Does Capital Mobility Undermine the Case for Aid?

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ABSTRACT

The conventional wisdom is 'yes' and the conventional wisdom may be wrong. Even under perfect capital mobility, aid in the form of grants allows domestic residents to increase consumption while incurring less debt. To study the importance of this, we use a dynamic dependent economy model which accommodates varying degrees of access to international capital markets. Contrary to the conventional wisdom, we find that the welfare effects of aid are not sensitive to the ease of access to capital markets. The model also describes plausible circumstances in which aid can raise welfare even when it reduces steady-state GDP.

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1 Introduction

It is widely believed that international capital mobility must weaken the case for foreign aid. In the recent literature, this argument is made explicitly in Moyo (2009) and Deaton (2013), with precedents in the writings of many other authors. In a detailed analysis, Caselli and Feyrer (2007) study the international variation in rates of return to capital, adjusted for international differences in the relative price of capital. They conclude that the variation is modest, and briefly argue that aid flows to developing countries are unlikely to have much effect on capital stocks and output. The implication is that aid is likely to be ineffective.

This paper questions the conventional wisdom. If we redirect attention from investment or GDP and instead focus on welfare, aid may have significant welfare benefits even when it does not greatly affect the path of the capital stock. Most aid takes the form of grants rather than concessional loans, but we look at both. When an economy has an open capital account, aid grants allow domestic residents to increase consumption and investment while incurring less external debt. In the model, the reduced need to incur debt is beneficial not only because there is less debt to service, but also via a pecuniary externality, since we follow Bardhan (1967) and many subsequent authors in assuming that lower levels of aggregate debt are reflected in lower borrowing costs. This debt-elastic borrowing cost also has implications for the timing of grants. It suggests that donors, for expenditure of a given present value, should front-load grants to keep borrowing costs down early in the convergence process.

The traditional case for aid emphasizes its effects on capital accumulation, but the reduced need for debt is a long-term benefit that has received less attention. In the models we consider, households receiving grants individually choose to incur less debt, as part of a decentralized equilibrium.[1] The essence of the paper's argument is that relaxing the intertemporal budget constraint of households is valuable even when aid does not greatly affect their investment decisions. In that case, the welfare benefits of aid should be less sensitive to the extent of international capital mobility than is usually assumed.

We investigate this hypothesis in detail, and find considerable support for it. We use a dynamic model of a small open economy which takes into account the effects of aid on the paths of debt and the real exchange rate. Using this model, we calculate the welfare gains from aid for economies that start some distance below their long-run growth path. Since we are interested in major transitions, we adopt a perfect-foresight model which allows us to solve for the global dynamics rather than approximating around a steady-state. In our main experiments, a perpetual aid flow equal to 5% of GDP along the balanced growth path will generate welfare gains equivalent to a 7.05% consumption gain in perpetuity, when the economy is relatively closed to capital flows and the steady-state debt-GDP ratio is 27%. If we then consider an otherwise equivalent economy with greater access to foreign capital, and a steady-state debt-GDP ratio of 84%, the welfare gain from the same level of aid is

[1] In some models, the effect of aid on the path of external debt could lower the probability of a financial crisis via the capital account, but we treat this question as beyond the scope of the paper. This is also true of questions arising from political economy considerations and volatile aid flows.

now equivalent to a 6.55% consumption gain in perpetuity. The welfare gains from aid are only modestly lower, given easier access to foreign capital.

As well as considering grants, we look at concessional loans. To keep as close as possible to the case of grants, we consider a scheme whereby the donor buys out existing debt at time zero, replacing it with a one-off concessional loan. We compare the welfare benefits of this policy with a stream of aid grants that has the equivalent cost to the donor in present value terms. The concessional loan effectively front-loads the transfers, partly by reducing the economy's debt burden at time zero, and thereby its borrowing cost. The front-loading benefits the recipient, and the concessional loan has welfare benefits that are higher than the benefits of ongoing grants. But, as in the case of grants, these welfare benefits are largely unaffected by the extent of capital mobility.

Throughout the paper, our focus is on low-income countries receiving aid. One issue that arises for low-income countries, especially where aid is concerned, is whether there can be a genuinely sharp distinction between consumption and investment. In practice, for those on low incomes, higher consumption may have lasting positive effects, through improved nutrition, health and shelter, and perhaps an easing of psychological pressures from living on scarce resources.[2] Higher consumption today may lead to higher productivity tomorrow. We therefore consider an extension to the analysis in which consumption is productive, in the sense of Steger (2002): higher consumption contributes to human capital, and this consumption-derived human capital increases output. Households are forward-looking and anticipate this effect in making their consumption decisions, which may lead them to incur more debt or defer investment. Our main conclusions continue to hold: the welfare gains from aid are similar to those cited above.

The results of the paper are developed using two-sector dynamic dependent economy models, with traded and non-traded goods. We build heavily on the work of Stephen Turnovsky and his co-authors, which develops tractable versions of this model suitable for a long-run welfare analysis. Chapter 4 of Turnovsky (1997) provides a textbook exposition of the basic dynamic model. In a paper that we draw upon extensively, Cerra et al. (2009) combine the dynamic dependent economy model with a debt-elastic cost of borrowing, instead of treating the capital account as either open or closed. We study the welfare benefits of aid in a closely-related setting, and discuss the preceding literature in the next section.

The dynamic dependent economy model has a striking implication which deserves to be better known: aid can raise welfare even in cases where it reduces steady-state GDP, compared to the case without aid. To derive this result, we assume that the traded sector is relatively capital-intensive. This matters for aggregate outcomes, because international transfers can lead to an increase in the size of the non-traded sector and a decrease in the size of the traded sector. If the traded sector is relatively capital-intensive, the general equilibrium outcome may be a reduction in the aggregate capital stock, and perhaps a

[2]On these latter effects, see Mullainathan and Shafir (2013).

reduction in steady-state real GDP, even when aid promotes higher welfare.[3] It gives a further reason to believe that cross-country regressions, which typically focus on GDP effects, can be misleading about the relationship between aid and welfare.

The remainder of the paper has the following structure. Section 2 describes the background to our paper and the related literature. Section 3 sets out the model and indicates some of its theoretical properties. Section 4 presents numerical simulations, considering alternative degrees of access to international capital markets. Section 5 presents an extension to the case of productive consumption. Section 6 describes an alternative extension, which solves for the social optimum when borrowing costs are debt-elastic. Section 7 concludes.

2 Background

The idea that capital mobility weakens the case for aid can be linked to a long-standing criticism of aid, advanced by Friedman (1958) and Bauer (1969, 1971). In a famous passage Bauer wrote, 'if all conditions for development other than capital are present, capital will soon be generated locally, or will be available to the government or to private businesses on commercial terms from abroad...' (Bauer, 1971, p. 97). As is well known, international capital flows have increased dramatically since the time Bauer was writing, and this seems to reinforce the argument that aid is less useful than formerly.[4]

The conventional wisdom has direct consequences for policy. For example, the belief that aid is less valuable to countries that are 'creditworthy' is built into the current architecture of the World Bank group. That architecture makes a formal distinction between countries eligible for IDA assistance, and those eligible for lending from the IBRD. Eligibility for IDA assistance, designed for low-income countries, is partly determined by whether countries are below an income threshold. But it is also influenced by the World Bank's internal assessments of creditworthiness (World Bank, 1989, 2010). These assessments have been confidential but, according to Galiani et al. (2016, p. 11), China and several other countries graduated from the IDA, and hence became ineligible for new IDA loans, while still below the relevant income threshold. In contrast, Bolivia remained eligible for many years after crossing the threshold, because it was judged not creditworthy. This approach to IDA eligibility assumes that countries are in less need of aid, and will benefit from it less, if they can readily access international capital markets.

