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NOTES

A NOTE ON FOREIGN AID, HUMAN CAPITAL, AND WELFARE

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Should foreign aid be tied or untied? We study this question in the context of a dynamic growth model in which agents can accumulate human capital through education. We compare the growth and welfare implications of three polar scenarios in which foreign aid is either (i) completely untied, (ii) tied to public investment in infrastructure, or (iii) tied to public spending on education. Our results indicate that tying aid to education is more beneficial from a long-run welfare perspective than the two alternative scenarios. We also compute the optimal allocation of foreign aid and find that the largest fraction of aid flows ought to be tied to public spending on education. Finally, we study the transitional dynamics of the recipient economy following an aid inflow and find that aid programs that are tied (entirely or partially) to public spending on education generally entail some welfare losses in the short run.

Keywords: Foreign Aid, Growth, Human Capital, Welfare

1. INTRODUCTION

Foreign aid to developing countries has reached its highest level in several decades. Official development assistance (ODA) increased from US$4.8 billion in 1960 to US$140 billion in 2012,[1] representing, on average, around 15% of the gross domestic product of the least developed countries (LDCs). Foreign aid can be completely untied or tied either by source, when the recipient country is obliged to spend the received transfer in the donor country, or by end use, when aid is linked to a specific commodity or a specific investment project in the recipient country. Although a large literature has attempted to evaluate the effectiveness of

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foreign aid, mainly from an empirical standpoint,[2] little theoretical research has been done to address the question of whether aid flows should be tied or untied.

The first attempt to address this question was made by Chatterjee et al. (2003), who developed a dynamic optimizing growth model in which aid flows can take the form of pure transfers or be tied to public investment in physical capital (or infrastructure). They find that tying aid to public capital is more beneficial from a growth and a welfare perspective. Chatterjee and Turnovsky (2004, 2007) extended this framework by allowing for a more general production technology and for endogenous labor supply, and showed that these extensions can alter the relative merits of tied and untied aid. For example, greater substitutability between private and public capital in production and more elastic labor supply tend to mitigate the long-run welfare gain from tied aid, potentially rendering it less preferable to untied aid. Under plausible parameter values, however, tied aid remains generally more advantageous than untied aid. Agénor and Yilmaz (2013) develop an endogenous growth model in which the government provides two categories of public services, infrastructure and health, and aid can be tied to either one of these categories or completely untied. They find that foreign aid will achieve the highest welfare and the fastest growth if it is tied to public spending on health.

Perhaps surprisingly, however, none of these studies account for human capital accumulation, nor for the possibility that foreign aid is tied to public spending on education. Conversely, although there is an extensive literature on the growth implications of human capital in general and education in particular [e.g., Lucas (1988); Glomm and Ravikumar (1992, 1998, 2003); Mankiw et al. (1992); Blankenau and Simpson (2004)], this literature generally abstracts from foreign aid. This neglect might be due to that fact that the fraction of total aid flows intended for education has historically been low, averaging less than 11% between 1971 and 2010. This observation is certainly perplexing given the widespread recognition of the importance of human capital as a growth engine, which is perhaps best exemplified by the international community's commitment in 2000 to provide universal primary education by 2015.[3]

In this paper, we investigate whether and to what extent tying foreign aid (or a fraction of it) to public spending on education improves social welfare in the recipient economy. For this purpose, we develop an optimizing growth model of a small open economy in which foreign aid can be completely untied or tied either to public investment in infrastructure or to public spending on education.[4] In the absence of foreign aid, public investment in infrastructure and spending on education are chosen to maintain a constant ratio of each of these expenditures to GDP.[5] The government runs a balanced budget in every period, so when foreign aid is not tied to public investment or to education, it is redistributed as a transfer to agents. Education increases human capital, which is an input into the production function of the private sector, just as are labor and public capital. The allocation of time between work, education, and leisure is chosen optimally by agents. Human capital accumulation depends on government spending on education and on the stock of public capital. Hence, public spending on education affects welfare both

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directly through its effect on leisure time and indirectly through its effect on the marginal productivity of private inputs.

The model is used to analyze the welfare and growth implications of foreign aid under different allocations schemes, both in the short and in the long run. In addition to analyzing the three polar scenarios in which aid is either completely untied or is tied exclusively to public infrastructure or to education, we compute the optimal allocation of aid flows, i.e., the share that should be allocated to each category of spending to maximize social welfare in the recipient economy. Because of the complexity of the model, the analysis is carried out via numerical simulations.

Our results indicate that under plausible parameter values, tying aid to public spending on education achieves the largest welfare gain compared with the two alternative scenarios in which aid is completely untied or tied exclusively to public investment in infrastructure. Unlike untied aid, which operates mainly through a wealth effect, both forms of tied aid affect the productive capacity of the recipient economy, albeit through different mechanisms. When aid is tied to public investment in infrastructure, it acts primarily as an externality in the production function, raising the marginal productivity of all private inputs. Compared with the initial (zero-aid) equilibrium, the recipient economy grows at a much higher rate in the long run, and agents enjoy more consumption but less leisure. When aid is tied to education, on the other hand, it acts as an externality in the human capital accumulation process, improving the efficiency with which education increases human capital. In the long run, the stock of human capital rises, which in turn increases the marginal productivity of private capital and labor. This increase, however, is not as large as in the case where aid is tied to public infrastructure, which results in a smaller increase in the growth rate. But given that leisure time barely falls compared with the initial equilibrium and that consumption rises most when aid is tied to public spending on education, this form of aid proves to be more beneficial from a welfare standpoint than the two alternative scenarios.

Notwithstanding the latter result, we find that the optimal allocation of foreign aid does not involve tying it exclusively to any of the spending categories. Instead, the welfare-maximizing scenario requires that 60 percent of aid flows be devoted to public spending on education, and the remaining 40 percent to public investment in infrastructure.

We also study the transitional dynamics of the recipient economy following the received aid under each of the three polar scenarios described, as well as under the optimal allocation scheme. We find that the time paths of key macroeconomic variables differ markedly across the different cases. Importantly, our results show that when foreign aid is untied or entirely tied to public investment in infrastructure, it improves welfare both in the short and in the long run. In contrast, when a sufficiently large fraction of aid is tied to public spending on education, an intertemporal trade-off in welfare arises, as the recipient economy enjoys a welfare gain in the long run but incurs a welfare loss in the short run. This suggests that aid programs that are tied to education become beneficial only gradually.

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The rest of the paper is organized as follows. Section 2 presents the model economy. In Section 3, we derive the balanced growth path. Section 4 discusses the effects of a permanent aid shock, both in the long run and along the transitional path toward the new equilibrium. Section 5 concludes.

2. THE ECONOMY

We consider a small open economy populated by an infinitely lived representative agent who produces a single traded good. The good can be used either for consumption or for investment. The agent has a unit of time that can be allocated between labor, education, and leisure. Time spent on education raises the stock of human capital, which is a productive input, just as are labor and physical capital. The government undertakes two types of discretionary expenditures, namely, investment in public capital and spending on education, which are financed by income taxation and foreign aid flows.

