\phi=1$)		Untied aid ($\phi=0$ is opt)		
	ΔW	ΔV	ΔW	ΔV	ΔW	ΔV	ΔW	ΔV	ΔW	ΔV	$\hat{\phi}$	ΔW	ΔV	ΔW	ΔV
$\tau=0.10$	26.97	0.87	7.26	-0.76	7.16	0.57	8.23	-0.58	8.89	0.13	0.39	-2.68	0.45	10.35	-0.48
$\tau=0.15$	27.73	1.09	6.87	-0.84	7.96	0.66	7.71	-0.64	8.92	0.07	0.53	-1.51	0.49	9.53	-0.52
$\tau=0.20$	28.45	1.37	6.51	-0.94	8.70	0.77	7.25	-0.70	9.12	0.32	0.68	-0.50	0.54	8.82	-0.56

involve intertemporal trade-offs. Instead, it results in an immediate and an almost constant increase in consumption, leisure, and therefore welfare, along the transition path.

Table 3 presents the sensitivity of the short-run and long-run welfare responses to the two types of aid shocks, for variations in s and θ . The following patterns emerge from the table:

- (i) Both the short-run and the intertemporal welfare gains from an untied aid shock are remarkably insensitive to variations in both s and θ . For plausible ranges of the parameters, an untied aid flow equal to 5% of GDP leads to short-run welfare gains of between 7% and 9% and long-run gains over the range of 5–10%, both measured by an equivalent variation in the initial stock of capital. The long-run gains are typically within 1 percentage point of the short-run gains suggesting a gradual increase over time.
- (ii) In contrast, both the short-run and long-run welfare gains from a tied aid of the same magnitude are highly sensitive to both parameters. For any given θ , the long-run welfare gains decline with s . On the other hand, welfare gains increase with θ for values of s less than 1. For high values of s , tied aid yields both short-run and long-run losses, the former being relatively independent of θ , and the latter increasing with θ . There is therefore a sharp contrast between the short-run and long-run welfare effects of tied aid.

Results (i) and (ii) from Table 3 are two key findings, and the following intuition may be provided. An untied aid flow has little effect on the stocks of public or private capital. The higher elasticity of substitution raises the level of output attainable from given stocks of capital, thereby raising consumption and welfare approximately uniformly. If the aid flow is tied, it increases the rate of investment in public capital. With a low elasticity of substitution this requires an approximately corresponding increase in private capital, leading to a large increase in output, consumption, and benefits. As the elasticity of substitution increases, the higher public capital is associated with a smaller increase in private capital, so that the increase in output, consumption, and welfare declines. This is exacerbated by the fact that for a high elasticity of substitution, the tied transfer generates a large increase in the real wage and its growth rate, leading to substantial substitution toward labor, which is further welfare-reducing.

The contrasting sensitivities of the welfare gains resulting from tied and untied aid shocks to changes in s and θ imply that the relative merits of the two forms of transfers, from a welfare standpoint, are also highly sensitive to these two structural parameters. To consider this, we shall focus on the benchmark case $s=1$, and consider variations in θ . As we have already noted, for $\theta=1$, tied aid is marginally superior to untied aid from a long-run (intertemporal) welfare point of view. But as θ declines and leisure becomes less important in utility, untied aid is superior to tied aid. Indeed in the limiting case of inelastic labor supply, $\theta=0$, an untied aid shock generates a long-run welfare gain of 8.66%, while the corresponding gain from a tied aid shock is much lower, at 6%. The less (more) important is leisure in utility, the more (less) tied aid crowds out private consumption, thus decreasing (increasing) the benefits, relative to untied aid. This comparison is sensitive to even small variations in the elasticity of substitution. For example, if $s=0.8$ tied aid dominates untied aid (intertemporally), irrespective of the importance of leisure (even for $\theta=5$), while if $s=1.2$, the reverse is true.