The architecture of the World Bank reflects the presumption that low-income countries find it harder to access international capital markets. Although capital flows to emerging markets have sometimes been substantial, this is less true for capital flows to the poorest countries. Looking at data for 2006-2010, Alonso et al. (2014) notes that, for the Least Developed Countries (as classified by the United Nations) the volume of aid was higher than

[3] It may seem surprising that welfare can be increased by transfers which ultimately leave GDP lower than it would have been. Note, however, that from a welfare perspective, a measure of net national disposable income — GNP plus international transfers, minus depreciation — will typically be more relevant than either GDP or GNP.

[4] See, for example, Deaton (2013, p. 273).

all other sources of international financing put together. This fits with the usual presumption that, among non-OECD countries, low-income countries receive a relatively modest share of global private inflows. This may be changing, however. Araujo et al. (2015) document that capital flows to low-income countries, including non-FDI flows, are now sometimes substantial. This reinforces the need to analyze aid in the context of capital mobility.

When returns to capital are examined, the samples often include relatively few low-income countries. This is true of the sample in Caselli and Feyrer (2007), with just seven countries in sub-Saharan Africa. The later study by Lowe et al. (2012) has an extended sample, but only ten low-income countries. It is also worth noting that in multi-sector models, the return to capital often varies less than in the one-sector Ramsey model. This suggests that the marginal product of capital could sometimes be relatively similar across countries, even when those countries are some distance below their long-run growth path.[5]

It is sometimes argued that aid can 'pump-prime' private capital flows, which could make aid more valuable in a world of capital mobility. If aid is used to finance infrastructure, or to improve the investment environment in other ways, then aid flows might lead to higher private capital flows and productivity gains. Formal versions of this argument seem easy to construct, but they are not the central focus of this paper.[6] Instead, we consider a case where the only direct effect of aid is to relax the intertemporal budget constraint, and show that this is similarly valuable regardless of how readily an economy can access foreign capital.

There is a close link between our results and the study of capital mobility by Gourinchas and Jeanne (2006). Using simulations of neoclassical growth models, they showed that the welfare benefits of capital account liberalization are surprisingly modest under standard assumptions. Foreign capital inflows bring forward capital accumulation and growth, but the economy would converge to its steady-state growth path even in the absence of capital inflows. Unless future utility is discounted at a high rate, opening the economy to capital flows has welfare effects that are small when compared with, for example, international differences in consumption per capita.[7] The same logic tends to imply that the welfare effects of aid will be dominated by their direct effect in raising consumption, rather than by promoting faster convergence of the capital stock. Once this is recognized, it is clear that a welfare-based case for aid may be largely unaffected by access to foreign capital.

Our paper is also closely related to Chatterjee and Turnovsky (2004). They consider the effects of aid in a one-sector model with a role for public capital. Their Table 4 reports the sensitivity of welfare effects (translated into equivalent increases in the initial capital stock) to capital market imperfections. If the elasticity of substitution between private and public capital is low, then the welfare gains from a pure aid transfer are relatively unaffected

[5] Bardhan (1996) briefly discusses the evidence on international returns to capital, and considers a range of mechanisms through which returns could be similar, while wages vary widely across countries.

[6] A range of growth models with public capital are analyzed in Agénor (2013).

[7] Carter and Temple (2016) consider several growth models in which convergence is slower: aid then has larger welfare effects, but the effect on the path of the capital stock often remains relatively modest. The main exception is when there is a subsistence consumption constraint that is close to binding. In that case, transfers can make a substantial difference to the path of the capital stock.

by the ease of access to capital markets. For higher values of the elasticity, the welfare gains are increasing in the ease of access. Our analysis differs in a number of ways. We consider only pure transfers with no role for public capital, but use a two-sector model with traded and non-traded goods, and calculate welfare effects based on solutions for the full dynamics. This allows us to study transitions for economies with initial positions well below steady-state. In contrast Chatterjee and Turnovsky (2004) work with a linearized version of their model, and consider the dynamics only close to steady state (they look at transitions from a zero-aid steady-state to one with aid equal to 5% of steady-state GDP).[8] A further difference is that we give more attention to the apparently paradoxical relationship that can arise between aid and real GDP in the long run. The result that a pure aid transfer can reduce a steady-state GDP measure can be seen in Table 3 of Cerra et al. (2009), where GDP is denoted by Z in their notation. We study these effects in more detail, quantifying the effects of aid on real GDP as well as welfare. A final difference is that we briefly consider concessional loans, as well as grants.

The model that we adopt does not treat the capital account as simply open or closed. Instead, we assume that the cost of borrowing is increasing in the level of debt. The slope of this relationship determines whether borrowing costs are relatively insensitive, which is the case of near-perfect capital mobility; or highly sensitive, corresponding to restricted access to capital markets. Papers on the dynamic dependent economy which adopt this approach include Bouza and Turnovsky (2011), Cerra et al. (2009), and Chatterjee and Turnovsky (2004, 2007). It is especially convenient for numerical simulations, because it ensures that the steady-state outcome for consumption does not depend on the initial stock of assets, the so-called 'unit root' problem. For more discussion, see Schmitt-Grohé and Uribe (2003), Buffie and Atolia (2011) and Végh (2013).

3 The model

We consider a two-sector model of a small open economy with infinitely-lived, identical households who are Ramsey consumers. There are two goods, one traded and one non-traded. The relative price of the non-traded good, denoted p, will be an endogenous variable. In this simple model of a small open economy, p corresponds to the real exchange rate, and an increase in p corresponds to a real appreciation. Unless otherwise stated, variables such as debt and total output will be expressed in terms of tradeables. To convey the structure of the model as simply as possible, we initially present a version of the model with no technical progress, and with the population normalized to one.

With this structure, we have to determine whether physical capital will be traded or non-traded. The choice is discussed in detail by Turnovsky (1997). For a large sample of countries, Bems (2008) calculates that, on average, nontradables account for 60% of investment expenditure. Brock and Turnovsky (1994) analyze a model with both traded

[8] Atolia et al. (2010) find that obtaining exact solutions for the dynamics, without linearizing, is especially important when calculating welfare effects.

capital (e.g., machinery) and non-traded capital (e.g., structures) and find that the dynamic paths in that general case are qualitatively similar to the case where capital is purely non-traded. We therefore adopt that simpler formulation. The choice is also convenient since it ensures that the rate of investment will be finite without requiring the introduction of adjustment costs, which means we can economize on parameter assumptions.

The assumption that physical capital has to be produced domestically will be a force working against fast convergence, even in an economy which can borrow abroad. Here and throughout the paper, our use of the term 'capital mobility' does not refer to physical capital. Instead, capital mobility will correspond to international trade in a financial asset (bonds).

We will typically assume that it is the traded sector which is relatively capital-intensive. This has been a common assumption in the literature.[9] This is important for the part of the analysis which demonstrates that aid transfers can reduce real GDP, even while they increase welfare. In other respects, the assumption is less critical.

Each agent is endowed with a fixed amount of labour, normalized to one unit at each instant of time. The agent supplies their labour in exchange for a competitively-determined wage w. In each sector, output is produced according to a production function with constant returns to scale, and diminishing returns to capital and labour, defined as follows:

$$Y_T = F(K_T, A_T L_T)$$
$$Y_N = G(K_N, A_N L_N)$$

where T will be used to index the traded sector and N the non-traded sector. K_T and L_T are the quantities of capital and labour used to produce traded sector output (Y_T); A_T is an index of labour-augmenting efficiency in this sector. Similarly, K_N and L_N are the quantities of capital and labour used in the production of the non-traded good Y_N, and A_N is an index of labour-augmenting efficiency in the non-traded sector.

