Aid Allocation Rules

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ABSTRACT

This paper studies the aid allocation rule used by major development agencies, and investigates optimal allocations when recipients are neoclassical economies undergoing transition dynamics. When recipients face aid absorption constraints, allocations that favor poorer recipients are not always optimal, contrary to what is assumed in assessments of donor performance. The most quantitatively significant determinants of the optimal sensitivity to recipient characteristics are the generosity of the aid budget and the extent of absorption constraints. In neoclassical recipients aid can only accelerate growth where there is already growth, so the optimal rule places little weight on growth and optimality is largely a matter of balancing recipient need against absorption constraints.

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1 Introduction

Most multilateral development agencies and some bilateral donors now use explicit formulae that allocate funds on the basis of a recipient's need for assistance, and ability to use aid effectively. The World Bank's International Development Association, for example, which allocated \$16.3bn in 2011, uses this formula as the basis of its individual country allocations:

$$Aid\ per\ capita_i = \kappa(CPR_i)^5 \left(\frac{GNI_i}{N_i}\right)^{-0.125} \tag{1}$$

where Country Performance Rating (CPR) is a proxy for the ability of recipient i to use aid effectively, income per capita (GNI/N) is a proxy for need and κ is a constant of proportionality that adjusts to the aid budget.[1] The weights, in this example -0.125 and 5, determine how a donor's allocation responds to the recipient's need for aid, and ability to use it, respectively. Other donors use variants of this rule.

The importance of the weights in these rules is clear; their basis is not. This paper asks how these weights should be chosen, when the donor's objective is the maximization of total recipient welfare, and when recipients are modeled as neoclassical economies undergoing transition dynamics that face constraints upon the quantity of aid they can use effectively.

Earlier theoretical work on optimal aid allocation rules, such as Behrman and Sah (1984) and Dudley and Montmarquette (1976), was essentially static. The most influential recent work on aid allocation rules, by Collier and Dollar (2002) and Collier and Dollar (2004), has no basis in a structural economic model, and has also been criticized for only looking one period ahead and taking no account of each recipient's longer-term development prospects (Wood, 2008). In contrast, the approach taken here will be forward-looking and dynamic. The optimal weights in the allocation rule studied here are those that maximizes a long-run objective taking into account the dynamic response of recipients as aid is allocated by the rule over time. The neoclassical model is stylized, but may be used to develop ideas about aid allocation that apply more generally.

The negative exponent upon recipient income in donors' allocation rules reflects the intention to direct aid where it is most needed. Empirical analysis of donor aid allocation practices always assumes that greater responsiveness to recipient need is desirable. Many indices for comparing donor performance have been constructed - including Easterly and Pfutze (2008), Knack et al. (2011) and Roodman (2011) - and all reward more pro-poor allocation.[2] This paper demonstrates that in the presence of absorption constraints, and for realistic levels of donor generosity, the optimal exponent upon recipient income could be

[1] Actual IDA allocations involve a number of additional adjustments. See World Bank (2010) for details.

[2] Knack et al. (2011) follow Dollar and Levin (2006) and construct a selectivity index from the (negative) elasticity of donor allocations to recipient income per capita. Easterly and Pfutze (2008) use donors' percentile rank according to share of aid going to low income countries. Roodman (2011) adjusts each donor's aid according to its recipients' poverty (income per capita); the poorer the recipient, the greater the weight.

less negative than in (1) or even positive, directing aid *away* from where it is most needed, to avoid too much aid being directed at economies that are unable to absorb it effectively.

The most quantitatively significant determinants of the optimal sensitivity to recipient income turn out to be the size of the overall aid budget, and the level and form of the aid absorption constraint. The curvature of the recipient household utility function, which determines the impact upon total welfare of redistributing consumption across recipients, is relatively unimportant in the presence of absorption constraints.

Although donors target a range of development outcomes, the dominant criterion of aid effectiveness in the economics literature is its effect upon output growth in recipient economies. The Collier and Dollar (2002) rule also emphasizes growth: the donors' objective is to maximize poverty reduction via growth and no weight is given to aid-funded consumption. An estimated empirical relationship between aid and growth is used to derive an allocation rule that achieves this objective. The derived rule places positive weights upon indices of poverty and institutional quality, in each recipient.

In this paper donors seek to maximize recipient welfare and the division of aid between consumption and investment is decided by welfare-maximizing households in recipient economies, giving a prominent role to the welfare gained via aid-funded consumption. In this setting, the objective of allocating aid where it is most able to stimulate output growth is overturned: maximizing welfare can entail allocating aid where it is *least* able to stimulate growth. Donors may have a greater impact upon welfare by raising consumption in stagnant recipients than by accelerating growth in recipients that would be growing in any case.

This seemingly paradoxical result is a corollary of what has been called "Bauer's paradox" (Temple, 2010): if the conditions for aid to accelerate development are in place, then development will already be taking place.[3] In the neoclassical growth model this paradox prevails because aid will only accelerate output growth when given to economies that are undergoing transition dynamics (Obstfeld, 1999).

Whilst few would claim the simple neoclassical model adequately captures the growth process in developing economies, the idea that aid can only be expected to cause growth in economies that are already growing may apply more generally. It is implicit in the idea that aid only causes growth in recipients with 'good policies', if good polices are identified as those conducive to growth.

In principle, a donor wishing to weight aid towards recipients where it will stimulate growth could augment the rule with a term that identifies the potential for aid-funded growth. In the neoclassical growth model, the impact of aid upon growth will be greater the further the recipient is beneath its balanced growth path and the greater is the prevailing marginal product of capital. If levels of productivity differ across countries, the distance from steady-state is not necessarily negatively correlated with income, so targeting poverty does not amount to targeting growth potential. Although donors cannot directly observe

[3] Bauer (1971), pp. 97 − 98, paraphrased.

the marginal product of capital in recipient economies, allocation rules could incorporate proxies or estimates. This paper will study the following augmented rule:

$$Aid\ per\ capita_i = \kappa(CPR_i)^{\gamma}\left(\frac{GNI_i}{N_i}\right)^{\beta}(R_i)^{\tau} \tag{2}$$

where R_i is the marginal product of capital in recipient i, and the specific weights in equation (1) have been replaced with parameters. In the Collier and Dollar (2002) rule, the positive weight placed upon the quality of recipient institutions arises because the impact of aid upon growth is conditional on institutional quality. In contrast, here the World Bank's Country Performance Rating (CPR) is interpreted as a proxy for the recipient's aid absorption constraints, or ability to use aid effectively.[4] The absorption constraint determines the relationship between a recipient's gross aid allocation and the proportion of 'effective' aid received by the representative household, which is assumed to be a decreasing function of gross aid intensity a_{it}/Y_{it}. The impact of effective aid upon output growth is determined by the optimizing behaviour of recipient households and the prevailing marginal return to capital, and is unrelated to the extent of absorption constraints.

In the framework of this paper, when aid recipients are neoclassical economies undergoing transition, little is gained by the ability to target aid where it will fund growth. The optimal responsiveness to recipient growth potential, the parameter τ, is small and the improvement in recipient welfare achieved, compared to the unaugmented rule, is negligible. This conclusion is reached from experiments in which the impact of aid upon growth is roughly consistent with empirical estimates, based on the work of Clemens et al. (2011), and in which there is substantial variation in the marginal product of capital across recipients.

The remainder of the paper proceeds as follows. Section 2 briefly discusses the empirical relevance of aid allocation rules. Section 3 discusses foreign aid in the neoclassical (Ramsey) growth model and introduces absorption constraints to the model. Section 4 introduces the aid allocation rule, and considers how the welfare-impact of aid is affected by a recipient's initial conditions, or potential for aid-funded growth. Section 5 conducts a set of experiments to investigate the optimal weights in the basic allocation rule. Section 6 uses a set of calibrated recipients to investigate the optimal weights in a more realistic setting. Section 7 investigates the optimal augmented rule, capable of targeting growth, and section 8 concludes.

2 Empirical relevance

Fixed-coefficient allocation rules are used by the World Bank's International Development Association and the African and Asian Development Banks. The European Development Fund uses rules that include some other characteristics, such as measures of economic vul-

[4] This is consistent with the construction of the CPR index, which gives a weight of 68 per cent to the Public Sector Management and Institutions cluster of the CPIA rating system, emphasizing the recipient's ability to use aid effectively.

nerability, and the Millennium Challenge Corporation uses an allocation procedure based on recipient income and a set of performance indicators. A few major bilateral donors use explicit rules, whilst others 'benchmark' their allocations against allocation formulae.[5]

The extent to which actual disbursements conform to these rules is unclear, and other factors behind aid allocation decisions, such as political motives and historical ties, have found empirical support.[6] There is, however, evidence that these allocation rules are empirically relevant. A straightforward estimating equation for a single donor is suggested by taking logarithms of the allocation formula:

$$\ln\left(\frac{a_{i,t}}{N_{i,t}}\right) = \kappa_t + \beta \ln \frac{Y_{i,t}}{N_{i,t}} + \gamma \ln CPR_{i,t} \tag{3}$$

In practice empirical studies sometimes pool the aid of multiple donors and estimate a variant of equation (3) with the intention of recovering average elasticities of aid to recipient characteristics across donors. Utz (2010) estimates a version of equation (3) for the pooled aid of multilateral and bilateral donors, moving $\ln N_{i,t}$ to the right-hand side and using a constant instead of time dummies for κ_t. His findings for IDA eligible recipients are reproduced in Table 1. Multilateral donors are more sensitive to recipient income and performance than bilateral donors, and if anything the responsiveness to income is even larger than the published allocation rules, such as equation (1), suggest.[7]

Table 1: Estimated aid allocation rule from Utz (2010)

	Total	Multilateral	Bilateral
$\ln(Y/N)$	-0.32^{*}	-0.53^{*}	-0.22
$\ln(N)$	0.47^{**}	0.48^{**}	0.45^{**}
$\ln(CPIA)$	2.7^{**}	3.22^{**}	2.66^{**}
Obs	93	93	93
R^2	0.98	0.95	0.97

Dependent variable: natural logarithm of Official Development Assistance. CPIA: World Bank Country Policy and Institutional Assessment. IDA eligible recipients only. Constant included but not reported. * Significant at 5% level, ** significant at 1% level.

[5] See Anderson (2008), Utz (2010) and Wood (2008) for details concerning donors' use of allocation rules.