4.3. Generalizations of the production function

Table 4 extends the comparison of the long-run welfare effects of tied and untied aid by allowing public capital to have the additional externality effect as introduced in Eq. (1a). The

main message of these results is clear and unsurprising. While the benefits of untied aid are relatively insensitive to ε (being mildly negative), the benefits of tied aid are highly sensitive to this effect, so that the latter is heavily favored as ε increases. Take, for example, the benchmark case of $\theta = s = 1$. Whereas tied aid is only marginally superior in the absence of this effect, it clearly dominates for $\varepsilon = 0.1$ (7.51% vs. 18.50%). Moreover, in cases where untied aid previously dominated tied aid (in the absence of the externality), tied aid may now not only be positive from a welfare standpoint but may also be superior to untied aid (in the presence of the externality). An example of this arises in the case where $s = 1.6$, $\varepsilon = 0.2$.²⁰

4.4. Sensitivity of transitional dynamics

We have recomputed the transitional paths for both types of aid to determine their sensitivity to variations in s and θ , as well as to ε . For untied aid, the time profiles retain the general qualitative characteristics illustrated in Fig. 2 for the benchmark case. Many of the qualitative characteristics of the transitional paths following a tied aid shock also remain as illustrated in Fig. 1, although, as Fig. 3 demonstrates, some substantive differences also arise.

The transitional time paths for leisure and the consumption–output ratio following a tied aid shock are sensitive to variations in the elasticity of substitution (s), and Fig. 3 compares them for three values of $s = 0.5$, 1, and 1.6, while θ remains at its benchmark value of unity. As already observed, for the benchmark economy, l and C/Y move together. For a low elasticity of substitution ($s = 0.5$), leisure generally increases, for reasons discussed in Section 4.1. The initial increase in leisure increases the marginal utility of consumption, so that C/Y initially increases, after which it declines steadily. This implies that l and C/Y move in opposite directions throughout the transition. For a high elasticity of substitution, l initially declines and continues to decline during the transition, just as in the benchmark case. But in this case, the initial decline in l is sufficiently sharp to cause a sharp decline in initial consumption, $C(0)$. The C/Y ratio overshoots its long-run response, and thus rises during transition, implying again that l and C/Y move in opposite directions while approaching the steady state.

5. Consequences for the government fiscal balance

Burnside and Dollar (2000) argue that the effectiveness of foreign aid depends upon “good” government policy, their index of which includes the budget surplus as one key factor. Our model enables us to address this issue in the following way.

Recalling Eq. (7), T represents the amount of lump-sum taxation (or transfers) necessary to finance the primary deficit and is therefore a measure of *current* fiscal imbalance. Defining

$$\begin{aligned}
 V &\equiv \int_0^{\infty} \frac{T(t)}{Y(t)} e^{-\int_0^t r(n) ds} dt \\
 &= \int_0^{\infty} \left[(\bar{g} + \phi\sigma) \left[1 + (h_2/2)(\bar{g} + \phi\sigma) \frac{y(t)}{z(t)} - (\tau + \sigma) \right] e^{-\int_0^t r(n) ds} dt \right] \quad (12)
 \end{aligned}$$

²⁰ We have also conducted sensitivity analysis using the generalized Romer production function in footnote 4. If $\varepsilon = 0$ in that model, tied aid is clearly undesirable, since it is obliging the recipient economy to devote the resources to an unproductive use. But if ε is sufficiently large (e.g. around 0.2) it is again the case that tied aid is not only beneficial, but also superior to untied aid.