2.1. Private Sector

The infinitely lived agent maximizes a lifetime utility function given by

$$U_0 = \int_0^\infty e^{-\rho t} \mathcal{U}(C, L, E)\, dt, \tag{1}$$

where C is consumption, L and E are the fractions of time devoted to work and education, respectively, and $\rho \in (0, 1)$ is the subjective discount rate. The instantaneous utility function, $\mathcal{U}(.)$, is assumed to satisfy the Inada conditions. Time spent on education increases the agents stock of human capital, which evolves according to

$$\dot{H} = \mathcal{H}\left(I_e, K_g, H, E\right) - \delta_h H, \tag{2}$$

where K_g is the stock of public capital, I_e is public spending on education, and $\delta_h \in (0, 1)$ is the depreciation rate of human capital. The human capital production technology, $\mathcal{H}(.)$ is increasing in all its arguments, is concave in time devoted to education, and exhibits constant returns to scale with respect to I_e, K_g and H.[6]

Output, Y, is produced using labor, L, human capital, H, private physical capital, K, and public capital, K_g:

$$Y = \mathcal{F}\left(L, H, K_g, K\right), \tag{3}$$

where the production function, $\mathcal{F}(.)$ is increasing in all its arguments and exhibits constant returns to scale in both the private factors, L and K, and the reproducible factors, H, K_g, and K. With the rate of depreciation denoted by $\delta_k \in (0, 1)$ the law of motion of private capital is

$$\dot{K} = I - \delta_k K. \tag{4}$$

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Capital accumulation is subject to adjustment costs given by

$$\mathcal{C}(I, K),$$

where $\mathcal{C}(.)$ is increasing and convex in I and decreasing in K.

The representative agent pays lump-sum taxes and income taxes to the government. It has access to a world capital market and its cost of borrowing includes a premium that increases with the economy's debt–capital ratio. Therefore, the agent's budget constraint is given by

$$\dot{D} = C + i(D/K)D + I + \mathcal{C}(I, K) + T - (1-\tau)\mathcal{F}\left(L, H, K_g, K\right), \quad \textbf{(5)}$$

where $\tau \in (0, 1)$ is the income-tax rate and T is lump-sum taxes (or transfers).

When solving the optimization problem, the agent takes public policies and the borrowing rate, $i(D/K)$, as given. The agent has no influence on the interest rate because this depends on the country's aggregate debt–capital ratio. With κ, ν, and ζ denoting the Lagrange multipliers associated with the constraints (2), (4), and (5), respectively, the optimality conditions with respect to the agent's choice of C, L, E, I, D, K, and H are, respectively,

$$\mathcal{U}_C = \zeta, \quad \textbf{(6)}$$

$$\mathcal{U}_L = -\zeta(1-\tau)\mathcal{F}_L, \quad \textbf{(7)}$$

$$\mathcal{U}_E = m\mathcal{H}_E, \quad \textbf{(8)}$$

$$1 + \mathcal{C}_I = q, \quad \textbf{(9)}$$

$$\rho - \frac{\dot{\zeta}}{\zeta} = i, \quad \textbf{(10)}$$

$$\frac{1}{q}\left[\mathcal{C}_K + (1-\tau)\mathcal{F}_K\right] - \delta_k + \frac{\dot{q}}{q} = i, \quad \textbf{(11)}$$

$$\frac{1}{m}\left[(1-\tau)\mathcal{F}_H\right] + \left[\mathcal{H}_H - \delta_h\right] + \frac{\dot{m}}{m} = i. \quad \textbf{(12)}$$

The budget constraint (5) and the following transversality conditions must hold:

$$\lim_{t\to\infty} \zeta D e^{-\rho t} = 0; \quad \lim_{t\to\infty} \nu K e^{-\rho t} = 0; \quad \lim_{t\to\infty} \kappa H e^{-\rho t} = 0. \quad \textbf{(13)}$$

In these equations, $\mathcal{U}_C, \mathcal{U}_L$, and $\mathcal{U}_E$ are the derivatives of $\mathcal{U}$ with respect to C, L, and E; $\mathcal{F}_L, \mathcal{F}_K$, and $\mathcal{F}_H$ are the derivatives of the production function with respect to L, K, and H; $\mathcal{H}_E$ and $\mathcal{H}_H$ are the derivatives of $\mathcal{H}$ with respect to E and H; $\mathcal{C}_I$ and $\mathcal{C}_K$ are the derivatives of $\mathcal{C}$ with respect to I and K; and $m \equiv \frac{\kappa}{\zeta}$ is the market price of human capital and $q \equiv \frac{\nu}{\zeta}$ is the market price of private capital.

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2.2. Government

Government spending in the recipient economy consists of two categories: investment in public capital (infrastructure), I_g, and spending on education, I_e. The government receives a flow of foreign aid, $\mathcal{A}$, which can be a pure transfer (untied) or tied either to public investment in infrastructure or to public spending on education,

$$I_g = \beta_g Y + \phi_g \mathcal{A} \tag{14}$$

and

$$I_e = \beta_e Y + \phi_e \mathcal{A}, \tag{15}$$

where β_g and β_e are the domestic cofinancing parameters, which satisfy $0 \leq \beta_g, \beta_e \leq 1$, and ϕ_g and ϕ_e are the fractions of aid tied to, respectively, public investment in infrastructure and public spending on education. The remaining fraction, $1 - \phi_g - \phi_e$, represents untied aid. As in Chatterjee and Turnovsky (2007), the flow of aid transfers, $\mathcal{A}$, is tied to the scale of the recipient economy:

$$\mathcal{A} = \mu Y, \tag{16}$$

where μ is a positive parameter.

If $\delta_g \in (0, 1)$ is the depreciation rate, the stock of public capital evolves over time according to

$$\dot{K}_g = I_g - \delta_g K_g. \tag{17}$$

We assume that the gross investment in public capital is subject to adjustment costs

$$\mathcal{G}(I_g, K_g),$$

where $\mathcal{G}(.)$ has the same properties as $\mathcal{C}(.)$.

The government collects lump-sum taxes, T, and income tax revenues, τY, and receives foreign transfers, $\mathcal{A}$, to finance its expenditures and the adjustment costs related to public capital accumulation, in such a way that it runs a balanced budget in every period.[7] Thus, its budget constraint is given by

$$T + \tau Y + \mathcal{A} = I_g + \mathcal{G}_g\left(I_g, K_g\right) + I_e. \tag{18}$$

Combining equations (5) and (18), the national budget constraint (balance of payment equation) can be written as

$$\dot{D} = C + iD + I + \mathcal{C} + I_g + \mathcal{G} + I_e - \mathcal{F}\left(L, H, K_g, K\right) - \mathcal{A}. \tag{19}$$

2.3. Functional Forms

Before describing the macroeconomic equilibrium, we need to specify the functional forms of $\mathcal{U}(.)$, $\mathcal{H}(.)$, $\mathcal{F}(.)$, $\mathcal{C}(.)$, $\mathcal{G}(.)$, and $i(.)$.

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We assume that preferences are described by the following isoelastic utility function:[8]

$$\mathcal{U}(C, L, E) = \frac{1}{\gamma}(C(1 - L - E)^{\theta})^{\gamma}, \tag{20}$$

where the parameter $\gamma < 0$ determines the intertemporal elasticity of substitution (which is given by $\frac{1}{1-\gamma}$), and $\theta > 0$ reflects the weight assigned to leisure in the utility function. The human capital formation function is assumed to be

$$\mathcal{H}\left(I_e, K_g, H, E\right) = I_e^{\omega_1} K_g^{\omega_2} H^{1-\omega_1-\omega_2} E^{\eta}, \tag{21}$$

where $\omega_1, \omega_2 \in (0, 1)$ and η is a positive parameter.