[6] See Alesina and Dollar (2000) and Hoeffler and Outram (2011). There are also official deviations from this simple formula. For example, the rule has been deemed to give insufficient aid to 'low income countries under stress', particularly post-conflict societies, that have low CPR scores. So many donors target such countries with supplementary funds. The AfDB has a dedicated Fragile States Facility, for example. Guillaumont (2008) argues this reveals the inadequacy of the simple allocation rule and proposes some extensions.

[7] The estimated coefficient on recipient population is evidence of small-country bias, something that is not investigated in this paper. The CPR score used in World Bank allocation rules differs from, but is highly correlated with, the overall CPIA. See World Bank (2011).

3 Aid in the Ramsey model

The main point of departure for this paper is Obstfeld (1999), in which foreign aid is analysed in Ramsey-type economies with initial conditions (capital per worker) beneath the state-state level.

An attractive feature of transition dynamics in the Ramsey model is the clarity of the relationship between aid, consumption, investment and growth. On the most basic conceptual level, foreign aid can be used to fund consumption or investment. Consumption is sacrificed for investment, with the purpose of raising future consumption. Investment generates output growth, but growth is not an end in itself; welfare is derived from consumption.

There is ample empirical evidence at the macroeconomic level that a large proportion of aid is consumed, Chatterjee et al. (2007) and Werker et al. (2009) being recent examples. Gertler (2012) finds that poor households divide cash transfers between consumption and investment in a fashion broadly consistent with the optimizing behaviour of recipient households in the neoclassical model. The empirical finding that aid largely funds consumption is sometimes cited as evidence that aid is largely wasted - an interpretation that is hard to motivate on theoretical grounds (Durbarry, 2004).

The introduction of aid into the Ramsey model is consistent with recent work which emphasizes the benefits of cash transfers to private households. Hanlon et al. (2010) argue that transfers direct to households would be more beneficial than traditional government-to-government aid. Given this recent work, it is natural to explore the consequences of relaxing household budget constraints, in a context where transfers can be wholly or partially invested, as in the Ramsey model.

This approach also has the advantage of simplicity. The neoclassical model is an aggregation of a large number of recipient households, each of which are too small to expect their behaviour to affect the economy's aid allocation. An obvious extension to the neoclassical model would be to incorporate a role for the government in the recipient economy, that might be expected to internalise the donor's allocation rule.[8]This would introduce complications of strategic interactions, in the context of dynamic games, that are beyond the scope of the present paper.

This paper also abstracts from the strategic problems that single donors face when allocating aid in the presence of other donors, and treats the problem as that of a single global donor. In the presence of multiple donors with different aid budgets, the optimal rule for a global donor corresponds to the weights that should be chosen if multiple donors are required to follow the same rule.

Foreign aid has been analyzed in more complex macroeconomic models, by Agénor et al. (2008) and Turnovsky (2011) for example, and aid allocation has been formulated as a dynamic contracting problem, most recently by Banerjee (2009) and Scholl (2009), but

[8] Hodler and Dreher (2012) presents a model in which recipients attract aid by choosing policies favored by donors.

the intention here is to understand optimal allocation rules as a function of the recipient characteristics that enter existing donor allocation rules, and to investigate whether aid-funded growth should play a role in allocation decisions. The basic idea here, of identifying an optimal allocation rule by simulating its use across multiple recipients over time, can be extended in many directions.

Donors are not explicitly modeled and aid is given in perpetuity, implicitly suggesting that recipient economies never catch up with donor economies; there is no absolute convergence. All but a few aid recipients seem unlikely to attain OECD levels of income over the coming decades, and until then aid allocation will be more a question of where to give aid rather than a question of when to withdraw it. In practice, convergence to a world technology frontier may occur in the long run, but the presence of discounting in the model attenuates the influence of the long run in any case.

3.1 The Basic Model

This section sets out the basic model of a neoclassical economy with aid, which is then extended with the addition of aid absorption constraints. The aid allocation rule itself is introduced later.

In this paper recipients are modeled as closed economies in transition, providing an environment in which aid may accelerate output growth - a prerequisite if the analysis is to be considered relevant by the donors who employ these allocation rules, and consistent with the empirical evidence that aid has a small positive effect upon growth (Clemens et al., 2011). Open economy models with credit market frictions would give aid a similar role, but would introduce complexities that are not the focus of the present paper.[9]

Aid may be consumed or invested in the same way as domestically produced output, so it enters into the equation of motion for capital in a straightforward fashion. Defining all variables in efficiency units, and assuming a Cobb-Douglas production function, the equation of motion for capital with aid becomes:

$$\dot{k} = k^{\alpha} + aid - c - (n + g + \delta) k \tag{4}$$

Where α is the output elasticity of capital, k, aid and c are capital, aid and consumption respectively, and n, g and δ are the rates of population growth, technological progress and depreciation, respectively. Subject to this, an infinitely-lived representative agent chooses consumption and investment to maximize lifetime utility, where utility is discounted at the rate ρ. Assuming a constant relative risk aversion instantaneous utility function, where σ captures the agent's willingness to shift consumption between periods, the solution to the maximization problem yields the familiar Euler equation, which describes the behaviour

[9] Such an approach would be consistent with the fact that to access IDA concessionary funds countries must be considered unable to "borrow on IBRD and market terms" (World Bank, 2010). 80 countries are currently eligible. Barro and Sala-i-Martin (2004) (p.171) conclude that 'an open economy with partial capital mobility looks much more like a closed economy than a fully open economy'.

of consumption over time. As noted by Obstfeld (1999), the presence of an exogenous flow of aid does not alter the intertemporal trade-off between consumption and investment, and hence aid does not enter into this expression:

$$\frac{\dot{c}}{c} = \frac{\alpha k^{\alpha-1} - \delta - \rho - n - \sigma g}{\sigma} \tag{5}$$

Together these equations imply the following steady-state levels for consumption and capital per unit of effective labour:

$$c^* = k^{*\alpha} + aid - (\delta + \rho + g)\, k^* \tag{6}$$

$$k^* = \left(\frac{\alpha}{\delta + \rho + n + \sigma g} \right)^{\frac{1}{1-\alpha}} \tag{7}$$

Aid does not enter into the expression for steady-state capital per effective worker, and thus does not affect the steady-state level of output per effective worker. This is because the long-run marginal product of capital is pinned down by structural parameters, such as the output elasticity of capital, and is thus independent of aid. Aid is present, one-for-one, in the expression for steady-state consumption per effective worker, which implies that aid is wholly consumed along the balanced growth path and does not stimulate steady-state investment and growth.[10]

Obstfeld (1999) provides full details of the dynamic response of the Ramsey model to receiving a fixed flow of aid. Even when initial conditions are substantially below steady-state, the representative household uses aid to fund consumption. In Obstfeld's basic calibration, the initial capital-labor ratio is less than one sixth of its steady-state value, yet 77.5 per cent of aid is consumed on impact.[11] Aid-funded investment accelerates the decline of the rate of return to capital accumulation, and in Obstfeld's baseline scenario the level of saving falls below the $aid = 0$ path after approximately 11 years. In other words, an economy that receives aid will bring forward its capital accumulation.

3.2 Absorptive Capacity

There are a number of reasons why donors may not wish to concentrate their resources on the poorest recipients; political motivations are often mentioned. But there are also various reasons to think that recipients may be unable to usefully absorb high levels of aid. Potential constraints include limited administrative capacity, a proclivity for waste and corruption that increases with abundance of aid received, and a range of structural

[10] Dalgaard et al. (2004) introduce aid to an overlapping generations model, and show that aid has an effect upon long-run productivity whose sign depends on how aid is allocated across generations. Their model also supposes a proportion of aid may be wasted.

[11] Comparing consumption at time $t = 0$ against a zero-aid counterfactual. It is not strictly possible to say how much aid is consumed in later periods, because consumption is higher relative to the counterfactual both because of the contemporaneous aid flow and past aid-funded investment.

arguments, such as Dutch Disease effects.[12] To introduce such considerations in a general way, I follow Carter et al. (2012) and take a 'reduced form' approach to the concept of aid absorption by adding an aid impact function to the standard expression for capital accumulation:

$$\dot{k}_t = k_t^\alpha + g\left(a_t, k_t\right) - c_t - (n + g + \delta)k_t$$

The aid impact function $g\left(a_t, k_t\right)$ determines the relationship between gross aid and effective aid. Some fraction of aid is wasted and this fraction is increasing in aid intensity, the ratio of aid to recipient GDP. This aid impact function is not internalized by recipient households, who are assumed to be too small to take account of how their investment decisions affect absorption.

Attempts to quantify absorptive capacity constraints in the context of aid allocation, such as Clemens and Radelet (2003), are generally based upon the estimated 'turning point' in aid-growth regressions - the level of aid intensity at which the marginal impact of aid upon growth is zero. Clemens et al. (2011) update the three most influential empirical aid-growth studies and find "substantial evidence" of diminishing returns, with estimated turning points in the range of 15 to 25 per cent of GDP. These estimates are based upon a quadratic functional form, which has particularly strong implications in the context of aid allocation: negative marginal returns at high levels of aid intensity. Other non-linear functional forms may fit the data equally well, without implying negative returns at high levels of aid intensity.

Unsurprisingly, the presence of negative marginal returns has a large effect upon the nature of optimal aid allocations. This is illustrated in this paper by the use of two alternative functional forms for the aid impact function, a quadratic in which the marginal impact of aid becomes negative at high levels of aid intensity:

$$g_A\left(a_t, Y_t\right) = \frac{a_t}{A_t L_t}\left(1 - \frac{a_t}{vY_t}\right) \tag{8}$$

and a logistic in which the marginal impact of aid tends to zero at high levels of aid intensity:

$$g_B\left(a_t, Y_t\right) = \frac{a_t}{A_t L_t}\left(1 - \frac{a_t v}{Y_t + a_t v}\right) \tag{9}$$

These expressions give net aid as a function of gross aid intensity, a_t/Y_t and the parameter v serves as an index of recipient absorptive capacity.[13] However, rather than insert v directly into the allocation rule, v may be translated into a more readily interpreted statistic: the percentage of aid absorbed at some reference level of aid intensity. For simplicity's sake, recipient absorptive constraints, as parameterized by v, are assumed to be constant

[12] See Bourguignon and Sundberg (2006) and van der Ploeg and Venables (2010) for discussion and theoretical treatments.

