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Foreign Aid Linked to Infrastructure and/or Pollution Abatement

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Abstract

This paper studies the macroeconomic effects of a permanent increase in foreign aid in a model that takes into account environmental quality. We develop a dynamic equilibrium model in which both public investment in infrastructure and environmental protection can be financed using domestic resources and international aid programs. The framework considers four scenarios for international aid: untied aid, aid fully tied to infrastructure, aid fully tied to abatement, and aid equally tied to both types of expenditures. We find that the effects of the transfers may depend on (i) the structural characteristics of the recipient country (the elasticity of substitution in production and its dependence on environment and natural resources) and on (ii) how recipient countries distribute their public expenditure. These results underscore the importance of these factors when deciding how and to what extent to tie aid to infrastructure and/or pollution abatement.

JEL classification: F35; H54; O41; Q20.

Keywords: Foreign Aid; Environment; Infrastructures; Endogenous Growth.

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1 Introduction

The Millennium Declaration, a United Nations initiative which aims to improve the standard of living of millions of people around the world, includes eight goals that represent human rights that everyone should be able to enjoy: 1. eradicate extreme poverty and hunger, 2. achieve universal primary education, 3. promote gender equality and empower women, 4. reduce child mortality, 5. improve maternal health, 6. combat HIV/AIDS, malaria and another diseases, 7. ensure environmental sustainability, and 8. develop a global partnership for development. As The Millennium Development Goals Report 2012 says, achieving all these goals by 2015 is difficult but not impossible. Much depends on the fulfillment of goal #8 (develop a global partnership for development), an objective that implies that international aid should not fall.[1] Regarding goal #7 (ensure environmental sustainability), the rate of deforestation is still alarmingly high, the loss of biodiversity continues with increasing risks of dramatic shifts in ecosystems, safe water supply remains a challenge in many parts of the world, and improvements in sanitation are bypassing the poor.[2]

Foreign aid to developing countries can become an important source to stimulate growth and to improve environmental quality. This paper studies the macroeconomic effects of foreign aid linked to infrastructure and pollution abatement through a dynamic equilibrium model in which both public investment in infrastructure and environmental protection can be financed using domestic resources and international aid programs.

An important part of the foreign aid to developing countries has been directed to improving transport infrastructure, power generation capacity and telecommunication networks. In fact, there is a wide consensus that an expansion of public investments in developing countries is fundamental to achieving sustained growth.[3] Chatterjee and Turnovsky (2005, 2007) study the consequences for growth and welfare of financing public investment through foreign aid in a dynamic intertemporal framework. Their results suggest that it is important to take into account the recipient's chances for substitution in production when deciding whether to tie or not the aid. In particular, their model predicts that aid programs fully tied to infrastructure are more effective than programs with untied aid in economies with a low elasticity of substitution in

[1] See Temple (2010) for a review of the relevant theory and evidence on the effectiveness of international aid. Easterly (2009) summarizes the success and failure of the international aid in Africa.

[2] WHO/UNICEF considers that sustainable development is impossible without focusing on safe water and sanitation programs.

[3] The contribution of infrastructures to stimulate growth has been widely studied in both theoretical and empirical research since the seminal article of Aschauer (1989). Recently, Calderón, Moral-Benito and Servén (2011) carried out an empirical analysis using a dataset for 88 countries for the period 1960-2000. They find little evidence of heterogeneity across countries in regard to the contribution of infrastructures on production.

production. As the substitutability in production increases, welfare gains rise when dealing with pure transfers, while tied aids show lower welfare gains even though the growth rate increases. Agénor and Yilmaz (2013) also contribute to this literature by considering two productive public services (infrastructure and health), access to the world capital markets limited only to governments and the existence of domestically and imported goods, which allows them to study the impact of aid shocks on the real exchange rate.[4]

Although development aid programmes might generate or exacerbate environmental problems if not implemented carefully, foreign aid can become an important source for governments to preserve or even improve environmental quality.[5] As far as we know, however, much of the literature that studies the relationship between growth and environment does not take into account the potential effects of international aid. Most of the research focuses on optimal fiscal policy issues (see, e.g., Economides and Philippopoulos (2008), Barman and Gupta (2010) and Nguyen-Van and Pham (2013)), and little attention is given to the link between environmental policies, economic growth and foreign aid in dynamic equilibrium models.[6] An exception is Chao, Hu, Lai and Tai (2012) which incorporate both foreign aid and environment to examine the growth and welfare effects of the *allocation* of aid in the recipient economy. They find that since public capital is a productive factor, the aid tied to infrastructure increases the growth and welfare, whilst the aid tied to pollution abatement may not be growth- and hence welfare-enhancing, since it crowds-out public inputs.

Our paper pursues this line of research, but we extend the analysis by considering the importance of these factors when deciding how and to what extent to tie aid to infrastructure and/or pollution abatement: the recipient country's dependence on environmental and natural resources, its chances of substitution in production, and how recipient countries distribute their public expenditure. In particular, following Chatterjee and Turnovsky (2005), we consider a constant-elasticity-of-substitution (CES) production function to study the effects of foreign aid in a small economy that faces restricted access to the world capital market. So, we take into account the existing controversy about the complementarity or substitutability of public and

[4]In this regard, Jarotschkin and Kraay (2013) find a modest impact of aid on the real exchange rate.

[5]Examples of programs, financed by United Nations, criticized for their environmental damage are the dams in Sardar Sarovar (India) and Pak Mun (Thailand), the development scheme in Polonoroeste (Brazil) or the mines in Singrauli (India). Besides, Arvin and Lew (2009) find that donors are sending mixed signals to recipient countries through their aid policies, rewarding them for the preservation of their forest but not for the reduction of their CO_2 emissions.