Capital and labor can move between the two sectors freely, with the sectoral allocations constrained by:

$$K_T + K_N = K \tag{1a}$$
$$L_T + L_N = L \tag{1b}$$

We assume the aid recipient is a debtor country, with limited access to the world capital market. It faces an upward-sloping supply of funds, so that the interest rate on external debt is increasing in a function of indebtedness, relative to traded sector output. To be more specific, the cost of borrowing will be written as:

$$r\left(\frac{D}{Y_T}\right) = r^* + \omega\left(\frac{D}{Y_T}\right); \quad \omega' > 0 \tag{2}$$

[9] Work that assumes the traded sector is relatively capital-intensive includes Kuralbayeva and Vines (2008) and Brock (2011); see also Froot and Rogoff (1995, p. 1675).

where D is the aggregate stock of external debt. r^* is the (given) world interest rate in terms of tradeables, and $\omega(.)$ is the borrowing premium, which is a function of the ratio of debt to traded sector output. This captures the idea that the cost of borrowing will be increasing in overall indebtedness. Support for the importance of this effect can be found in the evidence of Edwards (1984) and Uribe and Schmitt-Grohé (2016).[10]

In the existing literature, the cost of borrowing is typically an increasing function of the ratio of debt to total capital, output, or a measure of trend output. In this paper, we use the ratio of debt to traded sector output. The idea is that, for two countries with the same level of debt, the economy with the larger traded sector will find it easier to generate the trade surpluses ultimately needed to service the debt.[11] This approach is especially useful in the context of an economy beginning a long way below its steady-state. It ensures that, along the equilibrium path, traded sector output will always be strictly positive. Otherwise, in the early part of a transition, the economy may specialize completely in the non-traded sector. This seems artificial, and would also complicate the numerical simulation of the model. Our approach is a simple way to ensure both sectors are active at each instant.

Each household has access to international goods and financial markets. When their choices are aggregated, the stock of debt D will evolve as:

$$\dot{D} = C_T + pC_N + pI + r\left(\frac{D}{Y_T}\right)D - Y_T - pY_N - Aid$$

where C_T and C_N are the household's consumption of the traded and non-traded good respectively, I is investment, and Aid is an exogenous flow of aid denominated in tradeables. The capital accumulation constraint is:

$$\dot{K} = I - \delta K \tag{3}$$

where physical capital depreciates at rate δ. The traded and non-traded goods are both assumed to be normal goods, with downward-sloping demand curves. Note that aid is modeled here as a pure transfer which relaxes the intertemporal budget constraints of households directly, rather than being routed via a government. For a discussion of the increasing potential relevance of this approach, see Carter et al. (2015).

We now consider the decision problem of a representative household accumulating capital and debt. Note that households are treated as atomistic throughout, and hence do not internalize the effects of their borrowing and capital accumulation on the economy-wide interest rate. We return to this point later, and will contrast the decentralized equilibrium path with the social planning solution.

The household's optimization problem is to choose consumption levels C_T and C_N; sectoral labour allocations L_T and L_N; sectoral capital allocations, K_T and K_N, and the rates of accumulation of debt and capital, $\dot{D}$ and $\dot{K}$, to maximize lifetime utility:

[10] For a dissenting view, see the commentary by Dornbusch published with Harberger (1986).

[11] Joshi and Little (1994, p.237) briefly mention that this would be a logical way to think about limits to the size of external debt.

$$\int_0^\infty u(C(t)) \cdot exp(-\rho \cdot t) dt \tag{4}$$

subject to equations (1a)-(3) and given initial stocks of capital $K(0)=K_0$ and debt $D(0)=D_0$. Here $C(t)$ will be an index of real consumption and $\rho > 0$ is the discount rate. Throughout the paper, we work with isoelastic instantaneous utility, so $u(C) \equiv C^{1-\sigma}/(1-\sigma)$ where the elasticity of intertemporal substitution is given by $1/\sigma$ and is strictly positive. In the special case where $\sigma = 1$, the instantaneous utility function is $u(C) = \log(C)$.

Preferences over the two goods are defined by a CES index for real consumption:

$$C \equiv \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{5}$$

with associated price index $P \equiv \left(\gamma + (1-\gamma)p^{1-\theta}\right)^{1/(1-\theta)}$ and where θ is the elasticity of substitution between tradable and non-tradable consumption. γ indexes the relative importance of tradable consumption.

When $\sigma \neq 1$, the current-value Hamiltonian takes the form:

$$H = \frac{C^{1-\sigma}}{1-\sigma} - \lambda \left[C_T + pC_N + pI + r\left(\frac{D}{Y_T}\right) D - Y_T - pY_N - Aid\right] + \mu(I - \delta K) \tag{6}$$

where λ and μ are the current-value shadow prices associated with income and the capital stock respectively; we will refer to λ as the marginal utility of wealth. This is a straightforward optimal control problem. We can write the conditions for the control variables as:

$$\frac{\partial H}{\partial C_T} = \gamma^{\frac{1}{\theta}} C_T^{-\frac{1}{\theta}} \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{1-\theta\sigma}{\theta-1}} - \lambda = 0 \tag{7a}$$

$$\frac{\partial H}{\partial C_N} = (1-\gamma)^{\frac{1}{\theta}} C_N^{-\frac{1}{\theta}} \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{1-\theta\sigma}{\theta-1}} - \lambda p = 0 \tag{7b}$$

$$\frac{\partial H}{\partial I} = -\lambda p + \mu = 0 \tag{7c}$$

and if we note that $Y_T = F(K - K_N, A_T L_T)$, the two costate variables will evolve as:

$$\frac{\dot{\lambda}}{\lambda} = \rho - \frac{\partial H}{\partial D} = \rho - r\left(\frac{D}{Y_T}\right) \tag{7d}$$

$$\frac{\dot{\mu}}{\mu} = \rho - \frac{\partial H}{\partial K} = \rho + \delta - \frac{\lambda}{\mu}\frac{\partial F}{\partial K} \tag{7e}$$

We also require the factors of production, capital and labour, to be allocated efficiently:

$$F_{K_T}(K_T, A_T L_T) = pG_{K_N}(K_N, A_N L_N) \tag{7f}$$
$$F_{L_T}(K_T, A_T L_T) = pG_{L_N}(K_N, A_N L_N) \tag{7g}$$

The two original dynamic constraints on capital and debt are:

$$\dot{K} = Y_N - C_N - \delta K \tag{7h}$$
$$\dot{D} = C_T + r\left(\frac{D}{Y_T}\right) D - Y_T - Aid \tag{7i}$$

and two transversality conditions are needed to ensure long-run solvency and optimality:

$$\lim_{t\to\infty} \lambda(t) \cdot D(t) \cdot \exp(-\rho t) = 0 \tag{7j}$$
$$\lim_{t\to\infty} \lambda(t) \cdot p(t) \cdot K(t) \cdot exp(-\rho t) = 0 \tag{7k}$$

We assume that an interior solution, with strictly positive output in both sectors, obtains throughout. In practice, as discussed previously, this will be ensured by the dependence of the borrowing cost on the ratio of debt to traded sector output.

Rather than solve explicitly for the slope of the consumption path, it will be analytically more convenient to work with the dynamics of the marginal utility of wealth, as in Hayashi and Prescott (2008). Equations (7a) and (7b) are the Frisch demands, relating consumption levels of the two goods to the relative price and the marginal utility of wealth. Among the other equations, equation (7d) is a version of the standard Keynes-Ramsey rule, relating the rate of decline of marginal utility to the interest rate. Equation (7i) corresponds to the current account deficit.

Equations (7f) and (7g) are based on intersectoral factor mobility, which leads wages and the marginal products of capital to be equalized across sectors. These conditions will obtain whether the factors of production are allocated by households directly, or through the decisions of firms in the traded and non-traded sectors maximizing the net present value of their profits in the standard way.[12] Note also that by differentiating (7c) with respect to time, and combining this with (7d), equation (7e) can be used to derive the standard

[12] For an exposition see, for example, Sen (1994)

arbitrage equation:

$$\dot{p} = p\left(r + \delta - \frac{\partial G}{\partial K_N}\right) \tag{8}$$

which implicitly relates the interest rate (in terms of tradeables) to the return to holding capital, allowing for the capital gain or loss in holding a unit of capital. If there is an equilibrium with a constant r and constant p, then the above expression, combined with (7f) and (7g), implies that the steady-state relative price is determined by supply conditions and independent of demand, including aid transfers.