[13] Here a_t expresses aid in the same units as output Y_t, but $g\left(a_t, k_t\right)$ gives net aid expressed in recipient-specific efficiency units, corresponding to *aid* in equation (4).

over time, although absorptive capacity will vary over time as income per capita varies.

Figure 1: g_A and g_B aid impact functions for different levels of CPR

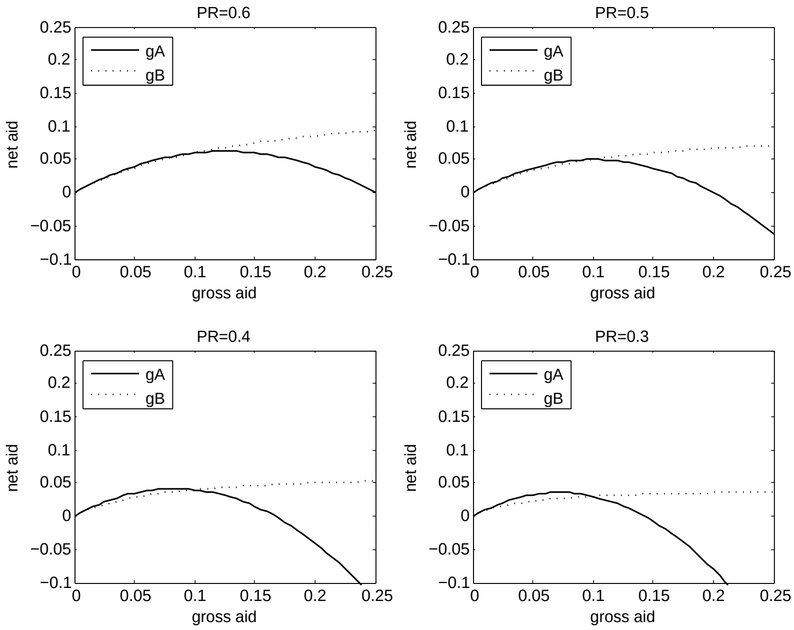


Figure (1) shows the two aid impact functions g_A and g_B at four levels of CPR. The horizontal axis shows gross aid intensity and the vertical shows net aid. The two functions track each other closely at lower aid intensities, but diverge at high levels as the marginal impact of aid becomes negative in the g_A function, culminating in a negative absolute net impact at very high aid intensities. The similarity of the two functions at lower levels of aid permits experiments that compare outcomes under g_A to those under g_B whilst holding the extent of the constraint constant.

4 Aid Allocation

This section presents the model used to study optimal aid allocation rules for multiple neoclassical recipients, and briefly discusses the empirical estimation of such rules. The section begins with some simple experiments designed to draw out some aspects of optimal aid allocation in a dynamic setting.

The analysis considers a donor with a fixed aid budget to disburse in perpetuity. In Carter et al. (2012) the optimal quantity of aid is determined within the model. But it may be that political considerations in donor countries are best understood as simply placing some arbitrary cap upon the quantity of aid - most likely as a percentage of national income, or of the government budget. In this case, the most relevant problem for aid agencies is how to allocate some exogenously-given quantity of aid, rather than anything resembling a calculation of optimal aid generosity.

The presence of diminishing returns in the utility function makes it natural to expect the greatest impact in poorer recipients. But how should a donor allocate aid between recipients with the same level of income but differing potential for aid-funded growth? As a preliminary exercise, to illustrate the impact of dynamics upon allocation decisions and give some insight into later results, I start by investigating how the impact of aid upon recipient welfare depends upon the scope for aid-funded growth, in the absence of absorption constraints.

In this experiment and all that follow, simulations are performed using the Matlab routine provided by Trimborn et al. (2008), a relaxation algorithm for computing transition paths in continuous-time macroeconomic models. An efficient algorithm is especially valuable in this context. When simulating transition for 20 recipients in section 6, which entails solving 40 non-linear differential equations simultaneously, the search for the optimal parameterization of the rule in each experiment takes several days, running in parallel on a high-powered computing cluster.

4.1 Aid-funded growth and welfare

Donors taking allocation decisions need to know where aid has the greatest impact upon welfare. It is perhaps natural to expect aid to have a greater impact upon recipient welfare when it has a greater impact upon growth, ceteris paribus. In a dynamic setting, the question of where a given quantity of aid has the greatest impact upon recipient welfare must be translated into a question concerning a given flow of aid for a given duration. The result that aid has the greatest impact upon welfare where it is least able to stimulate output growth, in the presence of Bauer's paradox, holds when the duration of the aid flow is sufficiently long. Here, this result is illustrated in its starkest form, when a fixed flow of aid is allocated in perpetuity. [14]

In this preliminary experiment initial income per-capita $Y_0/N_0 = Ak_0^\alpha$ is held constant whilst the levels of productivity and the initial capital-labour ratio are varied together, in order to vary the distance from steady-state and scope for aid-funded growth.

The impact of aid upon welfare is measured relative to a zero-aid counterfactual using Hicksian equivalent variation, as in Gourinchas and Jeanne (2006). This makes the change in lifetime utility arising from aid easier to interpret, by transforming it into an equivalent percentage change in consumption in perpetuity. More precisely, the Hicksian equivalent variation corresponds to a percentage increase that if applied to consumption at every instant along the counterfactual zero-aid path, would result in the same utility gain as delivered by aid. Lifetime utility for each economy can be readily calculated from the simulation. The formula for Hicksian equivalent variation in the current model, assuming $\sigma \neq 1$, is:

[14] Carter et al. (2012) introduce a framework to derive the fully flexible optimal path of aid, unconstrained by an allocation rule or fixed budget. In that setting, a donor allocating aid between two economies of identical initial income, one stagnant and one growing, would optimally give the growing economy slightly more aid, over the first few years.

$$HEV = \left(\frac{U_a}{U_0}\right)^{\frac{1}{1-\sigma}} - 1 \tag{10}$$

where U_a is lifetime utility with aid and U_0 the lifetime utility without, calculated at time $t = 0$.

Figure 2: Initial conditions and welfare impact of aid

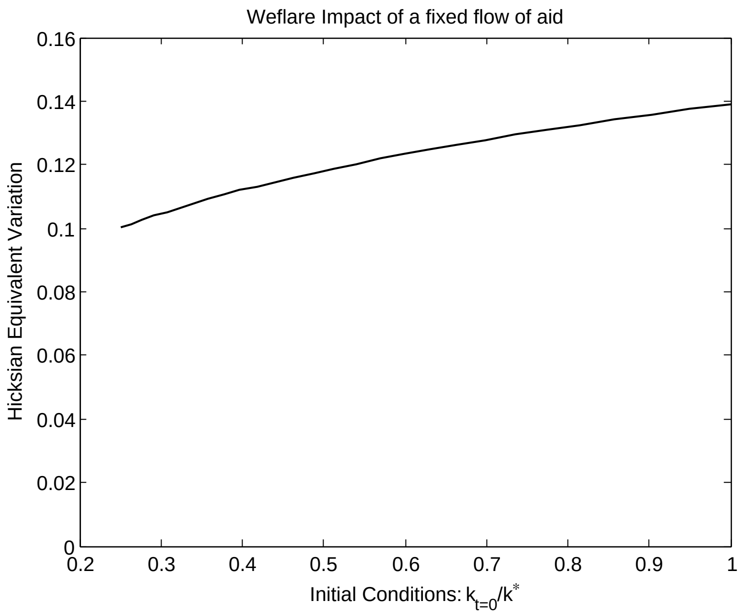


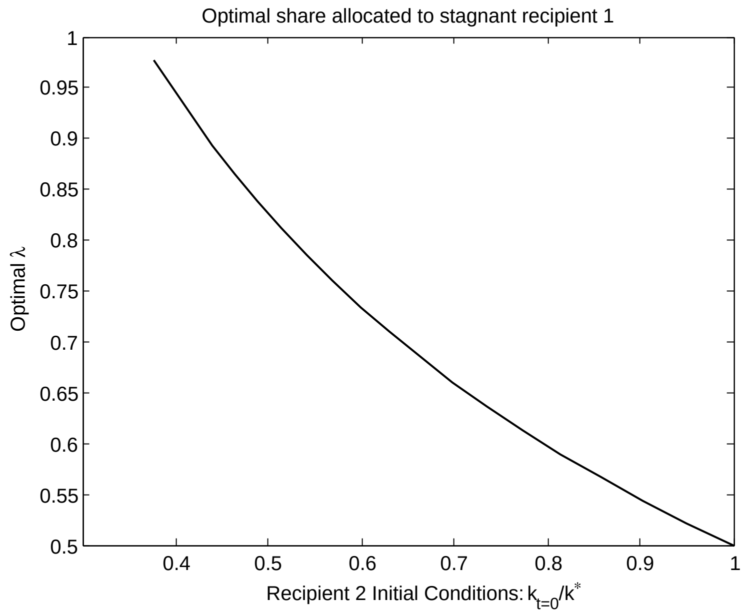
Figure (2) shows the impact of a constant flow of aid upon recipient welfare, holding initial per-capita income constant and varying the initial distance from steady-state, and hence the scope for aid-funded growth.[15] The impact of a given flow of aid upon lifetime welfare is greater the nearer the economy is to its steady state (when $k_0/k^* = 1$), and the more aid feeds into consumption and the less into investment and growth.

Now consider a donor faced with the problem of dividing a fixed flow of aid between two recipients of identical initial income but differing growth potential, with the objective of maximizing the sum of recipient lifetime welfare. In this experiment, recipient 1 is 'stagnant', in steady-state at the start of the simulation, and receives a flow $a_1 = \lambda D$, whilst recipient 2 is growing, initially beneath steady-state, and receives $a_2 = (1 - \lambda)D$, where D is the sum of aid to be disbursed. Figure (3) shows the optimal distribution parameter λ as the scope for aid-funded growth in recipient 2, initial distance beneath steady-state, is varied.

The idea that aid should be allocated where it is most able to accelerate growth is not supported in this forward-looking setting: the greater the scope for aid-funded growth in recipient 2, the smaller its optimal share of aid. Although recipient incomes are initially

[15] The structural parameters used in this experiment are $\alpha = 0.4$, $\sigma = 1.5$, $\delta = 0.06$, $g = 0.02$, $n = 0.015$, $\rho = 0.03$. Initial population is 1 in each recipient and the aid flow is equivalent to 10 per cent of total initial recipient income. Parameter choices will be discussed later in this paper.