[6]We note that some of these papers study this link when dealing global pollution problems. For example, Economides and Miaouli (2006) study the effects of commonly used cross-country transfer programs on uncoordinated national environmental policies, economic growth and natural resources in a federal economy when pollution is transboundary.

private investments in developing countries, because both crowding-in and crowding-out effects of public investments on private investments in developing countries are observed (see Atukeren (2005)).[7] In addition to untied aid we also consider the aid *allocation* to infrastructure and/or abatement, a matter which is also empirically relevant because according to the OECD 2013 Report, most international aid is partially tied to economic and social infrastructure at a 58% rate in developing countries.[8]

Our results show that policy recommendations on incoming transfers must not only take into account the structural characteristics of the recipient country (the elasticity of substitution in production and the degree of dependence of the economy on environment and natural resources) but also how recipient countries distribute their public expenditure on abatement and/or infrastructure. For example, when the recipient country's expenditure in infrastructure is low relative to the total, aid programs fully tied to infrastructure are more effective than partially or untied aid programs. However, when this expenditure in infrastructure is high, the effectiveness of the transfers depend on the recipient's chances of substitution in production and its degree of dependence on environment and natural resources. For countries with a low dependence, the effectiveness of transfers from abroad depends on the recipient's opportunities of substitution in production. In particular, untied aid programs are more effective than tied ones (regardless of their allocation) when the elasticity of substitution between factors is high. However, in those countries with a higher dependence on environment and natural resources, transfers devoted to both infrastructure and pollution abatement are more effective regardless of the recipient's opportunities of substitution in production. These results underscore the importance of the factors we study to decide when, how and to what extent aid may be tied to infrastructure and/or pollution abatement. In this regard, we want to emphasize the ability of the intermediate aid type to achieve Millennium Development Goals 7 and 8 for these countries, insofar as these transfers are growth- and hence welfare-enhancing and allow to complement domestically financed expenditure on pollution abatement.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 describes the equilibrium and the dynamics of the economy. Section 4 analyzes the effects of foreign aid allocation on real activity. The significance of the results of the work are discussed

[7]On the one hand, low values for the elasticity of substitution in production between private and public capital are associated with cases in which public investment is necessary or beneficial for private investment, a feature that one may think would reflect a developing country. On the other hand, higher values for the elasticity of substitution in production are associated with economies with well-developed financial markets in which private sector projects can be crowded out by public investment if the latter is financed by borrowing, something which raises the cost of private investment. Thus, it is important to consider this aspect.

[8]Untied aid refers to pure transfers. By tied aid we mean aid used to finance specific projects.

in Section 5. Section 6 concludes with some final remarks.

2 The model

We consider a small open economy populated by a continuum of identical, infinitely lived agents, which produce and consume a single traded commodity and may borrow in world capital markets. There is also a public sector that finances public expenditures, transfers to households, and also finances pollution abatement expenditures through proportional taxes on output and international aid. In particular, following Chatterjee and Turnovsky (2005), we develop an augmented model that includes the impact of environmental quality in the utility of consumers and the effort of the government on abatement.

Agents produce a single good, Y, with private capital, K (that can be seen as a composite of physical and human capital), and public capital K_G, using the CES production function:

$$Y = \alpha[\eta K_G^{-\rho} + (1-\eta)K^{-\rho}]^{-1/\rho},\ \alpha > 0, 0 < \eta < 1, \rho > -1,$$

where α is a scale factor, η is the productive elasticity of public capital, and $\sigma \equiv \frac{1}{1+\rho}$ represents the intratemporal elasticity of substitution between private and public capital in production. The substitutability between private and public capital increases with σ.

Agents derive utility from the consumption good and the environmental quality, and discount future utility at a rate $\beta \in (0,1)$. They maximize their discounted lifetime utility:

$$W(C,E) = \int_0^\infty (\frac{C^\gamma}{\gamma} + a\ln E)e^{-\beta t}dt,\ \ -\infty < \gamma < 1, a > 0$$

where C is consumption and the intertemporal elasticity of substitution in consumption is given by $s = \frac{1}{1-\gamma}$; $E \in [0,1]$ denotes environmental quality and a weights the impact of environment on utility. Environmental quality is a public good displaying an index of environmental quality, e.g. air quality, land quality, state of natural resources or even a biodiversity index. In addition to the agent's environmental valuation, a indicates the extent to which countries depend on environment and natural resources. When $E = 1$ there is no environmental pollution in the economy and consumer's utility is not "damaged", whilst $E = 0$ implies that the economy cannot recover from this situation in that increases in consumption does not increase consumer's utility.[9]

The rate of change of environmental quality is given by:

$$\dot{E} = mE(1-E) - \frac{P}{A}E. \tag{1}$$

[9]This incorporates the notion of "environmental disaster" as in Acemoglu et al. (2012).

This specification for the evolution of environmental quality captures how this variable is affected by environmental degradation and abatement. On the one hand, we consider a logistic function, $mE(1-E)$, for the growth of environmental quality with a rate of environmental regeneration equal to m.[10] On the other hand, the evolution of the environmental quality is assumed to depend on the pollution/abatement ratio as a proportion of environmental quality, $\frac{P}{A}E$. This reflects the effort of the government to mitigate environmental degradation. As in Gupta and Barman (2009) and Orubu and Omotor (2011), among others, we assume that the source of pollution is consumption.[11] We assume that every unit of consumption generates π units of pollution, $P = \pi C$, as a joint product of consumption. Brock and Taylor (2010) proposed the following constant returns to scale abatement function: $A(C, Z) = C^d Z^{1-d},\ 0 \leq d \leq 1$, which assumes that consumption generates pollution, but the economy's efforts at abatement, Z, clean the environment. Using this specification, the pollution/abatement ratio can be expressed as $\frac{P}{A} = \pi(\frac{C}{Z})^{1-d}$. For simplicity, we consider $d = 0$ and, hence, $\frac{P}{A} = \pi\frac{C}{Z}$.

So we can express the rate of change of environmental quality as:

$$\dot{E} = mE(1-E) - \pi\frac{C}{Z}E. \tag{2}$$

Agents may borrow on international capital markets. Let N denote the stock of debt held by households. The interest agents have to pay is given by:

$$r(N/K) = r^* + \omega(N/K),\ \omega' > 0,$$

where r^* is the world interest rate which is exogenously determined, and $\omega(N/K)$ is the country-specific borrowing premium which grows with the debt/private capital ratio (N/K) of the country. We consider $\omega(N/K) = e^{b(N/K)} - 1$ which is an upward sloping curve. It reflects the case of perfect world capital market when $b = 0$.

Agents also accumulate private capital. The cost in units of output for each unit of investment (I) is 1 plus an adjustment cost, which is an increasing function of the $\frac{I}{K}$ ratio:

$$\Psi(I, K) = I(1 + h_1\frac{I}{2K}).$$

[10]In this logistic function the rate of accumulation of the stock is bounded, so that in the absence of pollution E converges to its maximum value of 1. This specification has already been used by Brown (2000) and Elíasson and Turnovsky (2004) as a growth function of renewable resources.