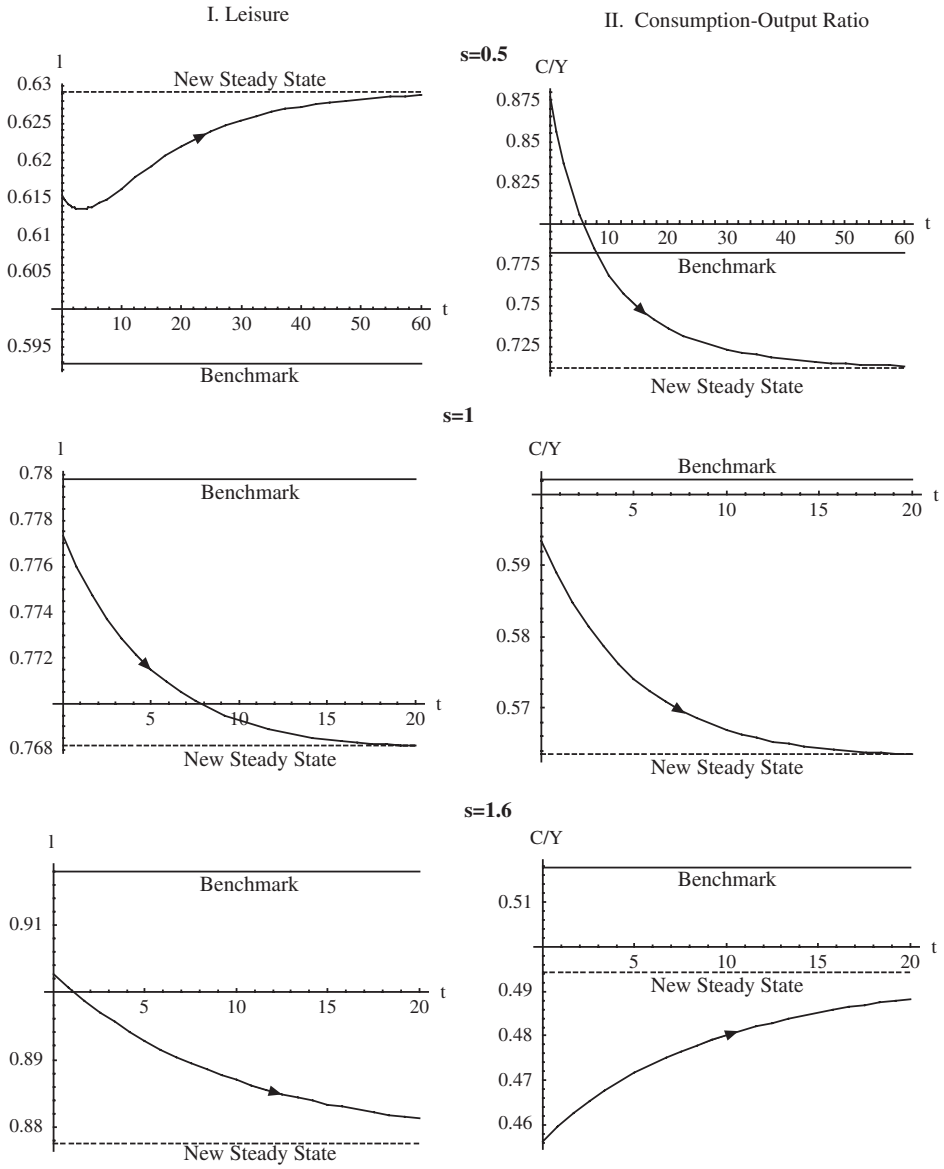


Fig. 3. Sensitivity of dynamics of leisure–consumption to elasticity of substitution (tied aid).

and substituting for the appropriate quantities from Section 2, V measures the present discounted value of lump-sum taxes per unit of current output necessary to balance the government budget over time, and thus provides a measure of the *intertemporal* fiscal imbalance. Table 5 summarizes the effects of aid on both intertemporal welfare, W , and the government’s intertemporal balance, V , for varying domestic fiscal configurations. A number of important insights emerge.

- (i) The welfare benefits from untied aid are relatively insensitive to variations in both the tax rate and the rate of government spending, decreasing mildly with the former and increasing mildly with the latter. In addition, untied aid always improves the intertemporal fiscal balance.
- (ii) The welfare benefits from tied aid increase slightly with the tax rate but decline dramatically with government spending. Tied aid always worsens the intertemporal deficit.
- (iii) For low rates of government expenditure tied aid involves a tradeoff in that increased welfare is accompanied by a larger intertemporal government deficit. For high rates of government expenditure, tied aid is both welfare-decreasing and also deteriorates the government's intertemporal balance. In contrast, untied aid always has a positive effect on both targets.
- (iv) The larger is the current government surplus, as parameterized by $\tau \bar{g}$, the more (less) beneficial is tied (untied) aid. "Good" policy in the Burnside–Dollar sense thus favors tied aid.
- (v) For $\bar{g}=0.05$, the optimal policy is an interior mix of tied and untied aid, while for more extreme rates of expenditure (e.g. $\bar{g}=0.02, 0.10$) optimal policy involves corner solutions.