Figure 3: Targeting the stagnant recipient



equal, the recipient in which aid will accelerate growth will already richer be the absence of aid, from a lifetime perspective, because it has growth to come. This is a version of Bauer's paradox: aid can only accelerate growth where there is already growth. Rather than target growth, donors should target stagnant recipients.

But of course donors do not allocate aid in perpetuity; a three-year budget window is typical. The allocation rule that is the object of study in this paper adjusts allocations continuously over time. An allocation rule capable of targeting growth will be presented in section 7. Should we expect such an optimal allocation rule to give relatively little weight to growth potential, in the presence of Bauer's paradox?

When aid allocations are fixed for a long duration, weighting aid towards the growing recipient means, over time, favoring the recipient that is both richer and for whom aid has lost the ability to spur growth, as transition dynamics are exhausted. But when using an allocation rule capable of switching aid away from recipients as they become richer and converge on their balanced growth paths, it may be optimal to weight aid towards growing recipients.

Even so, the presence of Bauer's paradox will attenuate the optimal weighting towards growth. Consider again the problem of allocating aid between two recipients of identical initial income but differing growth potential. Should we expect to see aid initially weighted towards growth, only to be switched away later? At time $t = 0$ the opportunity cost of weighting aid towards growth is that current consumption is not raised in the stagnant recipient; the benefit is raising *future* consumption in the growing recipient. How much does raising future consumption contribute to the donor's objective? That depends on the counterfactual level of the consumption path in the recipient where aid funds growth, and in the neoclassical setting as the magnitude by which aid may raise future consumption rises, so the level of the counterfactual consumption path rises and the welfare gained by raising consumption falls. So Bauer's paradox weakens the case for weighting aid towards growth, even when aid allocations are not fixed for long durations and can be switched away as growth occurs.

4.2 Aid Allocation Rules

We now turn to the problem of a donor who wishes to allocate a fixed quantity of aid D between recipients, according to a rule that varies the allocation over time. More precisely, D is the initial level of the path of the global aid budget, which is assumed to grow at the rate g, corresponding to the rate at which labor-augmenting technology A grows. In what follows, a two-recipient case will be presented for ease of exposition, but generalization to multiple recipients is trivial. The allocation problem can be reduced to time-varying distribution parameters that allocate aid: $aid_{i,t} = \lambda_{i,t} D$.

The donor chooses a path for $\lambda_{i,t}$ that maximizes the sum of recipient lifetime utility:

$$\max_{\lambda_{i,t}} \int_0^\infty U\left(c_{1t}\right) e^{-\rho t} dt + \int_0^\infty U\left(c_{2t}\right) e^{-\rho t} dt$$

where each recipient $i = [1, 2]$ solves:

$$\max_{c_i} \int_0^\infty U\left(c_{i,t}\right) e^{-\rho t} dt$$

$$\text{s.t. } \dot{k_{i,t}} = k_{i,t}^{\alpha} + aid_{i,t} - c_{i,t} - (n + g + \delta)\, k_{i,t}$$

$$aid_{i,t} = \lambda_{i,t} D,\ k_{1,t=0},\ k_{2,t=0}$$

But, for the purpose of this paper, rather than choose an unrestricted optimal path for $\lambda_{i,t}$, the donor is required to commit to an aid allocation rule that defines $\lambda_{i,t}$. Expressed in logarithms, and replacing the specific coefficients in equation (1) with parameters β and γ, the aid allocation rule is:

$$\ln aid_{i,t} = \ln N_{i,t} + \beta \ln \frac{Y_{i,t}}{N_{i,t}} + \gamma \ln P_i \tag{11}$$

where P replaces CPR for sake of notational compactness. In the case of two recipients, the distribution parameter can be written as:

$$\lambda_{i,t} = \frac{aid_{i,t}}{aid_{i,t} + aid_{j,t}}$$

At time t, country i receives $\lambda_{i,t} D$. The aid allocation rule can then be substituted into this expression, to give:

$$\lambda_{i,t} = \frac{y_{i,t}^{\beta} P_i^{\gamma} N_{i,t}}{y_{i,t}^{\beta} P_i^{\gamma} N_{i,t} + y_{j,t}^{\beta} P_j^{\gamma} N_{j,t}}$$

This definition of $\lambda_{i,t}$ has the necessary property of being bounded between 0 and 1, and of being 0.5 when the two recipients are identical. The speed at which λ moves towards its bounds in response to differences in recipient income per capita and absorptive capacity is determined by β and γ respectively.

Note that the formulation $aid_{i,t} = \lambda_{i,t} D$ differs from equation (1) which does not explicitly account for the quantity of aid disbursed (it is implicit in κ). $aid_{i,t} = \lambda_{i,t} D$ can be re-written:

$$aid_{i,t} = \frac{D}{y_{i,t}^{\beta} P_i^{\gamma} N_{i,t} + y_{j,t}^{\beta} P_{j,t}^{\gamma} N_j} \left(y_{i,t}^{\beta} P_i^{\gamma} N_{i,t} \right)$$
$$\ln aid_{i,t} = \kappa_t + \ln N_{i,t} + \beta \ln \frac{Y_{i,t}}{N_{i,t}} + \gamma \ln P_i$$

where $\kappa_t = \ln \left[D / \left(y_{i,t}^{\beta} P_i^{\gamma} N_{i,t} + y_{j,t}^{\beta} P_j^{\gamma} N_{j,t} \right) \right]$. The term κ_t is time-varying but identical across recipients in each period, and can be captured in empirical applications by donor-specific time-dummies.

This rule does not determine a recipient's allocation as a function of its characteristics in isolation. The coefficients β and γ determine the responses to how a recipient *differs* from other recipients. Strictly speaking, the standard interpretation of β as capturing the predicted change in aid allocated to recipient i if its income increases, holding all else constant, is misleading because that recipient's income also enters κ_t. What matters is whether a recipient's income has changed relative to the incomes of other recipients, not how it changes in isolation.

The analysis will now proceed in two parts. In section 5 a number of examples are employed to illustrate the determinants of the optimal coefficients in the aid allocation rule. The points made about aid allocation are primarily conceptual. In section 6 the optimal coefficients will be found for a set of calibrated aid recipients.

5 Aid allocation principles

In this section the determinants of the optimal coefficients in an aid allocation rule are investigated via a series of experiments. The baseline recipient calibrations employed in these illustrative experiments are shown in Table 2 and the structural parameter choices in Table 3. Data are taken from Penn World Table version 7.1. The experiments constitute departures from this baseline, varying one aspect at a time. The allocation rule is applied to a set of six recipients, a number large enough to introduce interesting variation but small enough to be easily presented.

Table 2: Baseline recipient calibration

Recipient	1	2	3	4	5	6
$k_{t=0}$	3	3	3	3	3	3
A	1	1	2	2	3	3
P	0.3	0.5	0.3	0.5	0.3	0.5
k*	6.11	6.11	6.11	6.11	6.11	6.11
$Y_{t=0}$	1.55	1.55	3.10	3.10	4.66	4.66

The baseline calibration of the six recipients used in this section's experiments.

Here P is defined as the percentage of aid absorbed when $aid/Y = 0.1$, approximately the mean level of aid intensity for recipients in Sub-Saharan Africa.[16] Initial conditions ($k_{t=0}$) are roughly 50 per cent beneath steady state and each recipient's initial rate of GDP growth, measured over the first simulated year, is 3 per cent. Total recipient output at $t = 0$ is 18.6. Productivity in the richest recipients, five and six, is three times higher than in the poorest, recipients one and two. This ratio is roughly an order of magnitude smaller than the gulf between the richest and poorest countries in Sub-Saharan Africa, so these initial experiments involve economies with more equal incomes than real aid recipients.[17]

Table 3: Baseline choice of structural parameters

Parameter	Value	Source
α	1/3	(1-Labor share of income) consistent with Gollin (2002)
ρ	0.03	Obstfeld (1999)
σ	1.5	Evidence surveyed in Hall (2009) and Jones (2011)
n	0.015	Approximate mean population growth rate since 1990
g	0.02	Approximate mean growth rate of real output per capita since 1990
δ	0.06	Bernanke and Gürkaynak (2002)

5.1 Aid generosity

The first experiment demonstrates that the generosity of the total aid budget, D, relative to initial total recipient income, has a large impact upon the optimal coefficients in the aid allocation rule. Table 4 shows optimal β and γ for four levels of generosity, $\frac{D}{\sum Y_i}$, for the two aid impact functions g_A and g_B.

The interpretation is straightforward: when a large quantity of aid is being allocated, a rule that responds strongly to recipient income can swamp the poorest recipient with aid. In the presence of absorption constraints, giving too much aid to poor recipients is wasteful; if the aid impact function implies a negative marginal impact of aid at high intensities, as

[16] P corresponds to unique values for v in the two aid impact functions, equations (8) and (9).

[17] Based on PWT 7.1, in 2010 PPP dollars mean income per capita was \$15026 in Gabon and \$282 in the Democratic Republic of Congo.

Table 4: Varying D

	g_A		g_B	
$D/\sum Y_i$	β	γ	β	γ
2%	-1.45	0.65	-2	1.6
3%	-0.58	0.625	-1.3	1.6
5%	0.2	0.625	-0.7	1.55
10%	0.975	0.625	-0.25	1.55

The optimal coefficients in the allocation rule as aid generosity varies, under alternative aid impact functions g_A and g_B

does g_A, then it may be optimal to direct aid away from the poorer recipients, so the optimal β is positive. The optimal sensitivity to absorptive capacity, γ, is virtually unaffected by the quantity of aid D.[18]

Because each recipient starts at an equal distance from steady-state in this experiment, relative incomes do not vary over time and hence neither does each recipient's share of the aid budget. Table 5 sets out the optimal shares, as aid generosity varies. The impact of increased generosity is large. For example, using the g_A impact function, increasing aid generosity from 2 per cent of total recipient income, to 3 per cent, cuts the share of the aid budget received by each of the two poorest recipients by 10 percentage points and roughly doubles the share received by the two richest.