[11]Orubu and Omotor (2011) investigate the relationship between per capita income and environmental degradation in Africa. They found an environmental Kuznets curve for suspended particular matter and observe that in the case of organic water pollutants the evidence weighs more in favor of rising pollution as per capita income increases. They note that these pollutants, most of them coming from food and beverages, are relatively higher than what is observed in some industrial countries.

Capital accumulation evolves according to the following law of motion:

$$\dot{K} = I - \delta_K K,$$

where δ_K is the rate of depreciation of private capital.

The agent's budget constraint is given by:

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

where τ is a tax on output and $\bar{T}$ are lump-sum taxes.

Public capital accumulation is financed by two income sources. One part is domestically financed, $\bar{G}$, and the rest of the resources, TR, come from foreign aid as follows:

$$G = \bar{G} + \lambda TR,\ 0 \leq \lambda \leq 1,$$

where λ shows the extent to which international aid is tied to cover public infrastructure expenditures.

In addition, we assume that the abatement spending is also partly domestically financed, $\bar{Z}$, and the rest of the resources come from abroad through international aid,

$$Z = \bar{Z} + \phi TR,\ 0 \leq \phi \leq 1$$

where ϕ represents the share of aid from abroad that is tied to abatement expenditures.

We assume that domestically financed government expenditure on infrastructure ($\bar{G}$) and domestically financed pollution abatement ($\bar{Z}$) are proportional to production $\bar{G} = \bar{g}Y$, $\bar{Z} = \bar{z}Y$. To sustain an equilibrium of ongoing growth, foreign aid must be restricted to the scale of the economy: $TR = \theta Y$, $\theta > 0$, and $0 < \bar{g} + \bar{z} + \theta < 1$ must hold.

Note that $0 \leq \lambda + \phi \leq 1$. When $\lambda + \phi = 0$ transfers from abroad are untied. Tied transfers correspond to $\lambda + \phi = 1$. We study tied aid allocation by considering three different combinations of $\lambda + \phi = 1$: (i) First, we consider that transfers from abroad can be completely tied to infrastructure, $\lambda = 1$ and $\phi = 0$; (ii) Second, that incoming transfers can be fully tied to abatement, $\lambda = 0$ and $\phi = 1$; (iii) Finally, with respect to the intermediate situations we take into account the middle values: $\lambda = 1/2$ and $\phi = 1/2$. These three scenarios are shown below in Table 2.

Analogous to private capital, gross public capital accumulation is also subject to quadratic adjustment costs:

$$\Omega(G, K_G) = G(1 + h_2 \frac{G}{2K_G}),$$

and the law of motion for public capital accumulation is given by:

$$\dot{K_G} = G - \delta_G K_G,$$

where δ_G is the rate of depreciation of public capital.

The government sets taxes (τ and $\overline{T}$) and expenditure parameters ($\bar{g}$ and $\bar{z}$) and maintains a balanced budget in every period:

$$\tau Y + TR + \bar{T} = \Omega(G, K_G) + Z.$$

Finally, from the agent's budget constraint and the government's budget we can obtain the national budget constraint:

$$\dot{N} = C + \Psi(I, K) + \Omega(G, K_G) + Z + r(N/K)N - Y - TR,$$

which states that output plus foreign aid and debt accumulation finance total expenditures on consumption, private and public capital, pollution abatement and interest payments.

3 Dynamic optimization

Agents maximize their discounted lifetime utility by choosing consumption and the accumulation of private capital and debt. Since the interest rate $r(N/K)$ is a function of the economy's aggregate N/K ratio, agents take it as given. The current value of the Hamiltonian associated to this problem is:

$$H = (\frac{C^\gamma}{\gamma} + a \ln E) + q'(I - \delta_K K) - v[C + \Psi(I, K) + r(N/K)N - (1-\tau)Y - \bar{T}],$$

and the optimality conditions are:

$$C^{\gamma - 1} = v,$$

$$q' = v(1 + h_1 \frac{I}{K}),$$

$$r(N/K) = \beta - \frac{\dot{v}}{v},$$

$$\frac{\dot{K}}{K} = \frac{q-1}{h_1} - \delta_K, \quad q \equiv \frac{q'}{v}, \tag{3}$$

$$\frac{\dot{C}}{C} = \frac{1}{1-\gamma}[r(N/K) - \beta], \tag{4}$$

$$\frac{\dot{q}}{q} = \delta_K + r(N/K) - \frac{(q-1)^2}{2h_1 q} - \frac{(1-\tau)(1-\eta)\alpha[\eta(\frac{K_G}{K})^{-\rho} + (1-\eta)]^{\frac{-(1+\rho)}{\rho}}}{q}, \tag{5}$$

where v is the shadow price of wealth in terms of international bonds, q' is the shadow price of private capital, and $q \equiv \frac{q'}{v}$ is the relative market price of private capital.

This first order conditions joint with the transversality conditions

$$\lim_{t\to\infty} vNe^{-\beta t} = 0 \ ; \ \lim_{t\to\infty} q'Ke^{-\beta t} = 0,$$

together with the equations that describe the public sector, the net rate of public capital accumulation and the evolution of the environmental quality describe fully the dynamic of the system.