Our simulations will consider an extended version of the model with population growth and technical progress. We assume that households are infinite-lived dynasties which grow in size at rate n, and which maximize lifetime utility:

$$\int_0^\infty \frac{(c(c_T, c_N)A_T)^{1-\sigma}}{1-\sigma} \cdot L(0) \cdot \exp\left[-(\rho - n)t\right] dt \tag{9}$$

where $L(0)$ is the initial population size, and c_T and c_N are consumption of the traded and nontraded good respectively, in efficiency units (to be defined below). Technical progress is assumed to take place in both sectors at a constant rate g. We will assume throughout that $\rho > n + (1-\sigma)g$, the condition under which lifetime utility will be finite.

Once the optimality conditions have been derived as before, a simple approach to deriving a steady-state with balanced growth is to normalize relevant variables by $X(t) \equiv A_T(t) \cdot L(t)$, thus defining them relative to the product of traded sector productivity and population. These redefined quantities will be represented by lower-case counterparts to the upper-case levels variables. We also define sectoral employment shares as $\ell_T \equiv L_T/L$ and $\ell_N \equiv L_N/L$. Note that k_T and k_N will denote K_T/X and K_N/X respectively; the capital labour ratios will be given by k_T/ℓ_T and k_N/ℓ_N.

A transformed costate variable, which will be constant along the balanced growth path, will be denoted $\hat{\lambda} \equiv \lambda A_T^\sigma$. Adopting this approach, the system of equations can be written in terms of four differential equations:

$$\dot{d} = c_T - y_T + r\left(\frac{d}{y_T}\right)d - (Aid/X) - (n+g)d \tag{10}$$

$$\dot{k} = y_N - c_N - (n + g + \delta)k \tag{11}$$

$$\dot{\hat{\lambda}} = \hat{\lambda}\left(\rho + \sigma g - r\left(\frac{d}{y_T}\right)\right) \tag{12}$$

$$\dot{p} = p\left(r\left(\frac{d}{y_T}\right) + \delta - G_{K_N}\right) \tag{13}$$

and a set of static equations which hold at each instant:

$$\hat{\lambda} = \gamma^{\frac{1}{\theta}} c_T^{-\frac{1}{\theta}} \left[\gamma^{\frac{1}{\theta}} c_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} c_N^{\frac{\theta-1}{\theta}}\right]^{\frac{1-\theta\sigma}{\theta-1}} \tag{14}$$

$$p\hat{\lambda} = (1-\gamma)^{\frac{1}{\theta}} c_N^{-\frac{1}{\theta}} \left[\gamma^{\frac{1}{\theta}} c_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} c_N^{\frac{\theta-1}{\theta}}\right]^{\frac{1-\theta\sigma}{\theta-1}} \tag{15}$$

$$y_T = F(k_T, \ell_T) \tag{16}$$

$$y_N = G(k_N, (A_N/A_T) \cdot \ell_N) \tag{17}$$

$$\partial y_T/\partial k_T = p\partial y_N/\partial k_N \tag{18}$$

$$\partial y_T/\partial \ell_T = p\partial y_N/\partial \ell_N \tag{19}$$

$$k_T + k_N = k \tag{20}$$

$$\ell_T + \ell_N = 1 \tag{21}$$

We now discuss the conditions for a balanced growth path. It can be seen above that the chosen normalizations eliminate the productivity levels from the system of equations, with one exception. This is the production function in the non-traded sector, equation (17), in which the ratio of the productivity levels appears. Given this, the assumption that A_N and A_T grow at the same rate will be needed for a balanced growth path in which the relative price p and normalized quantities such as $y_N \equiv Y_N/X$, $c_N \equiv C_N/X$ and $k_N \equiv K_N/X$ are constant over time. We maintain this assumption throughout.[13]

The model set out above is essentially that of Cerra et al. (2009). Our version does not have a role for government, but introduces balanced growth, made straightforward by the normalization chosen above. As a four-dimensional system, the details of the transition paths have to be analyzed numerically for specific parameter values and functional forms. Cerra et al. (2009) indicate that the model will be saddle-path stable: there are two state variables (capital and debt) and two jump variables (the marginal utility of wealth, and the relative price of the nontraded good). Our simulation results are consistent with these dynamics.

In terms of characterizing the growth path, the steady-state interest rate (in terms of tradeables) will be pinned down by the Keynes-Ramsey rule in the usual way, so that $r = \rho + \sigma g$ along the balanced growth path. In turn, since borrowing costs are influenced by just one endogenous variable — the ratio of debt to traded sector output — the equilibrium interest rate pins down the value of this endogenous variable. Varying capital market access through the borrowing cost function, $r(d/y_T)$, will alter the steady-state ratio of debt to traded sector output, but not the steady-state interest rate. It can also be seen that these outcomes are independent of the amount of aid. The result that the equilibrium interest rate is not influenced by aid is familiar from the work of Obstfeld (1999) for a one-sector

[13] Froot and Rogoff (1995) and Rogoff and Obstfeld (1996) emphasize that the relative price will change over time even if productivity growth rates are the same in both sectors. However, this result arises when sectoral *TFP* growth rates are the same. When productivity growth is exclusively labor-augmenting, at rates which are the same across sectors, our result holds.

Ramsey model.

4 Numerical analysis

Having described the model, we will now use simulations to study the welfare effects of aid. A reliable calculation of welfare effects requires us to solve for the full dynamics, rather than linearize in the vicinity of the steady-state. To achieve this, we use the relaxation algorithm of Trimborn et al. (2008). This can be used to solve the system of differential equations (10)-(13) together with the static equations (14)-(21). The approach is based on a finite-difference method and generates fast and convenient numerical solution of a system of differential equations when a solution exists.

For numerical solutions, we will need to be specific about functional forms. The production technology in the non-traded sector will be assumed Cobb-Douglas. For the traded sector, we will assume the production technology is CES. The cost of external borrowing will be an increasing and convex function of the ratio of debt to traded output, as follows:

$$r\left(\frac{d}{y_T}\right) = r^* + \psi\left(\exp\left(ap \cdot \frac{d}{y_T}\right) - 1\right) \tag{22}$$

which is similar to Cerra et al. (2009) but using the ratio of debt to traded sector output, rather than debt to the value of the capital stock. r^* is the world real interest rate in terms of tradeables, and the parameters $\psi > 0$ and $ap > 0$ influence the borrowing premium above the world rate. Note that ap can be interpreted as the semi-elasticity of the variable component of the borrowing cost with respect to the debt-traded output ratio. In the case of perfect capital mobility, $ap = 0$ and the country borrows at the world interest rate, $r = r^*$. We will set $\psi = 1$, and use only ap to index the (inverse of) the degree of capital mobility. Relatively high values of ap correspond to limited access to foreign capital.

We begin by calibrating a benchmark economy with the set of parameters presented in Table 1. These parameters are chosen to represent a small, open, developing economy which we assume to start out from known initial capital-output and debt-output ratios.[14] We calibrate the level and growth rate of aid transfers such that, in the benchmark case, aid is equal to 5% of steady-state GDP.

To ensure a balanced growth path, we assume that the labor-augmenting productivity indices in the traded and the non-traded sector grow at the same rate, equal to 2% per annum. This corresponds to the rate adopted in Mankiw et al. (1992). We assume the depreciation rate is equal to 6% per annum, which is a standard value in the literature. We set the elasticity of intertemporal substitution to be 0.50, implying $\sigma = 2$, a standard choice and one consistent with estimates in Havranek et al. These parameter choices are sufficient to determine, via the Keynes-Ramsey rule, the equilibrium interest rate in terms of tradeables, which is equal to 7%.