Table 5: Varying D, optimal λs

	g_A				g_B			
D	2%	3%	5%	10%	2%	3%	5%	10%
λ_1	0.27	0.19	0.12	0.07	0.23	0.19	0.15	0.12
λ_2	0.37	0.26	0.17	0.10	0.51	0.42	0.33	0.26
λ_3	0.10	0.13	0.14	0.14	0.06	0.08	0.09	0.10
λ_4	0.14	0.18	0.20	0.19	0.13	0.17	0.20	0.22
λ_5	0.05	0.10	0.15	0.21	0.03	0.04	0.07	0.09
λ_6	0.08	0.14	0.21	0.29	0.06	0.10	0.15	0.20

The optimal division of aid between recipients 1 to 6 as aid generosity varies, under alternative aid impact functions g_A and g_B. Shares may not sum to one due to rounding.

Figures (4) and (5), based on aid impact functions g_A and g_B respectively, provide some additional insight into the first experiment. They show the levels of wastage and aid intensity in each recipient under the optimal allocation rule, for the four levels of aid generosity.

The optimal sensitivity to absorptive capacity, γ, ensures that wastage is equalized for recipients of equal income. When aid generosity is low, the optimal allocation strongly favors the poor countries and the optimal sensitivity to income, β, pushes aid towards zero-marginal return territory in the poorest recipients. When aid generosity is increased, under functional form g_A, the optimal β falls so that the level of aid intensity and wastage in

[18] The sensitivity of the aid allocation to recipient income also depends on the generosity of the aid budget in the framework of Collier and Dollar, although this is not emphasized by the authors.

Figure 4: Vary generosity: g_A Aid waste and intensity

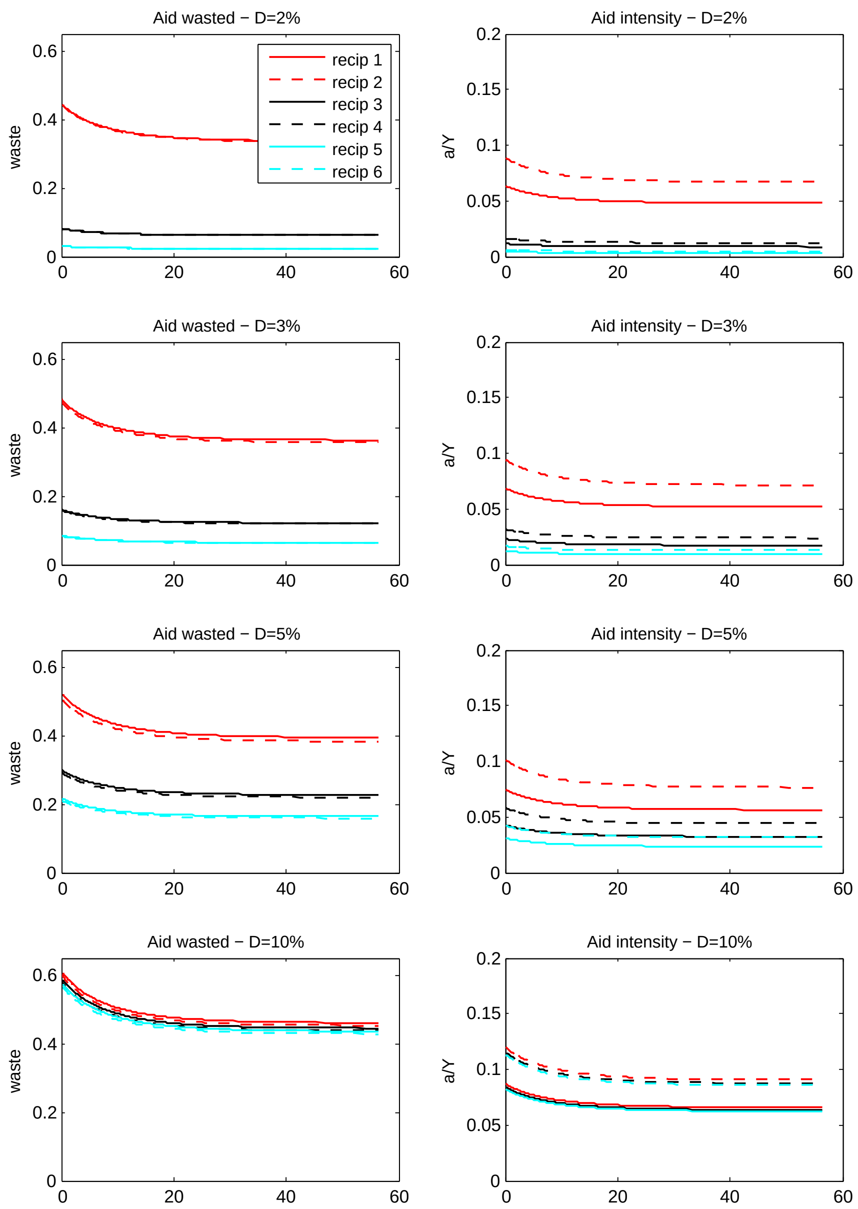
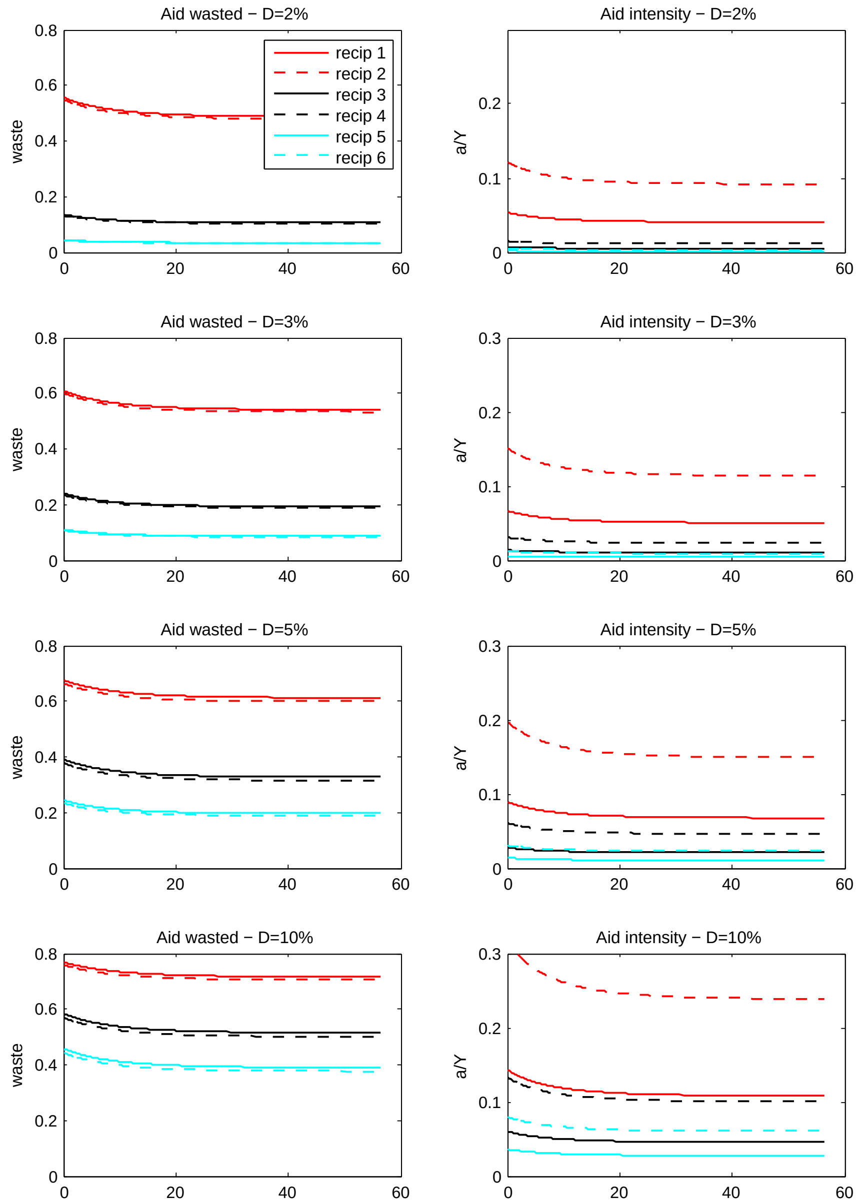


Figure 5: Vary generosity: g_B Aid waste and intensity



the poorest recipients is unchanged, to avoid pushing aid over the turning point. Wastage and aid intensity increases in the richer recipients until, under the highest level of aid generosity, aid is pushed towards zero returns in all recipients and wastage is equalized.[19] Under functional form g_B, aid intensity can be increased in the poorer recipients without incurring negative returns, so the optimal β is larger (more negative). At higher levels of aid generosity, a higher sensitivity to income permits a larger spread between the allocations of the intermediate and richest recipients, without imposing negative returns on the poorest recipient. Under g_B when aid generosity is at the 10 per cent level, 80 per cent of aid is wasted in the poorest recipients and the marginal dollar of gross aid delivers just 5¢ of effective aid, measured at time $t = 0$. It might be surprising that such an allocation could be optimal, but this reflects the curvature of utility functions: it is worth paying a high price in wasted aid to help the poor.

5.2 Diminishing marginal utility of consumption

The second experiment, summarized in table 6, involves varying σ, the curvature of the utility function. As expected, sensitivity to recipient income is increasing in σ, but the effect is surprisingly modest in comparison to the effect of changes in D. The optimal sensitivity to absorptive capacity is virtually unaffected. This modest impact upon the optimal β reflects the role of wastage; even in a world where the marginal utility of consumption is much higher in poorer recipients, relative to the richer, little is gained by allocating more aid towards them if it is only to be wasted.[20] However, σ has a greater impact upon β in the case of aid impact function g_B, where the welfare cost of giving poor countries too much aid is lower. This allows the rule to target more aid toward poor recipients in the long run, without doing too much damage in the short run.[21]

Table 6: Varying σ

	g_A		g_B	
σ	β	γ	β	γ
1.1	-0.45	0.65	-0.8	1.6
1.2	-0.5	0.65	-0.9	1.6
1.5	-0.6	0.65	-1.3	1.6
2	-0.65	0.65	-1.9	1.55

The optimal coefficients in the allocation rule as the curvature of the utility function is varied, under alternative aid impact functions g_A and g_B

[19] If aid generosity is increased further, wastage would diverge again because negative returns are more costly in poorer recipients.