The production function is assumed to be Cobb–Douglas and is given by

$$\mathcal{F}\left(L, H, K_g, K\right) = Z H^{\alpha_1} {K_g}^{\alpha_2} L^{\alpha_1+\alpha_2} K^{1-\alpha_1-\alpha_2}, \tag{22}$$

where $\alpha_1, \alpha_2 \in (0, 1)$ and Z represents technological progress.[9]

The capital-adjustment-cost functions for private and public capital are given by, respectively,

$$\mathcal{C}(I, K) = \pi_1 \frac{I^2}{2K} \text{ and } \mathcal{G}\left(I_g, K_g\right) = \pi_2 \frac{I_g^2}{2K_g},$$

where π_1 and π_2 are positive parameters.

Finally, as in Chatterjee and Turnovsky (2005, 2007), the borrowing rate, i, grows with the ratio of foreign debt to capital according to

$$i(D/K) = i^* + \exp\left(a\frac{D}{K}\right) - 1,$$

where i^* is the exogenous risk-free world interest rate and a is a positive parameter.

3. BALANCED GROWTH PATH

On a balanced growth path, C, K, K_g, H, Y, and D grow at the same constant rate, which we denote by Γ, whereas q, m, L, and E remain constant. That is,

$$\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{K}_g}{K_g} = \frac{\dot{H}}{H} = \frac{\dot{Y}}{Y} = \frac{\dot{D}}{D} = \Gamma$$

and

$$\dot{q} = \dot{m} = \dot{L} = \dot{E} = 0.$$

The balanced growth path will be defined using the functional forms described in the preceding. From (9), we can express the growth rate of private capital as a function of q:

$$\frac{\dot{K}}{K} \equiv \Gamma_k = \frac{q-1}{\pi_1} - \delta_k. \tag{23}$$

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Taking logs and differentiating condition (6) with respect to time yields

$$(\gamma - 1)\frac{\dot{C}}{C} - \theta\gamma\frac{\dot{L} + \dot{E}}{1 - L - E} = \frac{\dot{\zeta}}{\zeta},$$

which, using (10), gives an expression for the growth rate of consumption,

$$\frac{\dot{C}}{C} \equiv \Gamma_c = \frac{1}{1-\gamma}\left[i - \rho - \theta\gamma\frac{\dot{L} + \dot{E}}{1 - L - E}\right]. \tag{24}$$

Substituting (14) and (16) into (17), we obtain the growth rate of public capital,

$$\frac{\dot{K}_g}{K_g} \equiv \Gamma_g = \left(\beta_g + \phi_g\mu\right)\frac{Y}{K_g} - \delta_g. \tag{25}$$

Using (15) and (16), the growth rate of human capital is given by

$$\frac{\dot{H}}{H} \equiv \Gamma_h = \left(\left(\beta_e + \phi_e\mu\right)\frac{Y}{H}\right)^{\omega_1}\left(\frac{K_g}{H}\right)^{\omega_2}E^{\eta} - \delta_h. \tag{26}$$

Finally, equation (19) yields

$$\frac{\dot{D}}{D} = \frac{C}{D} + i + \frac{I}{D}\left(1 + \frac{\pi_1}{2}\frac{I}{K}\right) + \frac{I_g}{D}\left(1 + \frac{\pi_2}{2}\frac{I_g}{K_g}\right) + \frac{I_e}{D} - \frac{Y}{D} - \frac{\mathcal{A}}{D}. \tag{27}$$

Let $k_g \equiv \frac{K_g}{K}$ denote the ratio of public to private capital stock, $h \equiv \frac{H}{K}$ denote the ratio of human to private capital stock, and $d \equiv \frac{D}{K}$ denote the ratio of national debt to private capital stock. Then we have

$$\frac{\dot{k}_g}{k_g} = \frac{\dot{K}_g}{K_g} - \frac{\dot{K}}{K},$$

$$\frac{\dot{h}}{h} = \frac{\dot{H}}{H} - \frac{\dot{K}}{K},$$

$$\frac{\dot{d}}{d} = \frac{\dot{D}}{D} - \frac{\dot{K}}{K}.$$

The dynamic behavior of the economy can be described by a system of six differential equations in k_g, h, d, q, L, and E. This dynamic system contains three state variables (k_g, h, and d) and three jump variables (q, L, and E). The stationary solution of this system is found by setting $\dot{k}_g = \dot{h} = \dot{d} = \dot{q} = \dot{L} = \dot{E} = 0$. The remaining variables, including the long-run growth rate, are known once k_g, h, d, q, L, and E are determined.[10]

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4. MACROECONOMIC EFFECTS OF FOREIGN AID

In this section, we study the macroeconomic effects of a permanent increase in the ratio of foreign aid to GDP, μ. We evaluate these effects at the new long-run equilibrium and along the transitional path toward that equilibrium. Given that the complexity of our model precludes analytical solutions, we resort to numerical methods to derive the equilibrium. To this end, numerical values must be assigned to the model parameters. In the following subsection, we discuss the calibration of the model and the implied initial steady state.

4.1. Calibration and Initial Steady State

We calibrate the model at an annual frequency and choose the parameter values so that the model represents a low-income developing economy. The benchmark economy is assumed to start out in an initial zero-aid steady state (that is, $\mu = 0$). Some of the model parameters are quite common in the literature and little uncertainty exists about their values. Other parameters, however, are less straightforward to calibrate, either because the empirical literature does not provide tight direct estimates or because there are likely significant disparities between the different countries regarding certain aspects of the data. For those parameters, we conduct an extensive sensitivity analysis, which we discuss in Section 5.

Our benchmark calibration is summarized in Table 1. Starting with the preference parameters, we set the rate of time preference, ρ, to 0.04, and the parameters γ and θ to -1.5 and 1.8, respectively. The first two parameters are quite standard, but we check the sensitivity of our results to alternative values of θ. There is very little information in the empirical literature regarding the parameters of the human capital accumulation process, so we draw on earlier studies in our benchmark calibration and consider alternative values in the sensitivity analysis. More specifically, we set the elasticity of human capital formation with respect to public spending on education, ω_1, to 0.15, that with respect to public capital, ω_2, to 0.05, and that with respect to education, η, to 1.[11] The steady-state level of technology, Z, is a scaling factor and is set to 0.6. The elasticity of output with respect to skilled labor, α_1, is chosen to be 0.4, as is commonly assumed in the literature. The elasticity of output with respect to public capital, α_2, is less common but the empirical literature provides estimates for this parameter that range from 0.11 to 0.26.[12] We set $\alpha_2 = 0.2$ and consider lower and higher values in our sensitivity analysis. We assume that human capital depreciates at a slower pace than physical capital, and accordingly set δ_h to 0.01, and both δ_k and δ_g to 0.05.[13] The domestic government cofinancing parameters, β_g and β_e, are both set to 0.05, consistent with empirical evidence.[14] The income tax rate, τ, is set to 0.15, but this value is likely to differ substantially across countries. We therefore allow for alternative values in our sensitivity analysis. The exogenous risk-free interest rate, i^*, is set to equal 5% whereas the borrowing-premium parameter, a, is chosen to ensure a plausible debt–output ratio. Finally, we set the adjustment cost parameters, π_1 and π_2, to 10.