[14] Note that output is not a state variable of the model, and so we use an iterative procedure to find the initial conditions for the state variables that generate the required outcomes at time zero.

Table 1: Parameters for the Benchmark Economy

Initial debt/output ratio	$D(0)/Y(0) = 0.2795$
Initial capital/output ratio	$p(0)K(0)/Y(0) = 1.23$ [1.94]
Preference parameters	$\rho = 0.03$, $\gamma = 0.5099$
Depreciation rate	$\delta = 0.06$
Traded sector elasticity of K/L substitution	$\sigma_{KL} = 0.80$
Traded sector steady-state capital share	$\pi_T^* = 0.35$
Non-traded sector output-capital elasticity	$\beta = 0.25$
Intratemporal elasticity of substitution	$\theta = 0.50$
Elasticity of intertemporal substitution	$1/\sigma = 0.50$
World interest rate in terms of tradeables	$r^* = 0.03$
Semi-elasticity of variable borrowing cost	$ap = 0.0392$
Weight on the borrowing premium	$\psi = 1$
Population growth rate	$n = 0.015$
Growth rate of efficiency (both sectors)	$g = 0.02$

Without loss of generality, we normalize the level of labor-augmenting efficiency in the non-traded sector to unity. We then infer the efficiency index for the traded sector so that, in the benchmark economy, the traded sector accounts for 40% of the value of total output in the steady-state. This is close to the unweighted average (0.405) calculated from the data for a range of countries by Morshed and Turnovsky (2004, Table 1) and to the value obtained for the Ivory Coast by Arellano et al. (2009).

With the equilibrium interest rate and the relative size of the traded sector known, we can then infer the key capital markets access parameter ap in order to match a given steady-state debt-output ratio. For the benchmark economy, we work with a value of 40% for this ratio, which is the same as in Cerra et al. (2009, p.162) and implies $ap = 0.0392$ in this calibration. We select the initial capital stock so that the initial capital-output ratio is 1.23, matching that in Carter et al. (2015), who construct their estimate based on a sample of low-income countries. We will also briefly consider an initial capital-output ratio of 1.94, corresponding to a country sample which spans a wider range of income levels. For comparison, Galiani et al. (2016) estimate the capital-output ratio to be roughly two in their sample of aid recipients.

Similarly, we choose initial debt so that the initial debt-output ratio matches that in a large sample of developing countries. We calculate the median of the ratio of net foreign assets to GDP for 74 countries in 2007.[15] The data on net foreign assets are taken from Lane and Milesi-Ferretti (2007).

The values of our preference parameters ρ and γ, and the world interest rate r^*, are similar to standard choices in the literature. For the value of γ, we use 0.5099: this implies that $\gamma^{1/\theta} = 0.26$, which corresponds to the case considered in Chapters 9 and 12 of Uribe and Schmitt-Grohé (2016), and Arellano et al. (2009, Table 2).

For the elasticity of substitution between tradable and non-tradable consumption, we use a value of 0.50, as in Chapters 9 and 12 of Uribe and Schmitt-Grohé (2016). They argue that this case has empirical support.[16] For comparison, Arellano et al. (2009, Table 2) use a value of 0.76 based on the estimate of Ostry and Reinhart (1992).

For the technology parameters, we impose an output-capital elasticity of 0.25 in the non-traded sector, which has a Cobb-Douglas production technology. This has been a standard choice in the literature: it corresponds to one of the two cases analyzed in Morshed and Turnovsky (2004), and the assumption of an output-capital elasticity of 0.25 for the non-traded sector is also used in Chapter 9 of Uribe and Schmitt-Grohé (2016), based on Uribe (1997). For the traded sector, we assume a CES production technology, with an elasticity of substitution between capital and labor of 0.80. We calibrate the distribution parameter of the CES production function so that the steady-state capital share is 0.35, implying that the traded sector is relatively capital-intensive. The equilibrium capital-output ratio is 2.23.

In the simulations, we will ultimately make use of several different national accounting concepts. GDP is gross domestic product, or the sum of domestic value added. GNI is gross national income, or GNP: in our model this will be equal to GDP minus interest payments on debt. Gross national disposable income (GNDI) will be GNI plus net receipts of transfers — in our case, aid. And all of these concepts have net counterparts, in which the total value of capital depreciation is subtracted. This latter adjustment will be more important than usual in our setting. This is because aid transfers are potentially associated with a lower steady-state capital stock, and hence with less need to cover the costs of depreciation, influencing welfare calculations.

First of all, we examine the effects of aid within this model. In the initial benchmark case, we assume that aid flows are equal to 5% of GDP in the steady-state. From this, we work backwards to obtain a time path for the (exogenous) flows of aid. We assume that aid is equal to a fixed share of the GDP of a donor country, and that the donor is growing along a balanced growth path. Hence aid per capita grows at the rate g in perpetuity. Under these assumptions, aid per effective worker is constant, which simplifies the analysis.[17]

[15] In our sample, most countries that were part of the Highly Indebted Poor Countries (HIPC) program had either completed it, or were near completion, by 2007. Source: http://www.imf.org/external/np/pp/eng/2011/110811.pdf

[16] In their case, it is also especially convenient for numerical solutions, because it leads the dynamics for debt and tradables consumption to be independent of non-traded output. In our case, this separation does not apply, because we treat traded output as endogenous and dependent on factor allocation, rather than determined by an exogenous endowment.

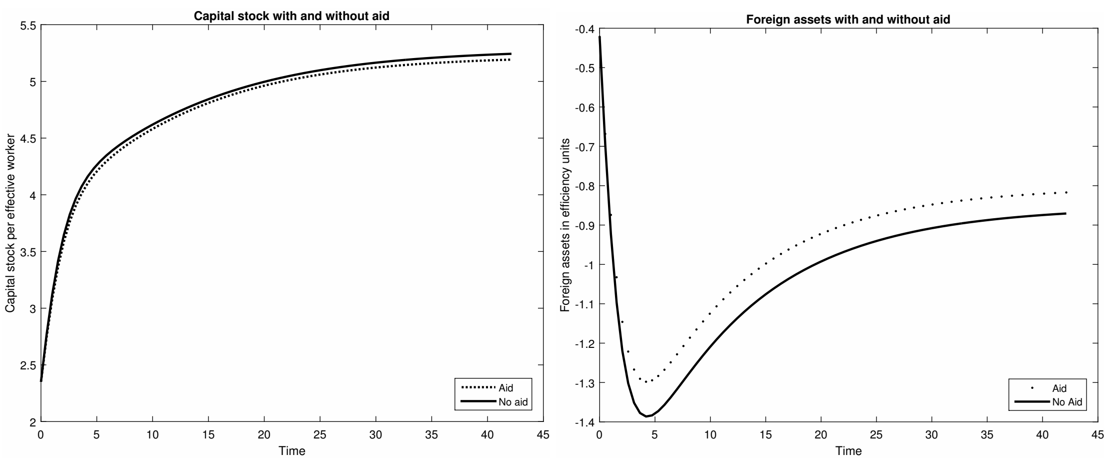
[17] Carter et al. (2015) use a similar approach. For a steady-state, we require that the long-run growth rate of aid is no higher than the long-run growth rate of efficiency.

We now discuss the effects of aid, assuming that the traded sector is relatively capital intensive. Figure (1a) shows the path of capital per effective worker without aid (the solid line) and with aid (the dashed line). It can be seen that less capital is accumulated in the presence of aid, for the reason briefly discussed earlier: transfers increase demand for traded and non-traded goods, and the latter effect implies that domestic output of the non-traded good must increase. This reduces the relative size of the traded sector, and if — as we assume — the traded sector is more capital-intensive, then long-run equilibrium can imply a lower capital stock and lower aggregate GDP in steady-state.[18]

This does not mean that aid is harmful, but it does mean that, in a model of this type, GDP and welfare can move in opposing directions. That aid reduces real GDP can be seen in Figure (2a), which shows a constant price measure of aggregate GDP, converging to a lower level in the case of aid.