[20] In addition to determining the impact upon total welfare of reallocating consumption across recipients, σ affects each recipient's willingness to invest and defer consumption, and hence the impact aid has upon growth.

[21] Since the allocations themselves are not the focus of this paper, figures showing the optimal aid shares, wastage and aid intensity are omitted here and for the experiments that follow.

5.3 International inequality

Table 7 summarizes the next experiment: varying international inequality by varying the distribution of TFP across countries, holding total initial recipient income constant so that aid generosity, $\frac{D}{\sum Y_i}$ is unchanged. The income ratio between the richest and poorest countries is varied between 1.6 and 7. Inequality has a large effect upon the optimal sensitivity to recipient income. This is potentially important: one might have imagined that because the aid allocation rule 'controls for income', the same rule could be used when allocating aid amongst different sets of recipients with different distributions of income, once an adjustment had been made to account for aid generosity. But this is not the case.

Why does the degree of international income inequality matter? First, because β controls the allocation response to *relative* incomes, any given β entails a greater share of the aid budget allocated to the poorest recipient, as inequality increases. Second, with total recipient income held constant, greater inequality means lower absolute income for the poorest recipient. So any given share of the budget entails higher levels of aid intensity and wastage in the poorest recipient, as inequality increases. Thus greater inequality amongst recipients implies that a less responsive (less negative β) allocation rule is optimal.

Table 7: Exp 3: vary inequality, $D/\sum Y_i = 0.03$

							g_A		g_B	
Recip	1	2	3	4	5	6	β	γ	β	γ
	0.5	0.5	2	2	3.5	3.5	0.18	0.63	-0.58	0.58
	0.75	0.75	2	2	3.25	3.25	-0.16	0.625	-0.9	1.135
A	1	1	2	2	3	3	-0.58	0.625	-1.275	1.58
	1.25	1.25	2	2	2.75	2.75	-1.08	0.63	-1.705	1.935
	1.5	1.5	2	2	2.5	2.5	-1.645	0.645	-2.165	2.195

The left panel shows the distribution of labor-augmenting technology across the six recipients. The right panel shows the optimal coefficients in the allocation rule in each case, under alternative aid impact functions g_A and g_B

In this case, using impact function g_A, when the poorest recipient is seven times poorer than the richest (a degree of inequality well within that observed amongst aid recipients) the optimal β is positive, despite the total quantity of aid being disbursed amounting to only 3 per cent of total recipient income (considerably less generous than actual aid flows). Using g_B, there is less need to direct aid away from poorer recipients, and it is sufficient merely to moderate the extent to which aid is pro-poor.

5.4 Absorptive capacity

The final experiment investigates the impact of the level of absorptive capacity (P), and of correlations between absorptive capacity and income. A positive correlation is of particular interest because it may be the case that poorer recipients are also the least able to absorb a given level of aid.

Correlations between income and absorptive capacity complicate the behavior of the aid rule. For example, if income and absorptive capacity are positively correlated, a positive coefficient on P in the aid rule also tends to direct aid toward richer recipients. The two coefficients can thus either reinforce or counteract each other.

Table 8: Varying absorptive capacity

Mean P	Correl (P, Y)	g_A		g_B	
		β	γ	β	γ
0.3	+	-0.235	0.225	-0.67	1.28
0.3	0	-0.31	0.395	-0.79	1.37
0.3	-	-0.25	0.645	-0.91	1.5
0.4	+	-0.47	0.395	-1.1	1.4
0.4	0	-0.58	0.625	-1.28	1.58
0.4	-	-0.59	0.995	-1.53	1.79
0.5	+	-0.775	0.62	-1.59	1.57
0.5	0	-0.95	0.95	-1.94	1.85
0.5	-	-1.11	1.495	-2.64	2.16

The optimal coefficients in the allocation rule as both the average level of absorptive capacity and its correlation with initial income are varied, under alternative aid impact functions g_A and g_B

The first column of Table 8 shows the mean level P amongst recipients. The second column shows the direction of correlation between P and initial income. The magnitude of the correlation is 0.6. The fifth row, with mean $P = 0.4$ and zero correlation between absorptive capacity and initial income, corresponds to the baseline calibration.

The interpretation is straightforward. When the average level of absorptive capacity amongst recipients is higher, for example, poorer countries are now able to absorb more aid so the optimal responsiveness to income, β, rises. The effect of correlations between absorptive capacity and income is similar. When the correlation is negative, poorer countries are able to absorb more aid and thus the optimal responsiveness to income changes.

6 Calibrated aid recipients

In this section the optimal coefficients in the aid allocation rule are located for a set of 20 recipient economies, calibrated using data from 20 sub-Saharan African countries, with the goal of identifying a plausible range for β, the sensitivity to recipient income. The magnitude of γ is of less interest, because we do not know how the implementation of absorptive capacity in these experiments relates to the World Bank's CPR score or the variants used by donors.

The combination of easily understood absorption constraints, and a distribution of recipient income taken from the data, permits comparisons with actual allocation practices. However, the coefficients identified here are optimal only in this highly-stylized setting. The coefficients specified in allocation rules as used by donors, such as Equation (1), and the allocation behaviour revealed by empirical research, are likely to reflect considerations excluded from the present paper. For example, the relatively large weight placed upon CPR scores by the World Bank may provide recipient governments with an incentive for reform, and the relatively low weight placed upon recipient income may compensate for the rule's lack of information about incomes distribution within recipients, by ensuring aid is available for poor sections of society in richer countries.

6.1 Calibration

The 20 simulated aid recipients are based on those sub-Saharan African countries with populations over 1 million and sufficient investment data to estimate capital stocks using the perpetual inventory method over the period 1960-2010, following the procedure used by Bernanke and Gürkaynak (2002). Data on output, investment and population are taken from the Penn World Table version 7.1.

Recipient economies each use a Cobb-Douglas aggregate production technology $Y_{i,t} = K_{i,t}^{\alpha}(A_{i,t}L_{i,t})^{1-\alpha}$. The structural parameters chosen are those used in the previous section (Table 3). Using the Cobb-Douglas production function, there is a straightforward mapping from each country's capital-output ratio in the data to an implied initial capital-labor ratio, expressed in efficiency units.[22] Once we have initial capital intensities, we can infer the level of technology:

$$k^* = \left(\frac{\rho + n + \delta + \sigma g}{\alpha}\right)^{\frac{1}{\alpha - 1}}$$

$$k_t = \left(\frac{K_t}{Y_t}\right)^{\frac{1}{1-\alpha}}$$

$$A_t = \frac{K_t}{L_t k_t}$$

where K_t and Y_t are taken from the data for 2010.

To calibrate absorptive capacity P, I turn to Dabla-Norris et al. (2012). The authors construct an index of the efficiency of public sector investment, for 71 countries, which serves here as a proxy for the efficiency with which foreign aid programs are administered. The index assesses four stages of public investment: project appraisal, selection, implementation and evaluation. It is based upon country diagnostics on public investment management systems conducted by the World Bank, existing budget survey databases and assessments carried out by donors, supplemented by expert surveys. I use the composite PIMI index, based on an average of the four sub-indices, normalized to lie between zero and one. This index has been used Gupta et al. (2011) to construct adjusted public capital stock data, using the perpetual inventory method but assuming that only a proportion of gross public

[22] Sub-Saharan economies with calibrated capital-labour ratios above their steady-states were discarded, with the exception of Guinea and Ghana that were only slightly above and are adjusted here to start in steady-state.

investment, corresponding to the normalized composite PIMI index, translates into effective installed capital.

In a similar spirit, I use the normalized PIMI index to capture the proportion of gross aid that translates into effective aid for each recipient. Gupta et al. (2011) assume a fixed proportion of waste at all levels of public investment, but the aid impact function $g(a,k)$ used in this paper models waste as an increasing function of aid intensity, and hence in the framework of this paper, the $PIMI$ index must correspond to waste at a particular level of aid intensity, aid_t/Y_t.

The aid absorption constraint is the most quantitatively important determinant of the optimal coefficients in the aid rule, for given aid generosity, yet empirical evidence concerning absorptive capacity at the macroeconomic level is weak, coming mainly from aid-growth research in which the precise shape of the relationship is often of only incidental interest.[23] Clemens et al. (2011) report a range of turning points in estimated aid-growth relationships of 15-25 per cent, but other authors have reported turning points at lower levels of aid intensity. To match this range of turning points in these calibrated experiments, three choices of the level of aid_t/Y_t at which to pin down wastage are employed: 0.1, 0.2 and 0.3. In this set of recipients, these choices imply average turning points across recipients, when using the g_A aid impact function, at levels of aid intensity of 8, 16 and 24 per cent, respectively.

Whilst an average turning point at 24 per cent of GDP is consistent with estimates from the growth literature, this calibration of the aid impact function implies a level of wastage that is potentially hard to reconcile with the microeconomic evidence. Niehaus and Sukhtankar (2011) survey empirical research and report estimated average leakage rates from public programs in the range of 18 to 87 per cent, and find a marginal leakage rate of 100 per cent after a statutory wage increase in India's National Rural Employment Guarantee Scheme.[24] When the turning point is calibrated at 24 per cent, if every recipient was to receive an aid flow equivalent to 10 per cent of national income, which corresponds to the mean level of aid intensity within Sub-Saharan Africa in 2010, the mean level of wastage across the twenty calibrated recipients would be just 20 per cent.[25]

The calibration of the 20 recipients used in this experiment is shown in Table 9. The experiment is run using four levels of aid generosity and three levels of absorptive constraint.

6.1.1 Aid generosity

OECD member countries donated aid equivalent to 0.32 per cent of their collective gross national income in 2010.[26] Smaller countries tend to be more generous, so the unweighted

[23] Researchers typically test the significance of a quadratic aid term, and do not investigate other nonlinear functional forms.

[24] See also the survey by Olken and Pande (2012)

[25] The more restrictive calibrations, with turning-point levels of aid intensity at 8 and 16 per cent, imply average levels of wastage across recipients of 60 and 30 per cent respectively, at 10 per cent aid intensity.