3.1 The decentralized equilibrium and the dynamics of the economy

Definition 1. *A decentralized equilibrium for this economy consists of allocations* $\{C, K, N, K_G, Z, E\}_{t=0}^{\infty}$ *and prices* $\{q\}_{t=0}^{\infty}$ *such that given initial conditions* $K(0)$*,* $K_G(0)$*,* $N(0)$*,* $E(0)$*, given a policy* $\{\tau, \bar{T}, \bar{g}, \bar{z}\}$, given the foreign aid θ, and given a scenario $\{\lambda, \phi\}$:

(i) *the problem faced by agents is solved;*

(ii) *the government's budget constraint is satisfied at all periods, and*

(iii) *the aggregate resource constraint of the economy is fullfiled.*

The definition of a decentralized equilibrium implies that the decision rules for C, K, N, K_G, Z and E are defined by equations (3) to (5) plus the following equations:

$$\frac{\dot{K}_G}{K_G} = (\bar{g} + \lambda\theta)\frac{Y}{K_G} - \delta_G, \tag{6}$$

$$\frac{\dot{N}}{N} = r(N/K) + \frac{C}{N} + \frac{(q^2-1)K}{2h_1 N} + \frac{(\bar{g}+\lambda\theta)Y}{N}(1 + h_2\frac{(\bar{g}+\lambda\theta)Y}{2K_G}) + \frac{(\bar{z}+\phi\theta)Y}{N} - (1+\theta)\frac{Y}{N}, \tag{7}$$

$$\frac{\dot{E}}{E} = m(1-E) - \pi\frac{C}{(\bar{z}+\phi\theta)Y}. \tag{8}$$

We define a balanced growth path (BGP henceforth) as an equilibrium path along which all real variables grow at the same rate (φ), and the relative price of capital (q) and the environmental quality are constant. Stationary time series can be obtained by expressing growing variables in relation to the stock of private capital: $c \equiv \frac{C}{K}$, $k_g \equiv \frac{K_G}{K}$, $n \equiv \frac{N}{K}$. The dynamic of the system can be describe with the following equations:

$$\frac{\dot{k}_g}{k_g} \equiv \frac{\dot{K}_G}{K_G} - \frac{\dot{K}}{K} = (\bar{g}+\lambda\theta)\alpha[\eta + (1-\eta)k_g^{\rho}]^{\frac{-1}{\rho}} - \frac{q-1}{h_1} - (\delta_G - \delta_K), \tag{9}$$

$$\frac{\dot{c}}{c} \equiv \frac{\dot{C}}{C} - \frac{\dot{K}}{K} = \frac{r(n)-\beta}{1-\gamma} - \frac{q-1}{h_1} + \delta_K, \tag{10}$$

$$\frac{\dot{q}}{q} = \delta_K + r(n) - \frac{(q-1)^2}{2h_1 q} - \frac{(1-\tau)(1-\eta)\alpha[\eta(k_g)^{-\rho} + (1-\eta)]^{\frac{-(1+\rho)}{\rho}}}{q}, \tag{11}$$

$$\frac{\dot{n}}{n} \equiv \frac{\dot{N}}{N} - \frac{\dot{K}}{K} =$$

$$= r(n) + \frac{c}{n} + \frac{q-1}{h_1}(\frac{q+1}{2n} - 1) + \frac{y}{n}[(\bar{g} + \lambda\theta) + (\bar{z} + \phi\theta) - (1+\theta)] + (\bar{g} + \lambda\theta)^2 \frac{y^2}{k_g}\frac{h_2}{2n} + \delta_K, \quad (12)$$

$$\frac{\dot{E}}{E} = m(1-E) - \pi\frac{c}{(\bar{z} + \phi\theta)y}. \quad (13)$$

Transitional dynamics as well as the steady state equilibrium can be derived from these equations. In the steady state $\dot{n} = \dot{k_g} = \dot{c} = \dot{q} = \dot{E} = 0$ and, hence, K, K_G, N, C grow at the same rate φ. Equations (9) to (12) form an autonomous equations system in c, k_g, n, q. Steady state values for $\widetilde{k}_g$, $r(\widetilde{n})$ and $\tilde{q}$, along with $\tilde{n}$ and the growth rate φ can be obtained from the first three equations, and $\tilde{c}$ is derived from equation (12). Once these steady state values are obtained we can determine $\tilde{E}$ from equation (13).

We solve this nonlinear system of differential equations by using a linear approach. Linearizing equation (9) to (13) around their steady-state values ($\widetilde{k}_g$, $\widetilde{c}$, $\widetilde{q}$, $\widetilde{n}$, $\widetilde{E}$) yields:[12]

$$\begin{bmatrix} \dot{k}_g \\ \dot{c} \\ \dot{q} \\ \dot{n} \\ \dot{E} \end{bmatrix} = \begin{bmatrix} f_{11} & 0 & f_{13} & 0 & 0 \\ 0 & 0 & f_{23} & f_{24} & 0 \\ f_{31} & 0 & f_{33} & f_{34} & 0 \\ f_{41} & 1 & f_{43} & f_{44} & 0 \\ f_{51} & f_{52} & 0 & 0 & f_{55} \end{bmatrix} \begin{bmatrix} k_g - \widetilde{k}_g \\ c - \widetilde{c} \\ q - \widetilde{q} \\ n - \widetilde{n} \\ E - \widetilde{E} \end{bmatrix}.$$

The dynamics of this economy can be approximated by this linearized system joint with the initial and the transversality conditions. Saddlepoint stability requires as many stable roots as state variables, which in our case implies that three negative roots are needed. Our numerical simulations below display a saddle-path dynamical structure.

[12] Where $f_{11} = \alpha(\bar{g} + \lambda\theta)[\eta(\eta + (1-\eta)\widetilde{k}_g^{\rho})^{\frac{-(1+\rho)}{\rho}} - (\eta + (1-\eta)\widetilde{k}_g^{\rho})^{\frac{-1}{\rho}}]$;
$f_{13} = \frac{-\widetilde{k}_g}{h_1}$; $f_{23} = \frac{-c}{h_1}$; $f_{24} = \frac{r'(\widetilde{n})\widetilde{c}}{1-\gamma}$;
$f_{31} = -(1+\rho)(1-\tau)(1-\eta)\alpha\eta[\eta\widetilde{k}_g^{-\rho} + (1-\eta)]^{\frac{-(1+2\rho)}{\rho}}\widetilde{k}_g^{-(1+\rho)}$;
$f_{33} = r(\widetilde{n}) - \frac{[r(\widetilde{n}) - \beta]}{1-\gamma}$; $f_{34} = r'(\widetilde{n})\widetilde{q}$;
$f_{41} = [(\bar{g} + \lambda\theta) + (\bar{z} + \phi\theta) - (1+\theta)]\alpha[\eta\widetilde{k}_g^{-\rho} + (1-\eta)]^{\frac{-(1+\rho)}{\rho}}\eta\widetilde{k}_g^{-(1+\rho)} + \frac{h_2(\bar{g}+\lambda\theta)^2}{2}\frac{\widetilde{y}}{\widetilde{k}_g}(2\alpha[\eta\widetilde{k}_g^{-\rho} + (1-\eta)]^{\frac{-(1+\rho)}{\rho}}\eta\widetilde{k}_g^{-(1+\rho)} - \frac{\widetilde{y}}{\widetilde{k}_g})$;
$f_{43} = \frac{\widetilde{q} - \widetilde{n}}{h_1}$; $f_{44} = r'(\widetilde{n})\widetilde{n} + r(\widetilde{n}) - \frac{\widetilde{q}-1}{h_1} + \delta_K$; $f_{51} = \pi\frac{\widetilde{c}}{\widetilde{z}^2}\widetilde{E}(\bar{z} + \theta\phi)\eta\alpha^{-\rho}(\frac{\widetilde{y}}{\widetilde{k}_g})^{1+\rho}$;
$f_{52} = -\frac{\pi}{\widetilde{z}}\widetilde{E}$; $f_{55} = m - 2m\widetilde{E} - \pi\frac{\widetilde{c}}{\widetilde{z}}$