In Figure (1b), we show the path taken by net foreign assets (so that declines in the path correspond to increased debt). Again, the solid line shows the path without aid, and the dashed line shows the path with aid. It can be seen that, when households receive transfers, they will incur less debt. A corollary is that aid recipients will face lower borrowing costs, increasing the welfare benefits of aid, although this effect is modest in practice (see Figure (3a)). The paths of the relative price and real wages are also relatively insensitive to aid: this reflects aid's modest effects on the path of the capital stock. The most important effect of aid is on the path of consumption: see Figure (4b). As anticipated, transfers allow aid recipients to maintain a higher level of consumption throughout. In this case, aid generates a welfare gain even though the path of real GDP is lower than before.

Figure 1: Capital stock and debt

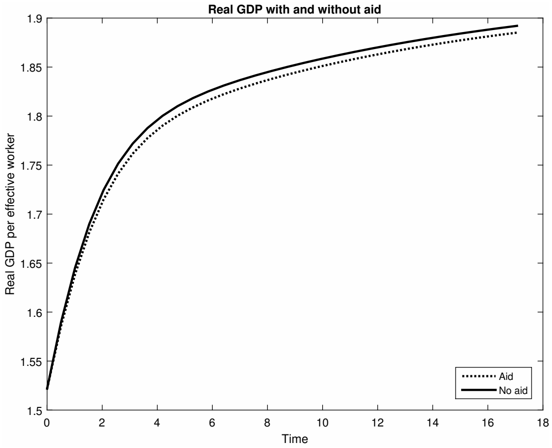


(a) Capital Stock (b) Foreign Assets

In the remaining figures, we present the effects of varying the ease of access to foreign capital. The benchmark value for ap is 0.0392; we also consider $ap = 0.02$ (greater access)

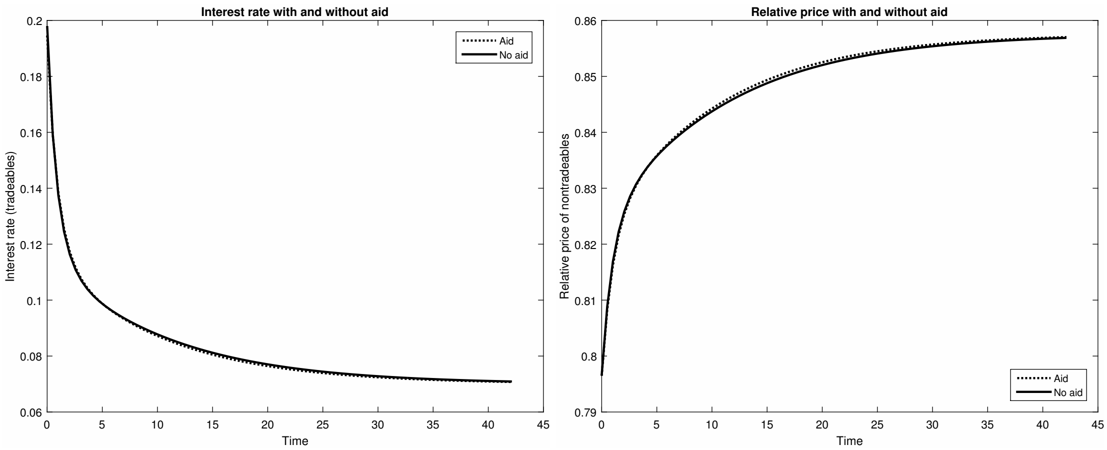
[18]This result can be seen in the analysis and simulations of Bouza and Turnovsky (2011) and Cerra et al. (2009).

Figure 2: Real GDP per effective worker



(a) Real GDP per effective worker

Figure 3: The interest rate and relative price



(a) Interest Rate

(b) Relative price

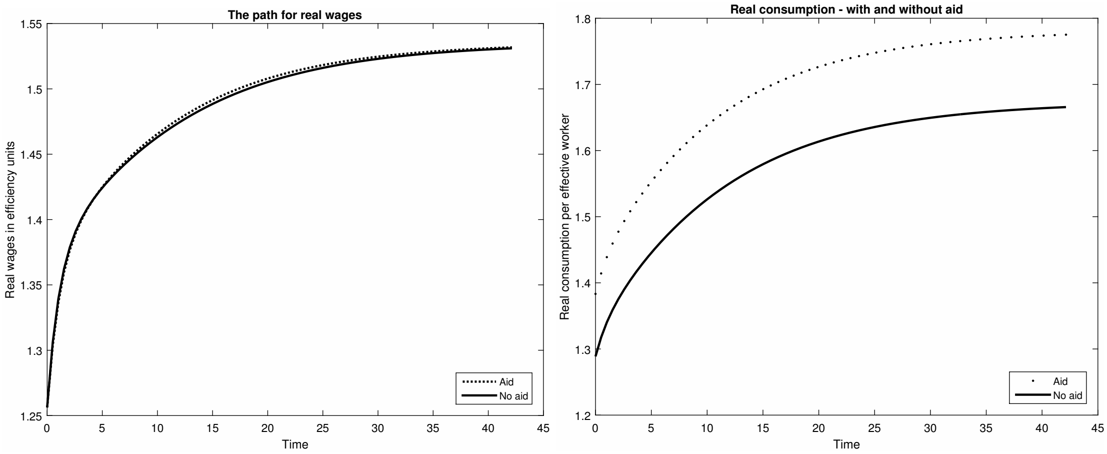
and $ap = 0.06$ (more limited access). This parameter variation has the expected effects on the capital stock and debt, with implications for the path of borrowing costs and the relative price of nontradeables.

To measure the welfare benefits of aid, we follow Gourinchas and Jeanne (2006) in using the Hicksian equivalent variation (HEV). Given the use of isoelastic preferences, there is a closed-form solution for the HEV in this setting, given by:

$$\Omega \equiv \left(\frac{U_{aid}}{U_{aid=0}} \right)^{\frac{1}{1-\sigma}} - 1 \tag{11}$$

if $\sigma \neq 1$, and $\Omega \equiv \exp(\rho(U_{aid} - U_{aid=0})) - 1$ if $\sigma = 1$. This has the standard interpretation: Ω translates a given increase in lifetime utility into the equivalent proportional increase in the consumption index, at each instant, that would generate the same increase in lifetime

Figure 4: Real wages and consumption



(a) Wages

(b) Real consumption

utility.

Here we focus on the case where the initial capital-output ratio is 1.23. We can think of these experiments as answering a donor's question: given today's stocks of debt and capital, to what extent will the welfare benefits of aid be contingent on what is assumed about the degree of capital mobility, from this point on wards? Table 2 shows the welfare gain from aid in terms of the Hicksian equivalent variation, presented as a percentage gain in consumption, under a range of degrees of access to capital markets. The only parameter we are varying is ap, so the steady-state interest rate is the same across these experiments, as is the value of aid when aid is given.