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TABLE 1. Benchmark calibration

Description	Parameter	Value
Preferences		
Discount factor	ρ	0.04
Preference parameter	γ	−1.5
Preference parameter	θ	1.8
Human capital accumulation		
Elasticity w.r.t. public spending on education	ω_1	0.15
Elasticity w.r.t. public capital	ω_2	0.05
Elasticity w.r.t. education	η	1
Production		
Elasticity w.r.t effective labor	α_1	0.4
Elasticity w.r.t. raw labor and public capital	α_2	0.2
Steady-state level of technology	Z	0.6
Depreciation rates		
Private capital	δ_k	0.05
Public capital	δ_g	0.05
Human capital	δ_h	0.01
Foreign aid		
Aid-output ratio	μ	0
Fraction of aid tied to investments in infrastructure	φ_g	0
Fraction of aid tied to public spending on education	φ_e	0
Policy parameters		
Income tax rate	τ	0.15
Cofinancing parameter (investment in infrastructure)	β_g	0.05
Cofinancing parameter (spending on education)	β_e	0.05
Others		
Adjustment-cost parameter (private capital)	π_1	10
Adjustment-costs parameter (public capital)	π_2	10
Risk-free world interest rate	i^*	0.05
Borrowing-premium parameter	a	0.15

The second column of Table 2 presents the resulting initial equilibrium of the economy. The steady-state ratio of public to private capital is 0.42 and the fraction of time devoted to labor is 0.27, whereas that devoted to learning is 0.06. Thus, leisure represents roughly 2/3 of the time available to agents. The consumption–output ratio is 0.71, the capital–output ratio is 1.87, and the ratio of human to private capital is 8.35. The debt–output ratio is 0.29 and yields an interest rate of 7.34%, implying that the equilibrium premium on borrowing is equal to 2.34%. The long-run growth rate for the benchmark economy is 1.34%.

4.2. Long-Run Steady-State Effects

The benchmark economy is now allowed to receive a permanent flow of foreign aid that is equivalent to 5% of its steady-state GDP (that is, μ rises from 0 to

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TABLE 2. Long-run effects of an increase in foreign aid

		New equilibrium ($\mu = 0.05$)			
	Initial equilibrium ($\mu = 0$)	Untied $\varphi_g = 0$ $\varphi_e = 0$	Tied to infrastruc. $\varphi_g = 1$ $\varphi_e = 0$	Tied to educ. $\varphi_g = 0$ $\varphi_e = 1$	Optimal allocation $\hat{\varphi}_g = 0.4$ $\hat{\varphi}_e = 0.6$
L	0.2668	0.2548	0.2712	0.2668	0.2686
E	0.0642	0.0595	0.0691	0.0674	0.0685
H/K	8.3474	8.0564	7.2009	10.0463	8.8034
K_g/K	0.4213	0.4139	0.8747	0.4346	0.6131
C/Y	0.7105	0.7624	0.6893	0.7069	0.6992
K/Y	1.8734	1.9600	1.7005	1.7285	1.6944
D/Y	0.2887	0.2469	0.3689	0.3562	0.3716
$i(\%)$	7.3388	6.9074	8.3076	8.1397	8.3447
$\Gamma(\%)$	1.3355	1.1629	1.7231	1.6559	1.7379
$\Delta W(\%)$	—	4.0869	10.8523	12.5214	14.0616

0.05). In what follows, we compare the growth and welfare consequences of this inflow under three polar scenarios about its allocation. In the first scenario, the received aid is left completely untied (that is, $\phi_g = \phi_e = 0$), so that the government continues to allocate fractions β_g and β_e of GDP to investment in infrastructure and to spending on education, respectively. In the second scenario, aid is completely tied to public investment in physical capital (that is, $\phi_g = 1$, $\phi_e = 0$), whereas in the third scenario, aid is entirely devoted to public spending on education (that is, $\phi_g = 0$, $\phi_e = 1$). We also compute the optimal allocation of foreign aid, i.e., the fractions $\hat{\phi}_g$ and $\hat{\phi}_e$ that achieve the largest long-run welfare gain. In all of these calculations, the welfare gain is measured as the equivalent percentage variation in the private stock of capital, that is, the percentage change in the initial stock of capital that would leave agents as well off as in the new equilibrium. As we show in the Appendix, this quantity is given by

$$\varphi = \left(\frac{c_f l_f^{\theta}}{c_b l_b^{\theta}}\right)\left(\frac{\rho - \gamma\Gamma_b}{\rho - \gamma\Gamma_f}\right)^{\frac{1}{\gamma}} - 1,$$

where variables with subscripts b and f pertain to the benchmark (initial) and after-shock equilibrium, respectively. For given benchmark values, c_b, l_b^{θ}, and Γ_b, φ is increasing in the ratio of consumption to the private stock of capital, in leisure, and in the long-run growth rate.

Untied aid. The effects of a permanent untied aid shock are presented in the third column of Table 2. When aid is untied, it amounts to a pure transfer payment that the government of the recipient economy redirects to agents. This transfer gives rise a positive wealth effect that induces agents to increase their

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consumption and to enjoy more leisure as they devote less time to work and to education. Moreover, agents reduce their foreign borrowing, which leads to a fall in the aggregate debt–output ratio, and thus the nominal interest rate, in the new steady state. As a result of the fall in nonleisure activities, the marginal productivity of private capital and the ratios k_g and h all decline, whereas the ratio of private capital to output rises in the new equilibrium. In turn, the fall in the reproducible factors, k_g and h, causes the economy to grow at a lower rate of 1.16%. Nonetheless, the increases in the consumption–capital ratio and in leisure time generate a welfare gain of 4.1% relative to the initial equilibrium.

Aid tied to public investment in infrastructure. The fourth column of Table 2 presents the long-run effects of an increase in aid tied to public investment in infrastructure. As expected, the ratio of public to private capital increases substantially, more than doubling in the new equilibrium. The received aid increases the marginal productivity of all private inputs and, to a lesser extent, the return to education, i.e., the efficiency with which education is converted into human capital. In the long run, these effects lead agents to substitute away from leisure and to devote more time to work and to education. Because foreign aid affects the productive capacity of the recipient economy, it has a larger impact on output than on consumption, implying a fall in the consumption–output ratio. Nonetheless, the ratio of consumption to the private stock of capital, c, increases to 0.4. On the other hand, the ratio of foreign debt to output rises, as the economy increases its external borrowing to finance its investment needs. The growth rate increases to 1.72% in the new equilibrium and the welfare gain is 2.5 times larger than in the untied-aid case. Therefore, the recipient economy is better off in the long run when all aid is tied to public investment in capital than when it is left completely untied. This result corroborates the conclusion reached by Chatterjee and Turnovsky (2007) under their baseline calibration.