[26] Net disbursements of Official Development Assistance, data downloaded from stat.oecd.org

Country	PIMI	k(0)	A	K	Y	L	Y/L
Benin	0.4	3.74	0.7	23.6	9.8	8.8	1.1
Guinea	0.275	3.88	0.6	21.9	8.3	10.1	0.8
Burkina Faso	0.525	2.41	0.7	25.6	14.2	15.7	0.9
Ghana	0.475	3.88	0.9	84.3	29.6	23.9	1.2
Congo, Republic of	0.125	2.85	1.6	17.9	8.9	4.0	2.2
Ethiopia	0.425	2.19	0.5	98.3	58.3	85.2	0.7
Gambia, The	0.225	2.17	1.1	4.2	2.5	1.7	1.5
Kenya	0.375	2.25	0.9	80.8	47.0	39.0	1.2
Madagascar	0.5	3.12	0.5	33.3	15.6	20.7	0.8
Mali	0.55	2.71	0.7	26.1	13.4	13.4	1.0
Mozambique	0.4	1.35	0.7	20.3	16.6	21.9	0.8
Rwanda	0.575	1.23	1.0	12.7	11.1	10.7	1.0
Sudan (before 2011)	0.275	1.43	1.9	119.0	93.7	42.8	2.2
Senegal	0.225	3.69	1.0	42.8	17.9	12.0	1.5
Sierra Leone	0.25	2.84	0.6	9.0	4.5	5.1	0.9
Swaziland	0.275	2.94	2.4	9.4	4.6	1.3	3.4
Togo	0.225	3.60	0.5	11.0	4.7	6.4	0.7
Tanzania	0.35	2.52	0.9	90.5	48.8	41.0	1.2
Uganda	0.35	1.49	1.0	48.7	37.3	32.4	1.2
Zambia	0.475	2.33	1.3	40.5	23.0	13.1	1.8

Table 9: Calibrated recipients

Calibration of the twenty recipients used in this section's experiments. See text for details.

mean generosity across donor countries was 0.48 per cent. That year Sub-Saharan Africa received aid equivalent to 3.7 per cent of its total GNI, or 5.4 per cent if South Africa is omitted. Small countries tend to receive relatively more aid, so the unweighted mean level of aid intensity across recipients was 10 per cent. The 20 countries calibrated for this exercise received aid equivalent to 8.6 of their collective GNI, with an unweighted mean of 11 per cent.

For the purposes of this experiment four levels of aid generosity are adopted: 4 per cent of total recipient income, roughly the 2010 figure for Sub-Saharan Africa including South Africa, 8.6 per cent, corresponding to the 2010 allocation for these twenty recipients, and two levels chosen by scaling current generosity, supposing OECD donations reach 0.5 per cent and 0.7 per cent of those countries' total income, and that the aid allocated to these twenty recipients is increased in proportion. That would imply aid budgets equivalent to 13.4 and 18.7 per cent of total income for these recipients. These levels of aid intensity may appear unrealistic, but they are of interest because OECD member countries have a longstanding generosity target of 0.7 per cent of their national income.

6.2 Optimal coefficients

Table 10 shows the optimal coefficients for the basic allocation rule, for the four levels of aid generosity and the three levels of absorption constraint. The optimal values of β range widely, from -3.05 to 1.78. The optimal β is positive under the most restrictive absorption

Table 10: Optimal coefficients, calibrated recipients

$D/\sum Y$	g_A		g_B	
	low absorption			
	β	γ	β	γ
0.04	-0.31	0.83	-1.005	1.855
0.086	0.9	0.65	-0.195	1.805
0.134	1.56	1.08	0.005	1.777
0.187	1.78	1.08	0.105	1.74
	medium absorption			
	β	γ	β	γ
0.040	-1.83	0.81	-1.66	1.815
0.086	-0.16	0.78	-0.67	1.77
0.134	0.55	0.69	-0.33	1.72
0.187	1.14	1.08	-0.145	1.67
	high absorption			
	β	γ	β	γ
0.040	-3.054	0.765	-2.379	1.712
0.086	-0.920	0.794	-1.058	1.710
0.134	-0.084	0.747	-0.603	1.669
0.187	0.448	0.687	-0.356	1.627

The optimal coefficients in the allocation rule for twenty calibrated recipients, for four different levels of aid generosity and three different calibrations of the extent of absorptive constraints, under alternative aid impact functions g_A and g_B

constraint at higher levels of generosity, for both aid impact functional forms g_A and g_B. Under less restrictive absorption constraints the optimal β is only positive in the presence of negative marginal returns to aid, under impact function g_A. For the current level of generosity to these recipients, $D/\sum Y = 0.086$, the sensitivity to recipient income in the the World Bank rule, Equation (1), of $\beta = -0.125$, would be close to optimal under the medium absorption constraint and form g_A, and roughly optimal under low absorption and g_B. In the absence of negative marginal returns, under g_B, the optimal sensitivity to recipient income is greater (more negative) than implied by $\beta = -0.125$ in all but the two most generous cases under the most restrictive absorption calibration.

Two messages emerge from this exercise. Firstly, for a realistic distribution of recipient incomes under absorption constraints that are consistent with current knowledge, it is not clear that greater sensitivity to recipient income is always desirable, especially if aid is to be scaled-up. Secondly, these results draw attention to the role of absorption constraints and the practical importance of research on this question. The existence of wastage and the existence, or otherwise, of negative marginal returns to aid matter greatly for aid allocation decisions. Absent negative returns, donors should be much more responsive to recipient income.

7 Aid and Growth

Growth is the predominant criterion of aid effectiveness, and it is commonly supposed that aid allocation decisions should be taken with the objective of maximizing aid's impact upon growth. What role does aid's impact upon growth play in the current setting?

This section will show that when donors commit to an allocation rule in perpetuity, the optimal allocation elasticity to recipient growth potential may be of either sign, because the rule can exploit correlations between income and growth potential to achieve time-varying sensitivity to recipient income, and this can dominate any gains achieved by stimulating growth in recipients. Furthermore, the improvement in total recipient welfare when donors have the ability to target growth, and do so optimally, is negligible.

In contrast to the CD approach, in this paper a recipient's Country Performance Rating is interpreted as a measure of its ability to use aid effectively, in the sense of delivering effective aid to recipient households. The impact of aid upon growth is determined by the optimizing behavior of households and the prevailing marginal return to capital. The log-linearized augmented rule, capable of targeting aid-funded growth, is as follows:

$$\ln aid_{i,t} = \kappa_t + \ln N_{i,t} + \beta \ln \frac{Y_{i,t}}{N_{i,t}} + \gamma \ln CPR_i + \tau \ln R_{i,t} \tag{12}$$

where $R_{i,t}$ is the marginal product of capital in recipient i. A positive value for τ entails that, for two recipients of equal income and absorptive capacity, aid will be weighted towards the recipient with the higher marginal product of capital at that point in time. The magnitude of β determines how quickly aid is switched away from a recipient as its relative income rises over time. The greater τ is relative to β, the more the rule is 'pro-growth', as opposed to simply targeting poverty, and the more frequently we would expect to observe a rich country receiving more aid than a poor one, on the basis of its growth potential.

The experiments in section 4 gave us reason to expect the optimal weighting towards growth may be small. But there is a more basic reason why it might not be worth diverting much aid away from stagnant recipients in this setting: the impact of aid upon growth is small. Under the baseline calibration of Obstfeld (1999), a perpetual flow of aid equivalent to 1 per cent of initial recipient income increases the rate of output growth by just 0.09 percentage points at $t = 1$, measured relative to the zero-aid counterfactual, even with an initial capital-labor ratio less than one sixth of its steady-state level and no absorption constraints. For the 20 calibrated recipients used here, the impact of aid upon growth is even smaller. If each recipient receives a perpetual flow of aid equivalent to 1 per cent of its initial income, the average rate of output growth across the set of recipients, at $t = 1$, is just 0.017 percentage points higher than with zero-aid. The solid line in Figure (6) shows how the average rate of output growth across the 20 recipient economies, receiving such an aid flow, differs from that in the zero-aid counterfactual.[27]

[27] It would be a mistake to conclude from this graph that aid only has a short-lived positive impact

Ideally the analysis of an augmented rule, capable of targeting growth, would be conducted in an environment in which aid has a realistic impact upon growth. Comparing the simulated impact of aid upon growth in these calibrated recipients with empirical estimates of the aid-growth relationship is difficult, because the range of estimates is large and includes zero. The estimates in Clemens et al. (2011), suggest that a 1 percentage point increase in aid/GDP raises the rate of output growth by 0.1 to 0.2 percentage points some years later, but there aid/GDP does not measure total aid intensity but rather relates to a subset of aid that is allocated to sectors, such as investment in physical capital, that the authors deem most likely to have an short-term impact on growth. This does not naturally compare to the impact of an undifferentiated aid flow that is then allocated to investment or consumption by recipient households.

To provide an environment in which aid has a greater impact upon growth than in the baseline case, I also consider sets of simulated economies in which two changes have been made to boost the impact of aid upon growth. The output elasticity of capital is increased to 0.75, corresponding to a broader concept of reproducible capital, and initial distances from steady-state have been increased. Other than providing a potentially more realistic magnitude for the impact of aid upon growth, these changes are not necessarily a step towards greater realism.[28]

The recipients' initial distances from steady-state are increased by taking the calibrated ratios $k_{i,t=0}/k^*$ and raising them to the powers 2, 3 and 4. This increases the average distance beneath steady-state, but it also induces a negative correlation between distance from steady-state and initial income, so as a final step each recipient's level of TFP is adjusted to restore the distribution of initial income in the data.[29]

The dashed lines in figure (6) show the average change in growth rate resulting from giving each recipient an aid flow equivalent to one per cent of initial income, under these calibrations. When distances from steady-state are greatest, the initial impact upon growth approaches 0.07 percentage points, reasonably close to the 0.1 reported by Clemens et al. (2011). This experiment employs four degrees of growth potential, and two levels of aid generosity.[30]

Table 11 shows the optimal coefficients for the augmented allocation rule, in this exper-

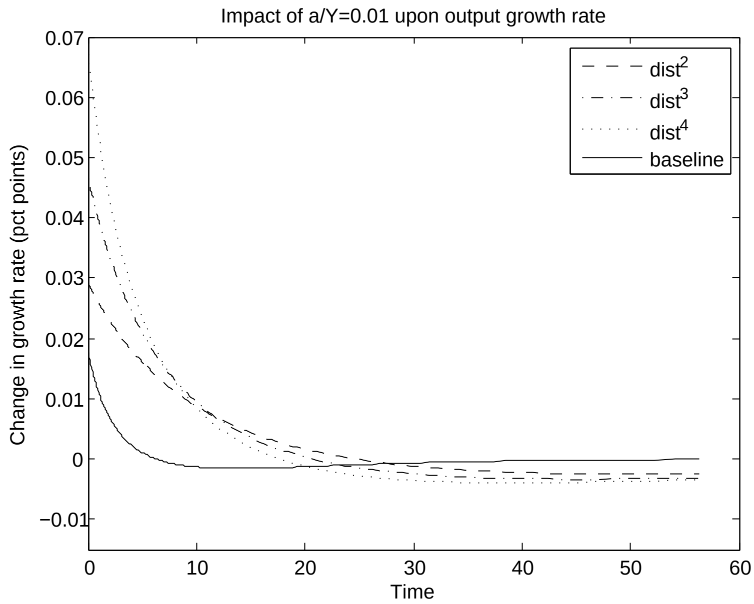
upon the pace of economic development, followed by a negative impact in later years. Aid accelerates the rate of convergence along the entire transition path. The rate of output growth is slower than the zero-aid counterfactual in later years because growth slows as convergence progresses, and aid has accelerated convergence. It would therefore be more appropriate to think in terms of aid's impact upon the rate of convergence. A graph comparing growth rates with and without aid, with the capital-labor ratio on the x-axis rather than time, would show a strictly positive impact.