4 The effects of foreign aid allocation on real activity

We use a numerical analysis to study the effect of different public spending policies and different allocations of international aid on growth, the evolution of the environmental quality and welfare.

First, we calibrate a benchmark economy taking as a reference a small open country that initially does not receive any aid from abroad, so that $\theta = 0$. Table 1 shows the parameter values considered.

The values for preference parameters (β and γ), production parameters (η, σ, h_1 and h_2), depreciation rates (δ_K and δ_G), interest rate (r), premium on borrowing (b) and tax rate (τ) are taken from Chatterjee and Turnovsky (2005).

As mentioned earlier, Atukeren (2005) found mixed evidence on crowding-in and crowding-out effects in developing countries. So we consider different degrees of the elasticity of substitution in production between public and private capital: $\sigma = 0.33$, a value that may characterize a country with limited substitution, and $\sigma = 1$, the value that corresponds to the standard Cobb-Douglas specification.

We establish the scale parameter $\alpha = 0.6$.

Policy parameters $\bar{g}$ and $\bar{z}$ measure the percentage of the domestic income devoted to finance infrastructure and abatement, respectively. We set $\bar{g} + \bar{z} = 0.05$ which means that 5 percent of the GDP is devoted to finance these expenditures. Domestically financed expenditure can be distributed among these categories in different ways. Given $\bar{g} + \bar{z} = 0.05$, we think of the distribution $(\bar{g}, \bar{z})$ as a country-specific policy. We look at three public policies. Under Policy 1 nearly all the government spending is devoted to infrastructure, $\overline{g} = 0.049$ and $\overline{z} = 0.001$. Under Policy 2 we still consider that domestically financed expenditure on infrastructure is higher than which is devoted to abatement, $\overline{g} = 0.04$ and $\overline{z} = 0.01$. Finally, Policy 3 considers that both expenditures are equally distributed, $\overline{g} = \overline{z} = 0.025$. This allows us to study how the results change when public policy becomes increasingly aware towards greater abatement efforts, given the percentage of total expenditure. Note that some policies that our model might pick up via infrastructures (and no via z), such as improving access to safe water or sanitation, are considered by the United Nations as key to achieving environmental sustainability.

As in Economides and Philippopoulos (2008) we use $m = 0.015$ for the rate of environmental regeneration and the value for π (units of pollution per consumed unit) is adjusted to obtain a constant value for the C/Z ratio at the benchmark steady state[13].

[13] From equation (13) in the steady state $\widetilde{E} = 1 - \frac{\pi \frac{\widetilde{C}}{\widetilde{Z}}}{m}$. Given $\sigma = 0.33$, we obtain the benchmark steady state

We study the effect of a permanent increase in foreign aid θ from 0 percent to 5 percent of GDP in several scenarios: unrestricted or untied aid, and three alternative allocations for tied aid which depend on the percentage of the aid directed to infrastructure expenditures and/or abatement (see Table 2). Table 3 reports the steady state values for $\sigma = 0.33$ and $\sigma = 1$.

Table 1. *Numerical values for the benchmark economy*

Parameter	**Value**
β: discount factor	0.04
$\frac{1}{1-\gamma}$: intertemporal elasticity of substitution	0.4 (γ = -1.5)
b: premium on borrowing	0.1
r^*: world interest rate	0.06
α: scale factor	0.6
η: productive elasticity of public capital	0.2
σ: the substitutability in production between private and public capital	0.33, 1
h_1, h_2: adjustment costs parameters	15
δ_K, δ_G: depreciation rates	0.05, 0.04
τ: tax rate	0.15
m: rate of environmental regeneration	0.015
θ: aid received as a percentage of national income	0

Table 2. *Scenarios for the international aid*

Scenario		**Values**
Untied	Pure transfers	$\theta = 0.05, \lambda = 0, \phi = 0$
Productive	Transfers fully tied to infrastructure	$\theta = 0.05, \lambda = 1, \phi = 0$
Green	Transfers fully tied to abatement	$\theta = 0.05, \lambda = 0, \phi = 1$
Intermediate	Transfers tied to abatement and infrastructure	$\theta = 0.05, \lambda = 0.5, \phi = 0.5$

The first column block in Table 3 reports the equilibrium values under Policy 1, 2 and 3 of every type of foreign aid for countries with a low elasticity of substitution in production, i.e. $\sigma = 0.33$. We can see that in a country with a low relative expenditure on infrastructure (Policy 3), the borrowing rate is below the world interest rate, which implies that the country is a net creditor as reflected by a negative value for $\frac{N}{Y}$. Note also that in this case the long-run

$\frac{\widetilde{C}}{\widetilde{Z}}$ ratio. Assuming $\widetilde{E} = 0.2$ for the initial steady state, we then derive π for Policies 1, 2 and 3.

growth rate is negative, since the borrowing rate is below the discount rate. As the weight of domestically financed expenditure on infrastructure increases, the relative price of private capital raises, which increases the borrowing rate. A country described by Policy 1 will become a net debtor. Moreover, moving from Policy 3 to Policy 1 we obtain a higher steady state ratio of public to private capital, which raises the marginal productivity of capital and leads to a higher long-run growth rate.

Regardless of the policy, if aid is fully or at least partially tied to infrastructure, a permanent increase in international aid raises the borrowing rate above the world interest rate, reducing current account surplus. However, the aid has no effect on the current account for green and untied scenarios.