6. Conclusions

The link between foreign aid, economic growth, and welfare depends crucially on the mechanism through which a particular aid program, whether tied or untied, is absorbed by the recipient economy. In this paper, we introduce several important aspects of this mechanism that have been absent from previous work. First, we highlight the importance of the endogeneity of labor supply as an additional margin through which foreign aid may impact on macroeconomic performance. Second, we focus on (i) the role played by the interaction of labor supply and public capital, and (ii) externalities associated with public capital accumulation in determining an economy's response to a foreign aid shock. In addition, we are also able to relate our theoretical model to the recent empirical literature by examining the impact of an underlying aid program on the recipient government's intertemporal fiscal deficit. While recent work by Chatterjee et al. (2003) and Chatterjee and Turnovsky (2004) has highlighted the role played by an economy's structural conditions in the absorption of aid, we view the current paper as further enhancing our understanding of the aid-growth link by focusing on the role played by relative prices (of consumption and leisure), production externalities, and the government's fiscal balance.

We conclude with two final comments. First, our results carry some important policy advice. They suggest that when donors decide on whether a particular aid program should be tied to an investment activity, careful attention should be paid to the recipient's opportunities for substitution in production, the elasticity of labor supply, and production externalities. It is perfectly possible for a tied transfer to have a presumably unintended adverse effect on the recipient economy, if that economy is structurally different from what the donor perceived. Second, we have abstracted entirely from any political economy factors relating to rent-seeking or corruption, which are clearly relevant issues in any foreign aid discussion. Recent work by Acemoglu and Robinson (2000) and others show that the existence of "political elites" and powerful interest groups in poor economies may be a deterrent to investment, technological change, and economic development. Further, the lack of institutions may also inhibit the effects of aid on growth. Clearly, the consequences of these are significant considerations for determining both the nature and composition of foreign aid and are important directions for future research.

Appendix A

This Appendix provides the detailed derivations of the macro-dynamic equilibrium.

A.1. Derivation of the equilibrium relationships (9a)–(9d)

The production function we consider is

$$Y = \alpha \left(\frac{K_G}{\bar{K}} \right)^\varepsilon [\eta \{(1-l)\bar{K}\}^{-\rho} + (1-\eta)K^{-\rho}]^{-1/\rho} \quad (1a)$$

The marginal rate of substitution between C and l is given by:

$$\frac{C}{Y} = \frac{\eta(1-\tau)}{A^\rho \theta} \left(\frac{l}{1-l} \right) \left(\frac{Y}{1-l} \right)^\rho \quad (A.1)$$

where, $A = \alpha(K_G/K)^\varepsilon$. Next, we recall the definition of $\Omega(z, l) \equiv \Omega = ((1-\eta)/\eta)[(1-l)z]^\rho$ given in Eq. (10a). Substituting this into the production function (1a), and into Eq. (A.1) we can express the output–capital ratio and consumption–capital ratios in the form

$$Y/K \equiv y = y(z, l) = \alpha z^\varepsilon [(1-\eta) + \eta(1-l)^{-\rho}]^{-1/\rho} \quad (A.2a)$$

$$\frac{C}{\bar{K}} \equiv c = c(z, l) = \frac{(1-\tau)}{\theta} \left(\frac{l}{1-l} \right) \left[\frac{1}{1+\Omega} \right] y \quad (A.2b)$$