Aid tied to public spending on education. We now turn to the analysis of the long-run effects of a permanent increase in aid tied to public spending on education, which are shown in the fifth column of Table 2. In this case, foreign aid acts primarily as an externality to the human capital accumulation process, which increases the efficiency with which education increases human capital. As the stock of human capital rises, it raises the marginal productivity of private capital and labor and causes the capital–output ratio to decline. Although the increase in public spending on education induces agents to devote more time to it, the effect on labor supply is ambiguous. On one hand, agents would like to work more because the marginal productivity of labor has increased, but on the other hand, agents' desire to devote more time to education and the positive income effect stemming from the increase in the marginal product of labor tend to reduce labor supply. It turns out that, given our calibration, these three motives offset each other exactly, leaving hours worked unchanged in the long run. As is the case when aid is tied to public investment in infrastructure, the shock has a larger effect

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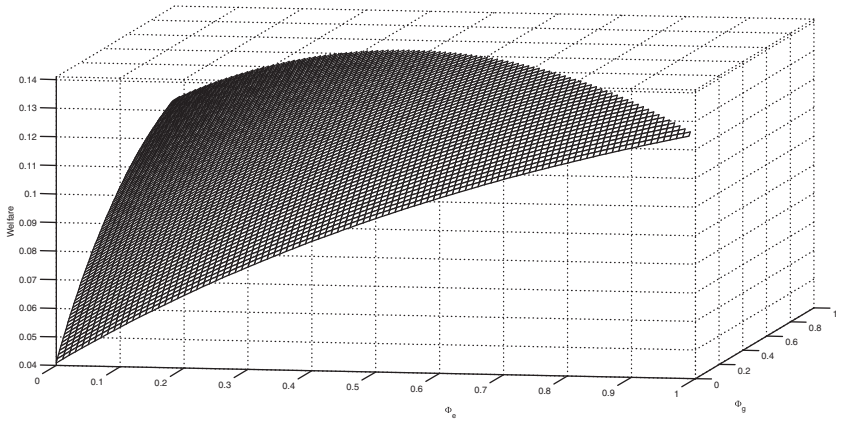


FIGURE 1. Long-run welfare as a function of ϕ_g and ϕ_e.

on output than on consumption, leading to a fall in the consumption–output ratio, but the ratio of consumption to the private stock of capital rises to 0.41. Tying aid to education allows the recipient economy to grow at a higher rate (relative to the initial equilibrium) of 1.66% and to achieve a larger welfare gain than in the two preceding scenarios.

It is worth emphasizing that the preceding theoretical predictions are consistent with available empirical evidence on the effects of foreign aid to education. For example, Michaelowa (2004), Michaelowa and Weber (2007), and Dreher et al. (2008) find a positive and significant relationship between aid to education and primary school enrollment rates. Moreover, Asiedu and Nandwa (2007) document that aid targeted at education fosters economic growth in low- and middle-income countries.

Optimal allocation of aid. So far, we have considered three "polar" cases in which aid is either untied, tied to public investment in infrastructure, or tied to spending on education. But although the last scenario was found to yield the largest welfare gain among the three alternative scenarios, this need not imply that it necessarily dominates any convex combination of the three polar allocation schemes. Put differently, it may well be the case that a larger welfare gain can be achieved by leaving a fraction of the aid flows untied and splitting the remaining fraction between investment in public capital and spending on education. To verify whether this is indeed the case, we compute the long-run welfare gain for all admissible values of ϕ_g and ϕ_e. The results are depicted in Figure 1. The figure shows that it is never optimal, from a long-run perspective, to leave a fraction of foreign aid completely untied and that, consequently, all aid should be tied. Furthermore, the figure shows that dividing foreign aid between investment in infrastructure and public spending on education can yield a larger welfare gain

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TABLE 3. Parameter values used in the sensitivity analysis

Parameter	Benchmark value	Alternative values
θ	1.8	0;3
ω_1	0.15	0.1;0.2
ω_2	0.05	0;0.15
η	1	0.7;0.85
α_2	0.2	0.1;0.3
τ	0.15	0.1;0.3

than tying aid to either one of these spending categories. Welfare is maximized when $\hat{\phi}_e = 0.6$ and $\hat{\phi}_g = 0.4$. The last column of Table 2 shows that under this scenario, the new steady-state values of most of the key variables lie in between the values implied by the two polar cases in which aid is either tied to public capital or to education. One notable exception is the marginal productivity of private capital, which increases most when aid is optimally allocated. As a result, the recipient economy achieves the highest growth rate, in addition to enjoying the largest welfare gain in the new equilibrium.

4.3. Sensitivity Analysis

This section studies the sensitivity of the results discussed previously to changes in the values of the model parameters. We focus on the weight of leisure in utility, θ, the parameters governing the human capital accumulation process, ω_1, ω_2, and η, the elasticity of output with respect to public capital, α_2, and the income tax rate, τ. Table 3 reports the alternative values used in the sensitivity analysis.

To conserve space, we only briefly summarize the main findings, and we refer the reader to the working paper of this article for more detailed results and discussions. We find that the optimal fraction of aid that should be tied to public spending on education, $\hat{\phi}_e$, is increasing in ω_1 and decreasing in θ, ω_2, η, α_2, and τ. Quantitatively, however, $\hat{\phi}_e$ displays little sensitivity with respect to most of the parameters. For instance, increasing θ from 1.8 to 3 lowers $\hat{\phi}_e$ only by 2 percentage points. In sum, our sensitivity analysis indicates that the conclusion that a substantial fraction of foreign aid ought to be allocated to education is robust.

4.4. Transitional Dynamics

The preceding analysis has focused on the long-run implications of foreign aid under different assumptions about its allocation. Although foreign aid is found to improve long-run welfare in all scenarios, this may not be the case in the short run, i.e., along the transitional path toward the new equilibrium. More importantly, a

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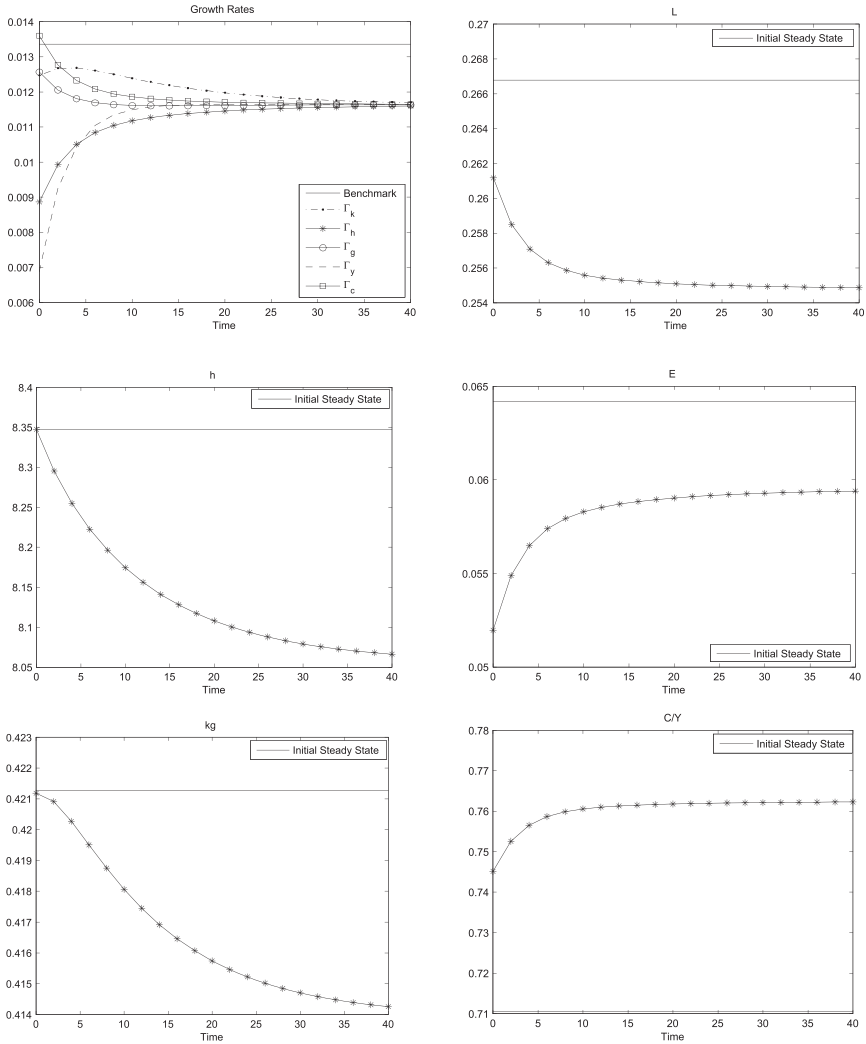