Regarding the growth rates, transfers tied to infrastructure generate the highest growth rates. They are followed by intermediate type aid. Green aid and untied aid generate the lowest growth rates. If we look at consumption, untied transfers yield higher consumption/output ratios, since they allow a greater amount of resources to be available for consumption.

Aid ordering differs if we look at the environmental quality: green aid is the best and untied aid is the worst. Note that pollution is a by product of consumption and, as noted already, the consumption/output ratio is higher when aid is untied.

Further, as the elasticity of substitution in production increases, in the second column block of Table 3, households devote more resources to capital investment and less to consumption, which leads to higher growth rates. Regardless of the policy and the scenario, when $\sigma = 1$ every country is a net debtor and they all display positive growth rates.[14]

Following King and Rebelo (1990), the welfare effect of a permanent increase in foreign aid from 0 percent to 5 percent is measured by a constant percentage change in the initial physical capital stock that, given the policy parameters $\tau, \bar{T}, \bar{g}, \bar{z}$, leaves the consumer indifferent between his lifetime utility with $\theta = 0$ and with $\theta = 0.05$. The welfare gain of this aid increase is measured by the value of $\digamma$ such that:

$$W(\{C(1+\digamma), E\}_{t=0}^{\infty}) = W(\{C^{'}, E^{'}\}_{t=0}^{\infty}), \tag{14}$$

where $\{C, E\}_{t=0}^{\infty}$ denote the consumption and environmental quality paths associated to the original BGP of an economy with $\theta = 0$, and $\{C^{'}, E^{'}\}_{t=0}^{\infty}$ denote the time paths of consumption and environmental quality that result after a permanent aid increase to 5 percent.

We study the welfare gains associated to the case that includes the transitional dynamics, $\digamma_t$. We also include the results for the long-run welfare effect by considering that the new

[14] Note that the higher the elasticity of substitution the higher the relative price of private capital and, hence, the higher the debt/output ratio.

steady state can be achieved immediately in order to study how the aid ranking may differ in some cases. We denote $\digamma_{nt}$ the corresponding welfare effect, where subscript nt represents that "no transition"' is taken into account. Finally, since the weight of the environment in the utility function may vary among countries we explore two possible values for this value. Tables 4 and 5 depict welfare gains for $a = 0.2$ and $a = 0.6$, respectively.[15]

4.1 *Long-run welfare effects:* $\digamma_{nt}$

In the absence of transition, we can order the scenarios from best to worst as a function of its effect on welfare as follows: for those countries with a lower dependence on environment and natural resources ($a = 0.2$) and that are spending equally on infrastructures and abatement ($\bar{g} = 0.025$ and $\bar{z} = 0.025$), productive aid is superior to all other types of aid for any σ, followed by the intermediate case of tied aid, then by untied aid, and the worst is green aid. This result is due to the fact that the higher the extent to which international aid is tied to infrastructure, the greater the impact of the incoming transfer since more resources are devoted to growth. The untied aid is superior to a green aid because in the latter case no incoming resource can be devoted to infrastructure. However, for countries with a higher dependence on environment and natural resources ($a = 0.6$), the green scenario becomes superior to the untied aid scenario because of its higher improvement of the environmental quality.

Productive aid remains the superior alternative under Policy 2 ($\bar{g} = 0.04$ and $\bar{z} = 0.01$) for $a = 0.2$, but for those countries with a higher degree of dependence on environment and natural resources ($a = 0.6$) the intermediate aid is the most effective. Further, under Policy 1 ($\bar{g} = 0.049$ and $\bar{z} = 0.001$), and regardless of the extent to which countries depend on their natural and environmental resources, a, intermediate aid is superior to all other transfers. Note that, for those countries with a higher dependence on environment and natural resources ($a = 0.6$), green aid is the second best alternative.

As the elasticity of substitution in production increases, regardless of a the welfare gains rise when dealing with pure transfers, while tied aids show lower welfare gains even though the growth rate increases. Note that this is because, in contrast to what happens with pure transfers, when aid is tied households enjoy less consumption.

4.2 *Total welfare effects:* $\digamma_t$

Once the transition is taken into account, regardless of σ and a, when the economy is spending equally on infrastructures and abatement (Policy 3) productive aid generates the largest welfare

[15] We denote by an asterisk those scenarios in which the increase in welfare is greatest for each case.

gains. This alternative is followed by intermediate aid, pure transfers and green aid. Moreover, for those countries with a low dependence on environment and natural resources ($a = 0.2$) the same ranking of alternatives is maintained regardless of the country's spending policy when $\sigma = 0.33$. However, when $\sigma = 1$ the degree of suitability of transfers depend on the distribution of domestically financed expenditure. In particular, as the weight in domestically financed expenditure on infrastructure increases, untied aid becomes a better alternative, in fact the best alternative when nearly all the government spending is devoted to infrastructure, i.e. $\overline{g} = 0.049$ and $\overline{z} = 0.001$. Further, regardless of the elasticity of substitution the welfare gains obtained from tied aid decrease as the ratio of aid used for pollution abatement increases. This latter result is consistent with Chao et al. (2012).

For countries with a higher dependence on environment and natural resources ($a = 0.6$), as the weight in domestically financed expenditure on infrastructure increases, intermediate aid becomes more important and is the superior alternative under Policy 1. Further, for these countries, untied aid is better than productive and green type aids if $\sigma = 1$, while pure transfers are the worst when the recipient's chances for substitution in production are low ($\sigma = 0.33$).

Note that, regardless of the elasticity of substitution in production σ and the degree of dependence on environment and natural resources a, as the weight in domestically financed expenditure on infrastructure increases the welfare gains associated with productive and intermediate aid fall despite the long-run growth rate boosts. This is because of the negative effect of these type of aid on both transitional and long-run consumption. However, welfare gains hardly vary for the untied case, whilst for green aid welfare rises gradually because foreign aid replaces the lower effort made by the country in abatement.

The results also show that, as in the case of F_{nt}, an increase in the elasticity of substitution in production generates higher welfare gains when dealing with pure transfers but lower welfare gains when aid is tied since in the latter case households enjoy less consumption.