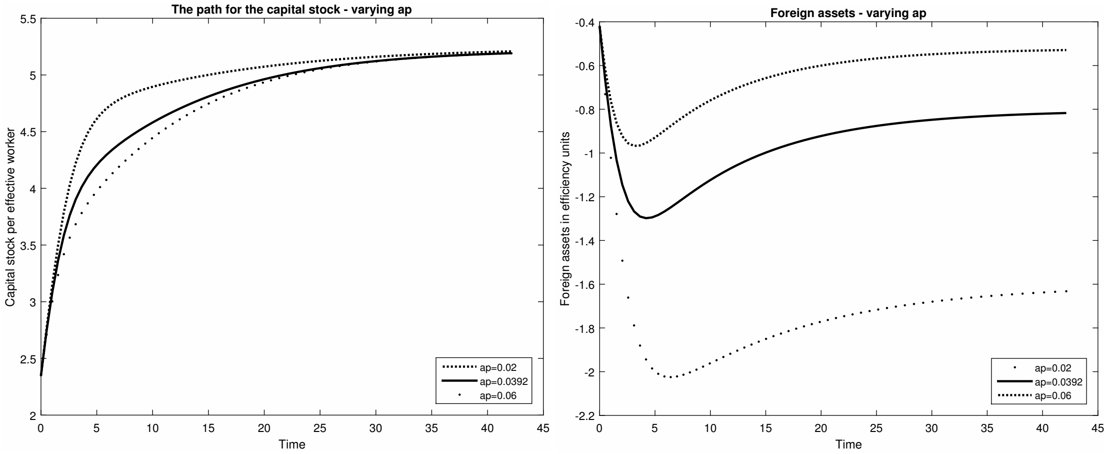
The final column of the table shows that the experiments span a wide range of access: the steady-state debt-output ratio (without aid) varies between 0.27 and 0.84. Yet the welfare gains from aid do not greatly vary, and aid is only slightly less beneficial in an economy relatively open to capital flows ($ap = 0.02$, $HEV = 6.55\%$) than in an economy relatively closed to capital flows ($ap = 0.06$, $HEV = 7.05\%$).

Table 2: Hicksian equivalent variation

ap	HEV	$(d/y)^*$
0.06	7.05%	0.27
0.0392	7.00%	0.40
0.02	6.55%	0.84

We now briefly consider the case of concessional lending. To retain much of the model and parameter assumptions used above, we look at the following scheme. Instead of providing a stream of grants, the donor buys out the existing stock of debt at time zero, and replaces it with concessional debt at the same level. We consider a case where no interest is payable on the concessional loan. We also assume that the borrowing cost is increasing

Figure 5: Capital Stock and Foreign Assets - varying ap



(a) Capital Stock (b) Foreign Assets

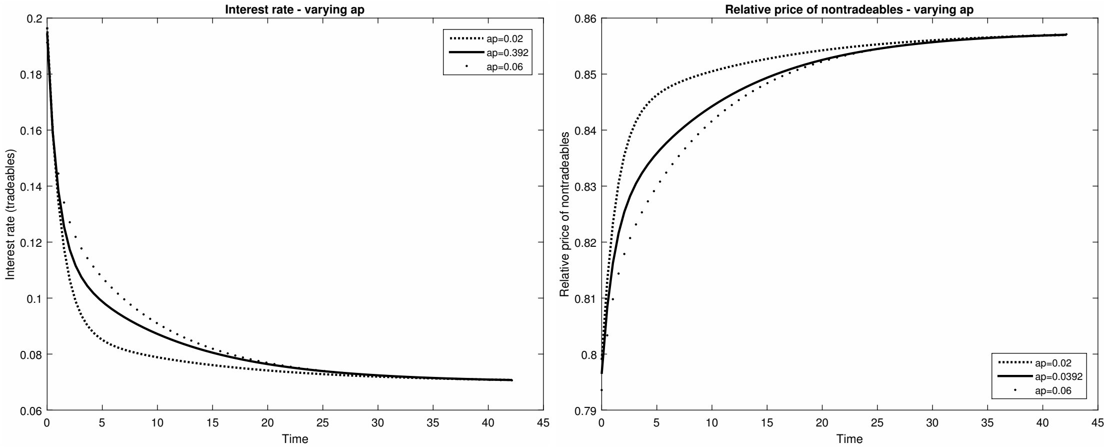
in non-concessional debt, as before, but independent of concessional debt. Asymptotically, given technical progress and population growth, the loan measured in efficiency units approaches zero. We compare the welfare gain from this scheme with that from a stream of aid grants, where the grant stream is chosen to have the same cost to the donor, in present value terms, as the total cost of the debt buy-out and concessional loan.

We find that, although the two policies effectively have the same cost to the donor, the welfare benefits of the debt buy-out and concessional loan are noticeably higher than the benefits of grants. The loan scheme effectively front-loads the benefits of the aid programme, reducing the debt burden at time zero and allowing the recipient to borrow at low cost in the early stages of the development process. This front-loading allows the recipient to achieve a higher level of welfare than would be possible from steadily growing grants with the same present value. From the perspective of this paper, however, the most interesting finding is that the welfare benefits from the concessional loan scheme are similar, regardless of the extent of capital mobility. In further work, we will examiner whether these results are robust to a borrowing cost that depends on concessional debt as well as non-concessional debt, as this will tend to reduce the welfare benefits arising from the concessional lending scheme considered here. We will also examine the timing of grants, and whether alternative front-loaded paths could deliver higher welfare, given that the cost of borrowing is debt-elastic.

5 Productive consumption

As we noted in the introduction, it is not clear that a sharp distinction between consumption and investment can be maintained for low-income countries. For poor households, higher consumption today could be associated with higher productivity in the future, through improved nutrition, health and shelter, among other mechanisms. This idea has been developed in the context of neoclassical growth models by Steger (2000, 2002). In this section,

Figure 6: Interest rate and relative price (varying ap)



(a) Interest Rate

(b) Relative price

we draw on the first of the two models in Steger (2002), which allows a straightforward extension of the preceding analysis.

Steger assumes that total capital is equal to the sum of physical capital and consumption-derived human capital, which are treated as perfect substitutes. Human capital depends on the level of consumption per capita; for simplicity, it depreciates at the same rate as physical capital. If x is an index of real consumption per head, and K_h is the total stock of consumption-derived human capital, then we have:

$$\dot{K}_h = L \cdot \phi(x) - \delta K_h \tag{23}$$

where the function $\phi(x)$ converts real consumption per head into human capital. Following Steger, we assume:

$$\phi'(x) > 0 \quad \phi''(x) < 0 \quad \lim_{x \to \infty} \quad \phi'(x) = 0 \quad \lim_{x \to \infty} \phi''(x) = 0 \tag{24}$$

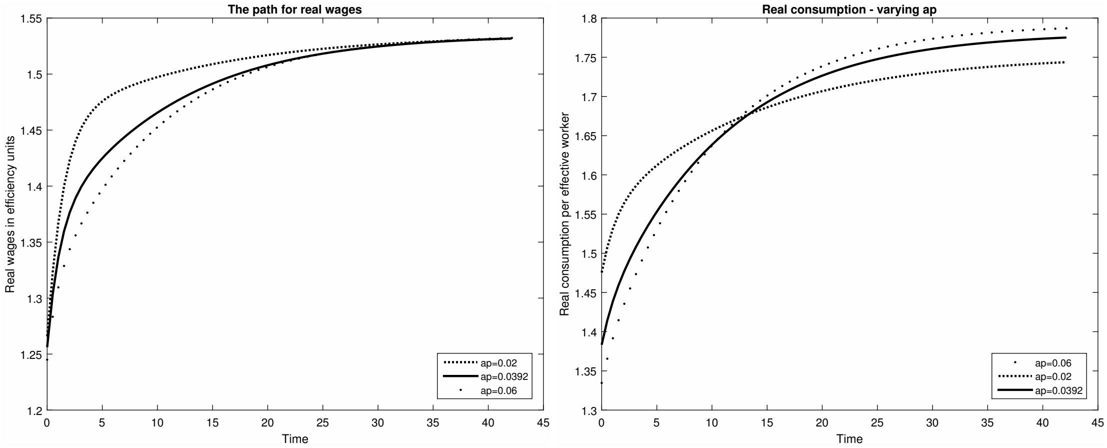
Rewriting (23) in terms of efficiency units, and combining with the standard equation for physical capital, we have:

$$\dot{k} = y_N - c_N + \phi(A_T \cdot c)/A_T - (n + g + \delta)k \tag{25}$$

where $c \equiv x/A_T$. The above differential equation is effectively the only change to the underlying assumptions of the previous model. When we work through the optimal control problem, the conditions (14) and (15) are modified to take into account the effect of consumption choices on consumption-derived human capital. It can be shown that.