FIGURE 2. Transitional dynamics: Untied aid.

form of aid that is more beneficial than another form from a long-run perspective may prove to entail a larger welfare cost in the short run. To investigate this issue, this section studies the dynamic adjustment of the economy during its transition from the initial to the new equilibrium under the different scenarios about aid allocation described in the preceding. Figures 2–5 show these transitional paths, whereas Table 4 reports the instantaneous response of key variables following the aid shock.[15]

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TABLE 4. Short-run effects of an increase in foreign aid

		New equilibrium ($\mu = 0.05$)			
	Initial equilibrium ($\mu = 0$)	Untied $\varphi_g = 0$ $\varphi_e = 0$	Tied to infrastruc. $\varphi_g = 1$ $\varphi_e = 0$	Tied to educ. $\varphi_g = 0$ $\varphi_e = 1$	Optimal allocation $\hat{\varphi}_g = 0.4$ $\hat{\varphi}_e = 0.6$
$\Gamma_k(0)\%$	1.3355	1.2472	1.4012	0.9074	1.0285
$\Gamma_h(0)\%$	1.3355	0.8868	0.8139	2.5405	1.9189
$\Gamma_g(0)\%$	1.3355	1.2563	7.8181	1.1296	3.3564
$\Gamma_y(0)\%$	1.3355	0.6883	3.3818	2.2543	2.6067
$\Gamma_c(0)\%$	1.3355	1.3599	1.5913	1.2507	1.3303
$L(0)$	0.2668	0.2612	0.2720	0.2525	0.2581
$E(0)$	0.0642	0.0519	0.0498	0.0881	0.0750
$h(0)$	8.3474	8.3474	8.3474	8.3474	8.7836
$k_g(0)$	0.4213	0.4213	0.4213	0.4213	0.4337
$\frac{c(0)}{y(0)}$	0.7105	0.7452	0.7065	0.7399	0.7320
$\Delta W(0)\%$	—	6.9542	4.2211	−8.9865	−4.6918

Untied aid. The dynamic adjustment of the economy following an untied aid shock is depicted in Figure 2. The welfare effect generated by the transfer causes consumption to temporarily grow at a faster rate. The transfer also increases leisure, as agents devote less time to work and to education. This in turn reduces the marginal productivity of private, public, and human capital, causing their growth rates to fall to 1.25%, 1.26%, and 0.89%, respectively, in the period following the shock. As a result, the growth rate of output initially declines to 0.69%, so that the consumption–output ratio rises.

Figure 2 also shows that although labor supply and time devoted to education both fall initially, their transitional paths differ sharply. Indeed, whereas labor continues to fall until it reaches its new steady-state level, time devoted to education rises in the subsequent periods, converging to its new steady-state level from below. It is worth noting that under this scenario, foreign aid improves social welfare both in the short run (along the transitional path) and in the long run, so there is no intertemporal trade-off along this dimension.

Aid tied to public investment in infrastructure. The transitional dynamics in the case where aid is tied to public investment in infrastructure is displayed in Figure 3. The received aid immediately raises the growth rate of public capital to 7.82%. In the subsequent period, the ratio of public to private capital starts to increase gradually toward its new steady-state level, thereby raising future marginal products of capital and hence the shadow price of private capital. As a result, the growth rate of private capital initially increases to 1.4%. Labor responds in a hump-shaped manner, continuing to rise for a few periods after the initial jump,

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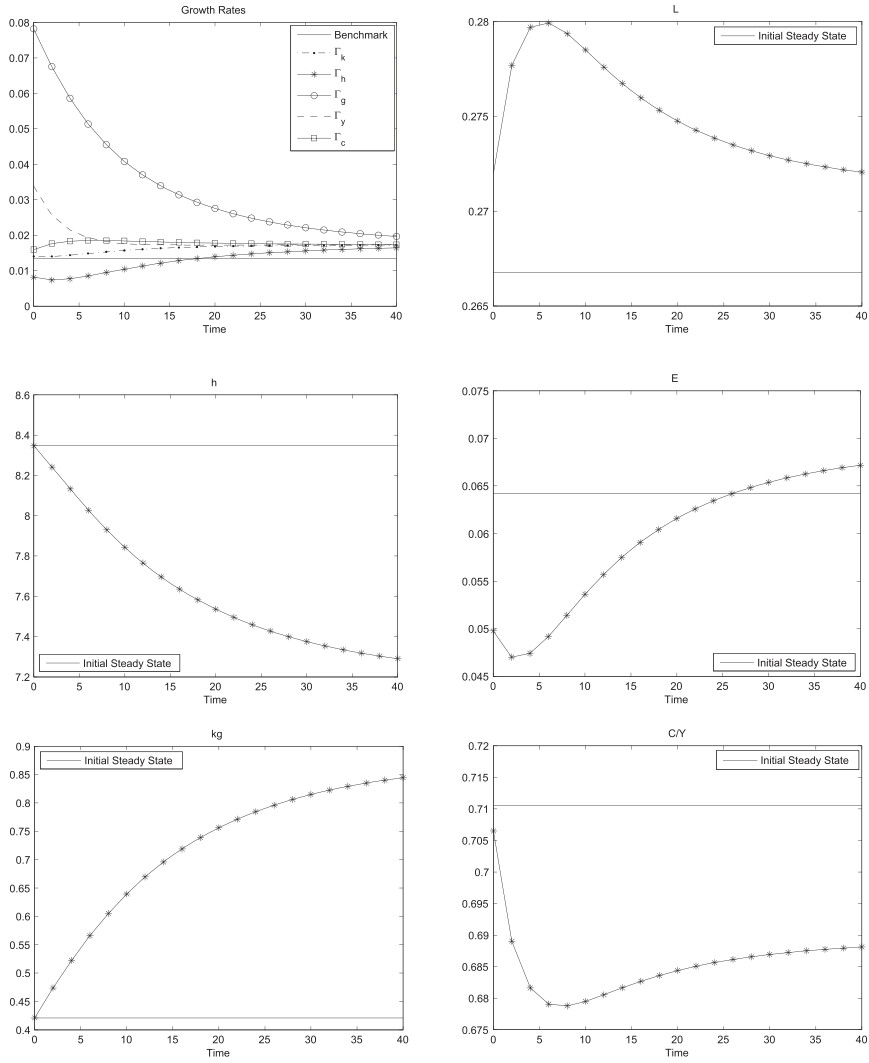


FIGURE 3. Transitional dynamics: Aid tied to public investment in infrastructure.