Then, differentiating the optimality condition, Eq. (3a), the marginal rate of substitution condition, Eq. (A.1), the production function (1a), all with respect to time, and recalling Eq. (4a), yields

$$(\gamma-1) \frac{\dot{C}}{C} + \gamma \theta \frac{\dot{l}}{l} = \frac{\dot{\lambda}}{\lambda} = \beta - r(N/K) \quad (A.3a)$$

$$\frac{\dot{C}}{C} - \frac{\dot{Y}}{Y} = \frac{\dot{l}}{l} + (1+\rho) \frac{\dot{l}}{1-l} + \rho \left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K} \right) - \varepsilon \rho \left(\frac{\dot{K}_G}{K_G} - \frac{\dot{K}}{K} \right) \quad (A.3b)$$

$$\frac{\dot{Y}}{Y} \equiv \psi_Y = \frac{1}{1+\Omega} \left[\Omega \frac{\dot{K}}{K} + \frac{\dot{K}_G}{K_G} - \frac{\dot{l}}{1-l} \right] + \varepsilon \left[\frac{\dot{K}_G}{K_G} - \frac{\dot{K}}{K} \right] \quad (A.3c)$$

Combining these four equations together with Eqs. (3c') and (6'), we can eliminate the growth rates, \dot{C}/C , \dot{K}/K , \dot{K}_G/K_G , \dot{Y}/Y , and $\dot{\lambda}/\lambda$ and express the dynamics of leisure by the differential equation:

$$\dot{l} = \frac{F(z, n, q, l)}{G(z, l)} \quad (A.4)$$

where

$$F(z, n, q, l) \equiv \left[\beta - r(\tilde{n}) + (1-\gamma) \left\{ \varepsilon \left(\frac{\dot{K}_G}{K_G} \right) + (1-\varepsilon) \left(\frac{\dot{K}}{K} \right) \right\} \right] l,$$

$$G(k, l) \equiv \left[\{\gamma(1+\theta)-1\} - (1-\gamma)(1+\rho) \left(\frac{\Omega(z, l)}{1+\Omega(z, l)} \right) \left(\frac{l}{1-l} \right) \right],$$

and

$$\psi_K(q) \equiv \frac{\dot{K}}{K} = \frac{(q-1)}{h_1} - \delta_K \tag{A.5a}$$

$$\psi_G(z, l) \equiv \frac{\dot{K}_G}{K_G} = g \frac{\dot{Y}}{K_G} - \delta_G = \alpha(\bar{g} + \sigma\phi)(1-l)z^{\varepsilon-1}[\eta\{1 + \Omega(z, l)\}]^{-1/\rho} - \delta_G \tag{A.5b}$$

Using Eqs. (A.3a) and (A.4) we can express the growth rate of consumption as

$$\psi_C \equiv \frac{\dot{C}}{C} = \frac{r(n) - \beta + \gamma\theta(1/l)[F(z, n, q, l)/G(z, l)]}{1-\gamma} \tag{A.5c}$$

while Eq. (9c) follows directly from the optimality condition (4b).

The equilibrium dynamics can now be represented by the following autonomous system in the stationary variables, z, n, q, l ,

$$\frac{\dot{z}}{z} = \frac{\dot{K}_G}{K_G} - \frac{\dot{K}}{K} = (\bar{g} + \sigma\phi) \frac{y}{z} - \delta_G - \left(\frac{(q-1)}{h_1} - \delta_K \right) \tag{A.6a}$$

$$\frac{\dot{n}}{n} = \frac{\dot{N}}{N} - \frac{\dot{K}}{K} = r(n) + \frac{1}{n} \left[c + \frac{q^2-1}{2h_1} + \{(\bar{g} + \sigma\phi) - (1+\sigma)\}y + \frac{h_2}{2}(\bar{g} + \sigma\phi)^2 \frac{y^2}{z} \right] - \left(\frac{(q-1)}{h_1} - \delta_K \right) \tag{A.6b}$$

$$\dot{q} = r(n)q - \frac{(1-\tau)(1-\eta)y^{(1+\rho)}}{\alpha^\rho z^{\varepsilon\rho}} - \frac{(q-1)^2}{2h_1} + \delta_K q \tag{A.6c}$$

$$\dot{l} = \frac{F(l)}{G(l)} = \frac{\left[\beta - r(\tilde{n}) + (1-\gamma) \left\{ \varepsilon \left(\frac{\dot{K}_G}{K_G} \right) + (1-\varepsilon) \left(\frac{\dot{K}}{K} \right) \right\} \right] l}{\{\gamma(1+\theta)-1\} - (1-\gamma)(1+\rho) \left(\frac{\Omega(z, l)}{1+\Omega(z, l)} \right) \left(\frac{l}{1-l} \right)} \tag{A.6d}$$

where, from above, $\Omega = \Omega(z, l)$, $y = y(z, l)$, $c = c(z, l)$, $\psi_K = \psi_K(q)$ and $\psi_G = \psi_G(z, l)$.