5 Discussion

Summing up, our study complements previous theoretical findings. On the one hand, Chatterjee and Turnovsky (2005) find that aid fully tied to infrastructure is more effective in countries with a low elasticity of substitution between factors. In fact, untied aid has no effects on growth even though it is welfare improving. Our study allows us to refine these results. For those economies with a low expenditure in infrastructure (under Policy 3 and 2), fully tied to infrastructure programs are more effective than others. However, when this expenditure in infrastructure is high (i.e. under Policy 1, which is the closest to the one studied in Chatterjee and Turnovsky

(2005)), the effectiveness of the transfers depend on the recipient's chances of substitution in production (σ) and its degree of dependence on environment and natural resources (a). For those countries with a low dependence on environment and natural resources ($a = 0.2$), an untied aid program is more effective than a tied one (regardless of its allocation) for countries with a high elasticity of substitution between factors ($\sigma = 1$), while fully tied to infrastructure aid programs remain the most effective ones for countries with low substitutability. However, regardless of the recipient's opportunities of substitution in production, intermediate transfers are more effective in countries with a higher dependence on environment and natural resources. The intuition behind this result is that this type of aid complements the internal policy on pollution abatement.

On the other hand, Chao et al. (2012) study the effects of transfers tied to both infrastructure and pollution abatement and show that a raise in the ratio of aid that is used for pollution abatement discourages the growth rate and, hence, welfare. Their results are consistent with ours for the Cobb-Douglas specification and a low degree of dependence on environment and natural resources, since welfare gains decrease as we move from productive to green scenarios. But, an increase in the degree of dependence of environment and natural resources of the recipient country might alter the effectiveness of the aid. Our extension allows us to consider not only this factor but also the recipient's chances of substitution in production. We find that the welfare gain could be the greatest at the intermediate scenario. Moreover, it is worth noting the ability of the intermediate aid type to achieve Millennium Development Goals #7 and #8 for those countries with a high dependence on environment and natural resources, insofar as these transfers are growth- and hence welfare- enhancing and allow to complement domestically financed expenditure on pollution abatement.

Our analysis may be extended in several directions. For instance, it may take into account temporary aids, which may generate different transitional dynamics and hence welfare consequences. However, maintaining the transfers is vital to ensure the fulfillment of the global commitment to promote development in poor countries. Also, in our model there is a unique commodity. By differentiating between domestic and importing goods, a large increase in foreign aid could raise the real exchange rate making the recipient country's goods less competitive in the world market. In this regard, Jarotschkin and Kraay (2013) find that "there is little evidence that aid inflows lead to significant real exchange rate appreciation". These and possibly other directions represent promising avenues for future research.

Table 3: Equilibrium Values

	Low substitutability case, $\sigma = 0.33$					*Cobb-Douglas case, $\sigma = 1$*				
	Benchmark	*Untied*	*Productive*	*Intermediate*	*Green*	Benchmark	*Untied*	*Productive*	*Intermediate*	*Green*
Policy 1: $\overline{g} = 0.049, \overline{z} = 0.001$										
φ	0.8%	0.8%	3.27%	2.25%	0.8%	3.16%	3.16%	3.91%	3.59%	3.16%
k_g	0.46	0.46	0.76	0.61	0.46	0.32	0.32	0.69	0.51	0.32
$\frac{\widetilde{c}}{\widetilde{y}}$	0.75	0.80	0.56	0.64	0.75	0.54	0.59	0.49	0.51	0.54
$\widetilde{q}$	1.87	1.87	2.24	2.08	1.87	2.22	2.22	2.33	2.22	2.28
$\widetilde{r}$	6.01%	6.01%	12.18%	9,64%	6.01%	11.92%	11.92%	13.79%	12.99%	11.92%
$\frac{\widetilde{n}}{\widetilde{y}}$	0.003	0.003	1.06	0.68	0.003	1.19	1.19	1.34	1.19	1.28
$\widetilde{E}$	0.21	0.15	0.40	0.97	0.98	0.45	0.40	0.50	0.98	0.98
Policy 2: $\overline{g} = 0.04, \overline{z} = 0.01$										
φ	0.14%	0.14%	2.95%	1.79%	0.14%	2.96%	2.96%	3.81%	3.46%	2.96%
k_g	0.41	0.41	0.71	0.56	0.41	0.26	0.26	0.63	0.44	0.26
$\frac{\widetilde{c}}{\widetilde{y}}$	0.78	0.83	0.59	0.68	0.78	0.55	0.60	0.50	0.52	0.55
$\widetilde{q}$	1.77	1.77	2.19	2.01	1.77	2.19	2.19	2.32	2.19	2.26
$\widetilde{r}$	4.35%	4.35%	11.37%	8.48%	4.35%	11.41%	11.41%	13.53%	12.65%	11.41%
$\frac{\widetilde{n}}{\widetilde{y}}$	-0.38	-0.38	0.95	0.49	-0.38	1.14	1.14	1.32	1.14	1.26
$\widetilde{E}$	0.21	0.17	0.41	0.80	0.86	0.44	0.39	0.50	0.85	0.90
Policy 3: $\overline{g} = 0.025, \overline{z} = 0.025$										
φ	-1.15%	-1.15%	2.3%	0.87%	-1.15%	2.5%	2.5%	3.6%	3.18%	2.5%
k_g	0.31	0.31	0.62	0.47	0.31	0.159	0.159	0.51	0.33	0.159
$\frac{\widetilde{c}}{\widetilde{y}}$	0.83	0.88	0.64	0.74	0.83	0.57	0.62	0.51	0.54	0.57
$\widetilde{q}$	1.57	1.57	2.09	1.88	1.57	2.12	2.12	2.29	2.12	2.22
$\widetilde{r}$	1.1%	1.1%	9.76%	6.18%	1.1%	10.28%	10.28%	13.03%	11.97%	10.28%
$\frac{\widetilde{n}}{\widetilde{y}}$	-1.41	-1.41	0.70	0.148	-1.41	1.00	1.00	1.29	1.00	1.20
$\widetilde{E}$	0.21	0.16	0.39	0.65	0.73	0.43	0.38	0.49	0.73	0.81

Table 4: Welfare Gains (a = 0.2)