before converging to its new steady-state level from above. An opposite path is displayed by time devoted to education, which falls initially, continues to decline for a few periods, and converges to its new long-run level from below. Given the large increase in the growth rate of public capital and the resulting increase in the growth rate of productive inputs, the growth rate of output increases substantially after the shock (3.38%) and exceeds that of consumption, causing the ratio of consumption to output to fall. These dynamic paths diverge markedly from those

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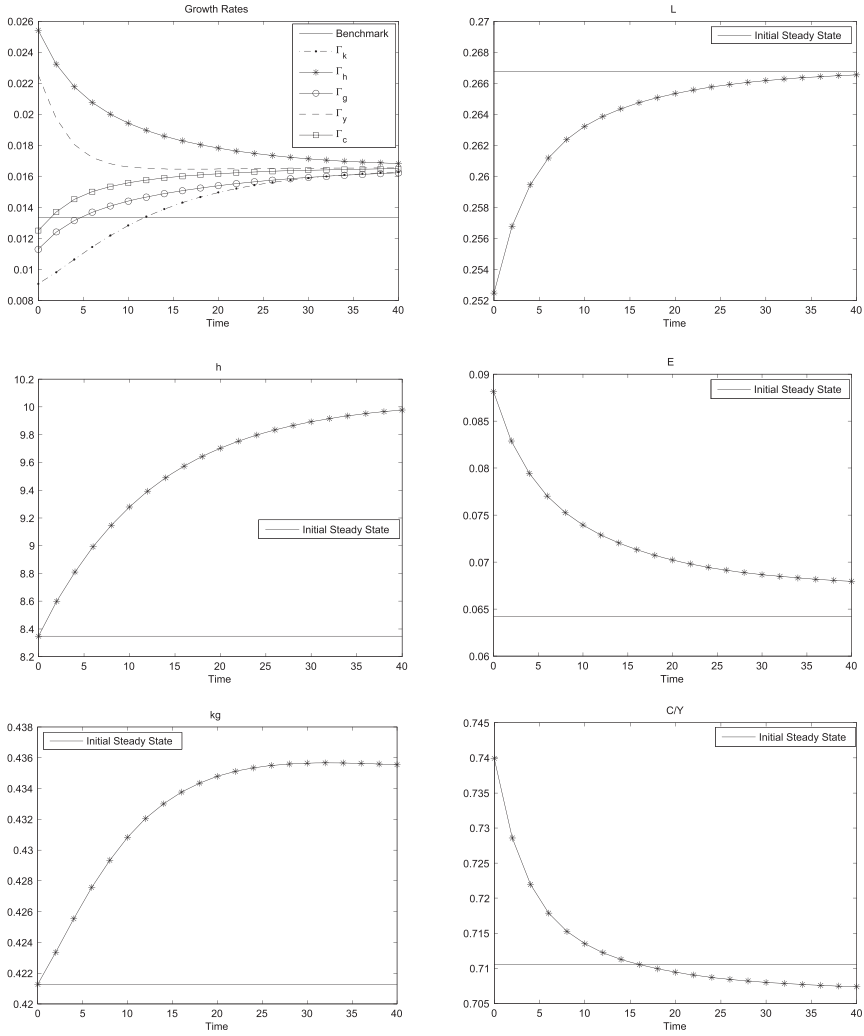


FIGURE 4. Transitional dynamics: Aid tied to public spending on education.

implied by the untied aid scenario. However, as in the untied-aid case, welfare increases both in the short and in the long run.

Aid tied to public spending on education. Figure 4 shows the transitional paths following a foreign aid shock tied to public spending on education. The transfer raises the growth rate of human capital immediately after the shock and in the subsequent periods. As a result, the ratio of human to physical capital, h, increases monotonically over time until it reaches its new steady-state level. Because the

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transfer raises the return to education, agents work less and devote more time to education. The fall in labor reduces the marginal productivity of private capital, whose growth rate initially declines to 0.91%. Nonetheless, owing to the large increase in the growth rate of human capital, the growth rate of output increases to 2.25%. Although the shock initially lowers the growth rate of consumption, it has a larger effect on the level of consumption than on that of output. As a result, the consumption–output ratio jumps immediately to 0.74 before declining gradually toward its new steady-state level.

Two important observations about the transitional dynamics of the economy in the case of a transfer tied to spending on education are worth emphasizing. First, the short-run effects of this transfer are opposite to those generated by a foreign transfer that is tied to public investment. Second, although aid tied to education unambiguously raises long-run welfare in the recipient economy, the transition toward the new equilibrium involves a sizable welfare loss, which amounts to a 9% fall in the initial stock of capital in the period following the shock (see the last row of Table 4). Our simulations indicate that, in the case of a transfer tied to public spending on education, the recipient economy will suffer a welfare loss for eight consecutive years after receiving the aid, before starting to achieve welfare gains.

Optimal allocation of aid. As stated, the largest welfare gain in the long run is achieved when 60% of aid is tied to education and the balance is devoted to public investment in physical capital. The transitional paths under this scenario, shown in Figure 5, are generally similar to those obtained in the case where aid is completely tied to public spending on education. The only notable exceptions concern the response of public capital, whose growth rate rises substantially in the former case, whereas it decreases in the latter, and the response of labor, which exceeds its initial level in the former case but remains permanently below it in the latter. Importantly, we find that although this scenario for aid allocation achieves the highest long-run welfare, its instantaneous effect is welfare-deteriorating, as is the case when aid is tied exclusively to public spending on education. When aid is optimally allocated, however, the recipient economy incurs welfare losses only during the first five years after the shock.

5. CONCLUSION

This paper has studied the optimal allocation of foreign aid in a dynamic growth model with human capital accumulation. Under a plausible parameterization of the model, we find that from a long-run welfare perspective, tying a large fraction of aid to public spending on education achieves a better economic outcome for the recipient economy than a scenario in which aid is mostly untied or mostly tied to public investment in infrastructure. This paper's results, therefore, have crucial policy implications regarding the conditionality of official development assistance to low-income countries.