A.2 Steady-state equilibrium

Steady-state equilibrium is attained when $\dot{z} = \dot{n} = \dot{l} = \dot{q} = 0$, so that

$$\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{K}_G}{K_G} = \frac{\dot{Y}}{Y} = \frac{\dot{N}}{N} = \tilde{\psi}.$$

$\dot{z} = \dot{n} = \dot{l} = \dot{q} = 0$ in Eqs. (A.6a)–(A.6d) and recalling (A.2a), (A.2b), (A.5a), (A.5b), and the definition of $\Omega(z, l)$, we can summarize the steady-state in the following form:

$$(\bar{g} + \sigma\phi)\frac{\tilde{y}}{\tilde{z}}z - \delta_G = \frac{\tilde{q} - 1}{h_1} - \delta_K \quad (\text{A.7a})$$

$$\begin{aligned} r(\tilde{n}) + \frac{1}{\tilde{n}} \left[\tilde{c} + \frac{\tilde{q}^2 - 1}{2h_1} + \{(\bar{g} + \sigma\phi) - (1 + \sigma)\}\tilde{y} + \frac{h_2}{2}(\bar{g} + \sigma\phi)^2(1 - \tilde{l})\frac{\tilde{y}^2}{\tilde{z}} \right] \\ = \frac{(\tilde{q} - 1)}{h} - \delta_K \end{aligned} \quad (\text{A.7b})$$

$$r(\tilde{n})\tilde{q} - \frac{(1 - \tau)(1 - \eta)\tilde{y}^{(1 + \rho)}}{\alpha^\rho \tilde{z}^{\epsilon\rho}} - \frac{(\tilde{q} - 1)^2}{2h_1} + \delta_K \tilde{q} = 0 \quad (\text{A.7c})$$

$$\frac{r(\tilde{n}) - \beta}{1 - \gamma} = \frac{(\tilde{q} - 1)}{h_1} - \delta_K \quad (\text{A.7d})$$

$$\tilde{y} = \alpha \tilde{z}^\epsilon [(1 - \eta) + \eta(1 - \tilde{l})^{-\rho}]^{-1/\rho} \quad (\text{A.7e})$$

$$\tilde{c} = \frac{(1 - \tau)}{\theta} \left(\frac{l}{1 - l} \right) \left[\frac{1}{1 + ((1 - \eta)/\eta)(1 - \tilde{l})^\rho} \right] \tilde{y} \quad (\text{A.7f})$$

These six equations can be solved for the steady-state values of \tilde{z} , \tilde{n} , \tilde{l} , \tilde{q} , \tilde{c} , \tilde{y} , and consequently, the equilibrium growth rate, $\tilde{\psi}$.

References

- Acemoglu, D., Robinson, J.A., 2000. Political losers as a barrier to economic development. *American Economic Review* 90, 126–130.
- Arrow, K.J., Kurz, M., 1970. *Public Investment, the Rate of Return, and Optimal Fiscal Policy*. Johns Hopkins University Press, Baltimore.
- Aschauer, D.A., 1989a. Is public expenditure productive? *Journal of Monetary Economics* 23, 177–200.
- Aschauer, D.A., 1989b. Does public capital crowd out private capital? *Journal of Monetary Economics* 24, 171–188.
- Auerbach, A.J., Kotlikoff, L., 1987. *Dynamic Fiscal Policy*. Cambridge University Press, Cambridge UK.