We have repeated the earlier simulations, holding constant the existing parameter values and initial capital stocks and debt levels, but now introducing a productive consumption mechanism in the same way as Steger. The welfare effects of aid in this extended model

Figure 7: Real wages and consumption (varying ap)



(a) Wages (b) Real consumption

are close to those reported in Table 2. Hence, at least under the parameter assumptions of these simulations, allowing consumption to be productive does not have major effects on the welfare benefits of aid, or their ranking across varying degrees of capital mobility.

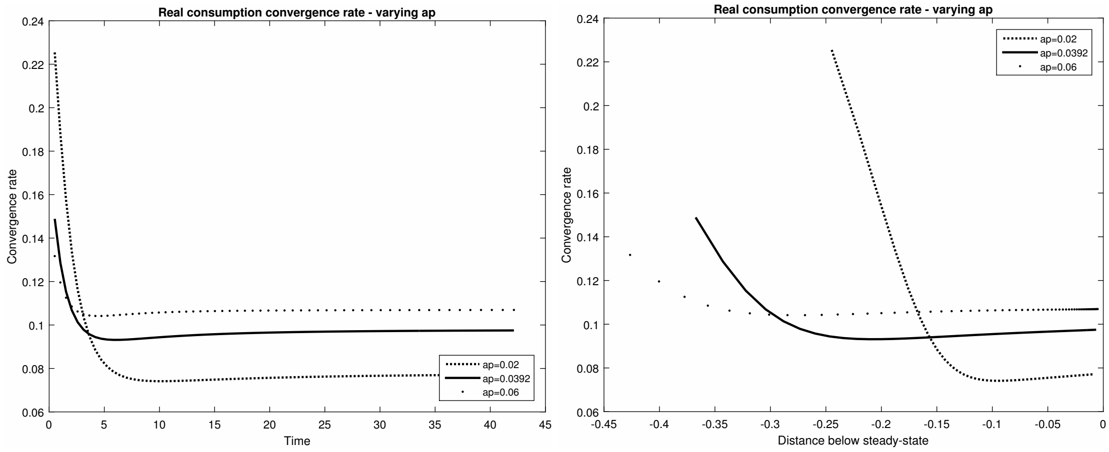
6 Social planning solution

The decentralized economy studied in sections 3 and 4 gives rise to two externalities, given that borrowing costs are increasing in the ratio of debt to traded sector output. The assumption of a debt-elastic interest rate has often been adopted in the literature since Bardhan (1967). As is well known, in a model of this kind, atomistic households will not internalize the negative effect of their borrowing on the economy-wide cost of borrowing. Collectively, households will borrow more heavily than would a social planner. Harberger (1986) developed this idea further, and argued that capital controls could be used to offset the externality associated with a debt-elastic interest rate.

In fact, the model we have studied involves two externalities rather than one, because borrowing costs depend on traded sector output as well as total debt. If an increase in the capital stock leads to an increase in traded sector output, this will lower the cost of borrowing for a given level of debt; but atomistic households will not internalize this effect when making their investment decisions.

This raises the question of whether the social planning solution for this economy could be decentralized through appropriate policies. The appendix shows that this can be achieved through a time-varying tax on borrowing and a capital subsidy, both of which are simple functions of the parameters and endogenous variables. This policy would be difficult to implement in practice, since it would require the policy instruments to be adjusted continuously, outside uninteresting special cases. Nevertheless, it is interesting to compare the associated welfare gains with the welfare benefits from aid, and also to ask whether com-

Figure 8: Consumption convergence rate (varying ap)



(a) Convergence rate over time (b) Convergence and distance to steady-state

bining aid with taxes and subsidies would be more or less beneficial than giving aid in isolation.

First of all, for our benchmark economy, we calculate the welfare benefits from the tax and subsidy that replicate the social planning solution. In the benchmark case, the use of these instruments leads to only modest welfare gains. We have also examined the welfare gains from aid, first for the decentralized economy without taxes and subsidies, and then for the economy where a tax and subsidy replicate the social planning solution. We find that the optimal tax and subsidy are mildly complementary to aid, rather than a substitute. The welfare effects of aid are slightly higher in economies which replicate the social planning solution with optimal debt and capital accumulation.

7 Discussion

One of the central findings of this paper is that the welfare benefits of aid are not greatly affected by the extent of international capital mobility; we have found that aid is only slightly less beneficial for countries that can readily access foreign capital. This result arises partly because transfers are used primarily to support higher consumption, rather than bring forward capital accumulation. This property of a calibrated growth model was first emphasized by Obstfeld (1999) and can be seen in some subsequent work on aid, including Arellano et al. (2009), Carter (2014), Carter et al. (2015) and Carter and Temple (2016). The empirical studies by Werker et al. (2009) and Temple and Van de Sijpe (2014), using instrumental variables, suggest that aid does indeed have stronger effects on consumption than investment, consistent with the earlier work of Boone (1996).

The idea that aid may finance consumption rather than investment is unlikely to appeal to aid advocates. It would typically seem easier for them to garner support for aid, and resist its critics, if aid had lasting benefits. In some ways, however, the conventional emphasis on investment as a means to lasting benefits may be misplaced. The analysis of this paper points to a different long-term benefit, which is that aid recipients incur less debt.

Even leaving aside the productive consumption mechanism, from the perspective of lifetime welfare, a sharp distinction between immediate and deferred benefits is somewhat moot. In the simulations presented here, households which receive aid are effectively deciding to prioritize their current welfare rather than accumulate capital rapidly. There is nothing inherently unreasonable in that decision, not least for those who are poor.[19] If there is latent resistance to the idea of welfare gains achieved primarily by higher consumption, with its unfortunate connotations of wastefulness, perhaps this could be overcome by recasting them as effects working via higher living standards.

8 Conclusions

In this paper we have studied the welfare benefits of aid, and the extent to which they are influenced by the ease of access to international capital markets. We find that the welfare benefits of aid are not greatly reduced by an ability to draw on foreign capital; in the simulation results, aid is only slightly less beneficial in countries that are relatively open to capital. Households use aid primarily to increase consumption, while incurring less debt. These results call into question the conventional wisdom that, in a world of increasing capital mobility, aid to low-income countries will be less beneficial than formerly.

Appendices

A Social planning solution

(Preliminary and incomplete.) The social planner's conditions for optimality differ in only two respects from the decentralized economy: the two dynamic conditions describing the evolution of the costate variables. These become:

$$\frac{\dot{\lambda}}{\lambda} = \rho - \frac{\partial H}{\partial D} = \rho - r\left(\frac{D}{Y_T}\right) - \frac{\partial r(D/Y_T)}{\partial D}D \tag{26}$$

$$\tag{27}$$

$$\frac{\dot{\mu}}{\mu} = \rho - \frac{\partial H}{\partial K} = \rho + \delta - \frac{\lambda}{\mu}\frac{\partial F}{\partial K} + \frac{\lambda}{\mu}\frac{\partial r(D/Y_T)}{\partial K}D \tag{28}$$

Using these results, it can be shown that a decentralized economy can mimic the social planning solution if there is a tax on borrowing equal to $\tau = \partial r/\partial D$, and a capital subsidy

[19] Investment today is valuable only because it allows higher consumption later, and the observation that consumption is the "sole end and purpose" of economic activity can be traced back to Adam Smith, and Chapter VIII of *The Wealth of Nations*.

equal to $s = \partial r/\partial K$, where the cost of borrowing is now $r + \tau$ and the return on capital, before depreciation, is now $(1 + s)F_K$.

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