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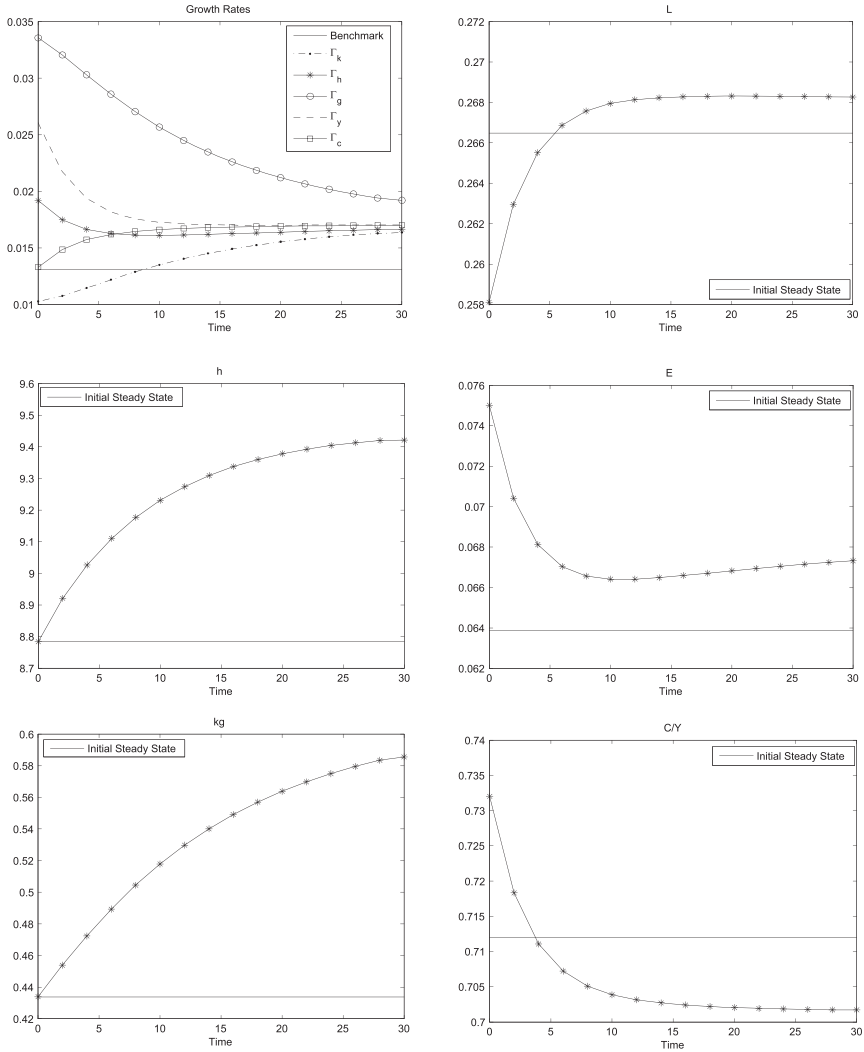


FIGURE 5. Transitional dynamics: Optimal allocation of foreign aid.

These results, however, have been derived in the context of a representative-agent setting, which implies that all agents in the recipient economy are identically impacted by the received aid. Because this is unlikely to be the case in reality, it would be interesting to reexamine the question of the optimal allocation of aid in a model in which the government weighs the different classes of agents differently (for example, privileging the poor). An equally important question is the effect of foreign aid on wealth and income distribution in the recipient economy. Addressing these questions would require extending the theoretical

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model developed in this paper to allow for heterogeneity across agents. We leave this task for future research.

NOTES

1. These numbers are extracted from OECD Stat (2012) and represent the gross disbursements of the Development Assistance Committee (DAC) countries.

2. Examples of empirical studies include those by Levy (1988), Burnside and Dollar (2000), Hansen and Tarp (2000, 2001), Collier and Dollar (2001, 2002), and Dalgaard et al. (2004).

3. See the Millennium Development Goals at http://www.un.org/millenniumgoals/.

4. Thus, as in Chatterjee et al. (2003) and Chatterjee and Turnovsky (2004, 2007), our definition of tied aid is based on the "end-use" criterion.

5. If the government were able to allocate resources optimally, then obviously untied aid would always be optimal.

6. In this specification, K_g measures public infrastructure (roads, school buildings, equipment, etc.), whereas I_e represents public spending on teachers' salaries and educational material.

7. When foreign aid is partially or completely untied, agents receive lump-sum transfers from the government.

8. Some authors, such as Ladrón-de-Guevara et al (1999) and De Hek (2006), pointed out that, under certain conditions, assuming that the stock of human capital does not affect the time spent on the different activities symmetrically can be a source of nonconvexities in the model and may lead to multiple steady states. We checked that this problem, which has been shown in the context of a closed economy, does not occur in our open-economy model.

9. The production function can be rewritten as $\mathcal{F}(L, H, K_g, K) = Z(LH)^{\alpha_1}(LK_g)^{\alpha_2}K^{1-\alpha_1-\alpha_2}$, where the terms L and LH can be interpreted as, respectively, raw and skilled labor.

10. See the working paper version of this article for details.

11. Glomm and Ravikumar (1998) set ω_1 to 0.15 and η to 0.8. Heckman et al. (1998b) estimate η to be 0.9, and Lau (2000) and Fougère et al. (2009) set it to 0.8.

12. For example, Dessus and Herrera's (2000) estimates of the income share of public capital range from 0.11 to 0.13 for a sample of 28 developing countries over the period 1981–1991. Aschauer (2000) reports an estimate of 0.24 using data from 46 low- and middle-income countries from 1970 to 1990. Arslanalp et al. (2010) estimate the output elasticity of public capital to be 0.26 for a sample of developing countries.

13. Unfortunately, we did not find empirical estimates of the depreciation rate of human capital for developing countries. However, our calibrated value is consistent with the estimates reported by Johnson and Hebein (1974), Arrazola et al. (2005), and Weber (2014) for, respectively, the United States, Spain, and Switzerland.

14. Arestoff and Hurlin (2006) estimate the average ratio of public expenditure on capital to GDP to be 4.42% for a group of 19 developing over the period 1974–1997. According to World Bank (2008), the ratio of public spending on education to GDP was 4.25% in 2005 for Sub-Saharan Africa, whereas a Report of the United Nations Secretariat (2004) states that this ratio was 4.6% for Africa and 4.1% for developing countries over the period 1990–2002.

15. To solve for the dynamic response of the economy, we use the reverse-shooting algorithm developed by Atolia and Buffie (2009).

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APPENDIX: DERIVATION OF WELFARE CHANGES

Welfare changes are measured by the equivalent variations in the private stock of capital following an aid shock, i.e., the percentage changes in the initial stock of capital necessary to make agents as well off at the benchmark equilibrium as at the after-shock equilibrium. Given the form of the utility function, and assuming that the economy is initially on a balanced growth path with a constant growth rate equal to Γ_b, the benchmark intertemporal welfare is given by

$$W_b = \int_0^\infty \frac{1}{\gamma}(c_b l_b^\theta K_b(t))^\gamma e^{-\rho t} dt \tag{A.1}$$

$$= \int_0^\infty \frac{1}{\gamma}(c_b l_b^\theta K_0)^\gamma e^{(\gamma\Gamma_b-\rho)t} dt, \tag{A.2}$$

where variables with subscript b pertain to the benchmark equilibrium, and K_0 is the stock of capital at $t = 0$. Because c_b and l_b are constant along the initial balanced growth path, the preceding expression reduces to

$$W_b = W_b(c_b, l_b, K_0) = \frac{1}{\gamma}\frac{\left(c_b l_b^\theta K_0\right)^\gamma}{\rho - \gamma\Gamma_b}. \tag{A.3}$$

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The intertemporal welfare in the aftershock equilibrium is given by

$$W_f = \int_0^\infty \frac{1}{\gamma}(c_b l_b^\theta K_f(t))^\gamma e^{-\rho t} dt \tag{A.4}$$

$$= \frac{1}{\gamma}\frac{\left(c_f l_f^\theta K_0\right)^\gamma}{\rho - \gamma\Gamma_f}, \tag{A.5}$$

where variables with subscript f pertain to the new equilibrium. Evaluating the percentage change in the initial stock of capital, K_0, that would make the representative agent as well off at the benchmark equilibrium as in the new steady state amounts to finding the quantity φ such that $W_b(c_b, l_b, (1+\varphi)K_0) = W_f$. This quantity is given by

$$\varphi = \left(\frac{c_f l_f^\theta}{c_b l_b^\theta}\right)\left(\frac{\rho - \gamma\Gamma_b}{\rho - \gamma\Gamma_f}\right)^{\frac{1}{\gamma}} - 1. \tag{A.6}$$

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