- Bardhan, P.K., 1967. Optimal foreign borrowing. In: Shell, K. (Ed.), *Essays on the Theory of Optimal Economic Growth*. MIT Press, Cambridge MA.
- Barro, R.J., 1990. Government spending in a simple model of endogenous growth. *Journal of Political Economy* 98, S103–S125.
- Barro, R.J., Sala-i-Martin, X., 1992. Public finance in models of economic growth. *Review of Economic Studies* 59, 645–661.
- Barro, R.J., Sala-i-Martin, X., 1995. *Economic Growth*. McGraw-Hill, NY.
- Baxter, M., King, R.G., 1993. Fiscal policy in general equilibrium. *American Economic Review* 83, 315–334.
- Berndt, E.R., 1976. Reconciling alternative estimates of the elasticity of substitution. *Review of Economics and Statistics* 58, 59–68.
- Bhagwati, J.N., 1967. The tying of aid. In: Bhagwati, J.N., Eckaus, R.S. (Eds.), *Foreign Aid*. Penguin, Harmondsworth.
- Burnside, C., Dollar, D., 2000. Aid, policies, and growth. *American Economic Review* 90, 847–868.
- Chatterjee, S., Turnovsky, S.J., 2004. Substitutability of capital, investment costs and foreign aid. In: Dowrick, S., Pitchford, R., Turnovsky, S.J. (Eds.), *Economic Growth and Macroeconomic Dynamics: Recent Developments in Economic Theory*. Cambridge University Press, Cambridge, U.K.
- Chatterjee, S., Sakoulis, G., Turnovsky, S.J., 2003. Unilateral capital transfers, public investment, and economic growth. *European Economic Review* 47, 1077–1103.
- Cooley, T.F. (Ed.), 1995. *Frontiers of Business Cycle Research*. Princeton University Press, Princeton, NJ.
- Devarajan, S., Xie, D., Zou, H.F., 1998. Should public capital be subsidized or provided? *Journal of Monetary Economics* 41, 319–331.
- Duffy, J., Papageorgiou, C., 2000. A cross-country empirical investigation of the aggregate production function specification. *Journal of Economic Growth* 5, 87–120.
- Easterly, W., 2003. Can foreign aid buy growth? *Journal of Economic Perspectives* 17, 23–48.
- Eicher, T.S., Turnovsky, S.J., 2000. Scale, congestion, and growth. *Economica* 67, 325–346.
- Fisher, W.H., Turnovsky, S.J., 1998. Public investment, congestion, and private capital accumulation. *Economic Journal* 108, 339–413.
- Futagami, K., Morita, Y., Shibata, A., 1993. Dynamic analysis of an endogenous growth model with public capital. *Scandinavian Journal of Economics* 95, 607–625.
- Gramlich, E.M., 1994. Infrastructure investment: a review essay. *Journal of Economic Literature* 32, 1176–1196.
- Güvenen, T., in press. Reconciling conflicting evidence on the elasticity of intertemporal substitution: a macroeconomic perspective. *Journal of Monetary Economics*.
- Hansen, H., Tarp, F., 2000. Aid effectiveness disputed. *Journal of International Development* 12, 375–398.
- Lucas, R.E., 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22, 3–42.
- Ortigueira, S., Santos, M.S., 1997. On the speed of convergence in endogenous growth models. *American Economic Review* 87, 383–399.
- Rebelo, S., 1991. Long-run policy analysis and long-run growth. *Journal of Political Economy* 99, 500–521.
- Romer, P.M., 1986. Increasing returns and long run growth. *Journal of Political Economy* 94, 1002–1037.
- Turnovsky, S.J., 2002. Intertemporal and intratemporal substitution and the speed of convergence in the neoclassical growth model. *Journal of Economic Dynamics and Control* 26, 1765–1785.
- Turnovsky, S.J., 2004. The transitional dynamics of fiscal policy: long-run capital accumulation and growth. *Journal of Money, Credit and Banking* 36, 883–910.
- World Bank, 1994. *World Development Report 1994: Infrastructure for Development*. Oxford University Press, New York.
- World Bank, 2004. *World Development Indicators*. CD-ROM, Washington, DC.