	Low substitutability case, $\sigma = 0.33$				*Cobb-Douglas case,* $\sigma = 1$			
	Untied	*Productive*	*Intermediate*	*Green*	*Untied*	*Productive*	*Intermediate*	*Green*
Policy 1: $\overline{g} = 0.049, \overline{z} = 0.001$								
F_{nt}	0.049	0.387	**0.404***	0.090	0.082	0.148	**0.152***	0.052
F_t	0.065	**0.432***	0.312	0.033	**0.090***	0.073	0.062	0.017
Policy 2: $\overline{g} = 0.04, \overline{z} = 0.01$								
F_{nt}	0.051	**0.618***	0.532	0.061	0.082	**0.187***	0.161	0.040
F_t	0.062	**0.654***	0.423	0.021	0.089	**0.109***	0.077	0.012
Policy 3: $\overline{g} = 0.025, \overline{z} = 0.025$								
F_{nt}	0.054	**1.627***	1.169	0.023	0.080	**0.297***	0.221	0.027
F_t	0.059	**1.603***	0.968	0.007	0.083	**0.212***	0.134	0.006

Table 5: Welfare Gains (a = 0.6)

	Low substitutability case, $\sigma = 0.33$				*Cobb-Douglas case,* $\sigma = 1$			
	Untied	*Productive*	*Intermediate*	*Green*	*Untied*	*Productive*	*Intermediate*	*Green*
Policy 1: $\overline{g} = 0.049, \overline{z} = 0.001$								
F_{nt}	0.016	0.572	**0.976***	0.352	0.063	0.169	**0.315***	0.181
F_t	0.064	0.452	**0.455***	0.111	0.088	0.075	**0.1025***	0.053
Policy 2: $\overline{g} = 0.04, \overline{z} = 0.01$								
F_{nt}	0.026	0.824	**0.961***	0.220	0.066	0.207	**0.276***	0.136
F_t	0.061	**0.674***	0.518	0.067	0.087	**0.111***	0.1028	0.038
Policy 3: $\overline{g} = 0.025, \overline{z} = 0.025$								
F_{nt}	0.043	**1.921***	1.516	0.076	0.068	**0.318***	0.301	0.089
F_t	0.058	**1.625***	1.030	0.022	0.077	**0.209***	0.146	0.018

6 Conclusions

This paper analyzes the macroeconomic consequences of a permanent increase in foreign aid by considering a dynamic equilibrium model that takes into account environmental quality. We assume that both public investment in infrastructure and environmental protection through pollution abatement can be financed by the domestic government and international aid programs. In this setting, we consider four scenarios for aid allocation: untied aid, aid fully tied to infrastructure, aid fully tied to abatement, and aid equally tied to both expenditures. Our results show that from a policy perspective it is necessary to adapt the transfers not only to the structural characteristics of the recipient country (the elasticity of substitution in production and the degree of dependence of the economy on environment and natural resources) but also to the policies that the country is implementing.

The main conclusions we find are the following. First, when the recipient country's expenditure in infrastructure is low, fully tied to infrastructure programs are more effective than partially or untied ones. Second, when this expenditure in infrastructure is high, the effectiveness of the transfers depend on the recipient's chances of substitution in production and its degree of dependence on environment and natural resources. When this dependence is low, the higher the substitutability in production, the more effective the pure transfers. However, in those countries with a higher dependence on environment and natural resources, transfers devoted to both infrastructure and pollution abatement are more effective, regardless of the recipient's opportunities of substitution in production. Third, for most cases fully tied to pollution abatement programs generate the lowest gains on welfare, since although this type of transfers get raise the environmental quality they have not growth consequences. Finally, if we look at the environmental quality untied aid is the most detrimental alternative.

Appendix

Let $\{C_0, E_0\}$ denote the consumption and environmental quality paths associated to the original BGP of an economy with $\theta = 0$, and $\{C_t, E_t\}$ denote the time paths of consumption and environmental quality that result after a permanent aid increase to 5 percent. If we consider that the new BGP can be achieved immediately, then the discounted lifetime utility with $\theta = 0.05$ will be given by:

$$W(C_1, E_1) = \int_0^{\infty} \{\frac{[\widetilde{c}_1 K_0 e^{\widetilde{\varphi}_{K_1} t}]^{\gamma}}{\gamma} + a \ln \widetilde{E}_1\} e^{-\beta t},$$

where $\{C_1, E_1\}$ denote the consumption and environmental quality paths associated to the new BGP of an economy with $\theta = 0.05$ and $\widetilde{\varphi}_{K_1}$ denotes the constant capital growth rate at the new BGP. Hence, the welfare gain that abstracts from the transitional effects will be given by the following measure:

$$\digamma_{nt} = [(\frac{\widetilde{c}_1}{\widetilde{c}_0})^{\gamma} (\frac{\widetilde{\varphi}_{K_0}\gamma - \beta}{\widetilde{\varphi}_{K_1}\gamma - \beta}) - \frac{a(\ln \widetilde{E}_1 - \ln \widetilde{E}_0)\gamma(\widetilde{\varphi}_{K_0}\gamma - \beta)}{\beta \widetilde{c}_0^{\gamma} K_0^{\gamma}}]^{\frac{1}{\gamma}} - 1,$$

where $\widetilde{\varphi}_{K_0}$ is the constant capital growth rate at the original BGP and subscript nt represents that no transition is taken into account.

However, a permanent increase in θ generates transitional dynamic effects that must also be taken into account. The dynamics that characterize the transition between the steady states are recovered from the linearized system and by plugging the variables into the utility function we obtain:

$$W(C_t, E_t) = \int_0^{\infty} \{\frac{[\widetilde{c}_t K_0 e^{\widetilde{\varphi}_{K_t} t}]^{\gamma}}{\gamma} + a \ln \widetilde{E}_t\} e^{-\beta t},$$

where φ_{K_t} is the capital growth rate along the path that takes the transitional effects into account. Then, the welfare gains of an increase in foreign aid that takes the transition path into account can be obtained as:

$$\digamma_t = [\frac{\gamma(\widetilde{\varphi}_{K_0}\gamma - \beta)}{-(\widetilde{c}_0 \widetilde{K}_0)^{\gamma}} (\frac{K_0}{\gamma} \int_0^{\infty} c_t^{\gamma} e^{(\varphi_{K_t}\gamma - \beta)t} dt + a \int_0^{\infty} \ln E_t e^{-\beta t} dt - \frac{a \ln \widetilde{E}_0}{\beta})]^{\frac{1}{\gamma}} - 1.$$

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