[28] Aid has a greater impact upon growth when recipients have Stone-Geary preferences and initial conditions that imply consumption close to the 'subsistence' level, which greatly prolongs transition dynamics more consistent with the data (Steger, 2009). This possibility is explored by Kraay and Raddatz (2007), who use simulations to find the quantity of aid required to attain certain development milestones, but the authors regard this approach as unattractive because country-specific levels of subsistence consumption are required to match growth data.

[29] The reason for this adjustment will become clear after the results of this experiment are presented.

[30] Absorptive capacity is held constant at a relatively high level, with average wastage across recipients of just 25 per cent when each recipient receives $a/Y = 0.1$.

Figure 6: The impact of aid upon growth



iment.[31] When aid generosity is 8.6 per cent of total recipient income, corresponding to the current allocation to these recipients in 2010, the optimal τ is negative under absorption function g_A, meaning that for two recipients of identical income and absorptive capacity but differing growth potential, aid would be weighted towards the recipient where it is least able to stimulate growth.

These results reveal less about the optimal weighting of aid allocations towards growth and more about the limitations of this form of allocation rule. The rule is inflexible because it does not allow the sensitivity to recipient characteristics to vary over time. The optimal rule may be too sensitive in earlier periods and insufficiently sensitive later. Even supposing coefficients that are optimal at some point in time, the rule is still constrained by its functional form. When there are multiple recipients the allocation which performs best across the whole set of recipients is still likely to leave scope for improvement. The introduction of the marginal product of capital to the allocation rule introduces a degree of freedom to adjust allocations, that can go some way towards correcting for these shortcomings. Depending on the configuration of recipient characteristics and form of the absorption constraint, the optimal τ located by numerical search may be of either sign. In effect, τ and β can be combined to produce time-varying sensitivity to recipient income.

Had each recipient's initial level of technology A not been adjusted to restore the distribution of initial income, when increasing distance from steady-state in these experiments, I would have introduced a negative correlation between initial income and the marginal product of capital. In that case, the optimal values for τ would have been predominantly negative and large, even under g_B, because a negative τ would direct aid away from poor

[31] Many of the experiments in section 5 could be repeated to study the determinants of the optimal sensitivity to growth potential. This gives similar results, omitted for reason of space.

Table 11: Growth-targeting rule

$D/\sum Y$	g_A			g_B		
	Calibrated					
	β	γ	τ	β	γ	τ
0.04	-1.6728	1.8147	0.4599	-1.667	1.821	0.4578
0.086	-0.1605	0.786	-0.1183	-0.6749	1.7756	0.2232
	Distance^2					
	β	γ	τ	β	γ	τ
0.04	-2.5375	0.995	0.625	-2.1858	1.745	0.5156
0.086	-0.7813	0.7812	-0.4375	-1.0002	1.646	0.1797
	Distance^3					
	β	γ	τ	β	γ	τ
0.04	-2.425	1.2263	0.375	-2.223	1.8113	0.5625
0.086	-0.9188	0.8625	-0.2305	-1.1576	1.6513	0.215
	Distance^4					
	β	γ	τ	β	γ	τ
0.04	-2.3188	1.4717	0.4531	-2.2045	1.905	0.5625
0.086	-0.9375	0.9813	-0.1016	-1.2232	1.6858	0.25

The optimal coefficients in the augmented allocation rule for twenty calibrated recipients, where τ now determines how allocations respond to a recipient's growth potential. The scope for aid-funded growth in recipients increases as initial distances from steady-state are increased: four calibrations of initial conditions are used here (see text), two levels of aid generosity, and the two aid impact functions g_A and g_B

countries at the start of the simulation, where it would be wasted, whilst allowing for greater sensitivity to income in later periods, when convergence has equalized R across recipients. If initially richer countries happen to be further from steady-state, then positive values for τ may be optimal, not just because there is some welfare gained by targeting growth, but also because the rule would initially direct aid away from poor countries whilst allowing for greater sensitivity later on.

But whilst the correlation between initial income and distance from steady-state may offer some clue to the interaction of τ and β, the sign of the optimal coefficient may be otherwise than the foregoing explanation suggests, if some recipients are significant outliers. In this set of calibrated recipients there is no significant correlation between initial income and marginal product of capital, but Ethiopia happens to have a slightly higher initial marginal product of capital than average. It carries a large weight in the donor's objective function because of its huge population, and because it is so poor, the optimal allocation entails pushing aid right up to the turning point in the aid impact function. When aid generosity is increased from 4 to 8.6 percent of total initial recipient income, in the baseline case under absorption constraint g_A, the optimal share of aid allocated to Ethiopia drops sharply, to prevent negative marginal net aid. When aid generosity is low, allocations are not pushed into negative marginal net aid territory, so the positive optimal τ reflects the gains from growth-targeting. But when aid generosity is higher, the optimal allocations pushed aid to Ethiopia close to the turning point in the g_A function, and a negative τ allows the rule to take some aid away from Ethiopia early on, but increase its share in later periods when it is able to absorb more aid.[32] This dynamic works against the interest of some other richer recipients with initially high marginal products of capital who could readily absorb more aid, but their loss is outweighed by Ethiopia's gain.

These might seem like 'nuisance' results that prevent us from evaluating the role of aid-funded growth in optimal allocation rules, but these problems highlight the consequences of inflexibility. The analysis shows that if donors really did commit to a rule with constant coefficients in perpetuity, then it really might be optimal to direct aid away from recipients with growth potential, to achieve the best allocation over the long-run.

These experiments also suggest that the optimal aid allocation rule ought to place a small weight upon growth potential, in this environment, even in the presence of substantial variation in the marginal product of capital across recipients. When the optimal τ is positive, it is far smaller than β.

The improvement in recipient welfare obtained under an allocation rule capable of targeting growth potential is negligible. For example, in the baseline calibration, under g_B and an aid budget equivalent to 4 per cent of initial recipient income, aid allocated by the optimal basic rule delivers a welfare gain equivalent to raising each recipient's consumption path by 4.8 per cent, relative to the zero-aid counterfactual.[33] The optimal augmented rule adds only a further 0.0005 percentage points to this figure.

Under the 'distance^4' calibration, where aid has its greatest impact upon growth, and under the same level of generosity and absorption constraints, the basic rule delivers a welfare gain equivalent to a 6.75 per cent consumption-path uplift, and the optimal augmented rule adds a further 0.009 percentage points.

This negligible gain from the ability to target growth is striking, because in this experiment there is great variation in growth potential across recipients. In this most extreme 'distance^4' calibration, some recipients have an initial capital-labour ratio of just 1 per cent of its steady-state value, whilst others start in steady-state.[34] One might have thought that such variation in the marginal product of capital across recipients would imply much could be gained from the ability to direct aid accordingly, but this is not the case.

8 Conclusion

This paper has used the standard neoclassical growth model with the addition of a simple aid absorption constraint to make some basic points about aid allocation rules, as widely used by development agencies.

The dominant theoretical treatments of aid allocation focus on growth maximization, but this objective would not be shared by recipient households in a neoclassical economy,

[32] The optimal βs in the basic rule, for these experiments under absorption function g_A (not reported), are smaller than in the augmented rule. The introduction of τ allows the rule to be more responsive to recipient income.

[33] The Hicksian Equivalent Variation computed from the sum of population-weighted recipient utilities.

[34] The steady-state marginal product of capital is 0.135, the mean initial marginal product of capital is 0.22 with standard deviation 0.09.

who would choose to consume the lion's share of an aid flow, rather than maximize growth, even when the economy is far beneath its steady-state with high marginal returns to investment. When donors have the objective of welfare maximization, aid-funded consumption in stagnant recipients should play a prominent role. When aid can only cause growth to the extent there is growth already, the optimal allocation rule is likely to place only a small weight on growth potential and the welfare gained from growth-targeting is likely to be small. In the presence of absorption constraints, under which aid becomes less effective as the quantity received relative to GDP rises, aid allocation is largely a matter trading-off need against waste. Weighting aid towards recipients with better institutions is justified because such recipients are more able to absorb aid.

Seen in this light, some simple considerations emerge that have received little emphasis in the aid allocation literature thus far. The optimal allocation rule depends greatly upon the generosity of the aid budget, relative to recipient incomes, and the distribution of recipient characteristics, most notably the degree of international income inequality.

The optimal sensitivity to recipient income, determined by the parameter β, varies substantially according to the form and extent of absorption constraints. The implementation of aid absorption constraints in this paper is consistent with what little evidence we have on this question. If absorption constraints exhibit negative marginal returns at high levels of aid intensity, or if absorption constraints entail levels of waste towards the higher end of the range of empirical estimates, then donors may currently be too sensitive to recipient income, and positive values for β could sometimes be optimal.

The analysis presented here is not intended to be a normative analysis of aid allocation, sufficient for direct policy implementation. For example the political economy of aid has been ignored, but may ultimately play the most important role in aid allocation decisions. The incentives that rules introduce for recipients may prove to be important. This paper abstracts from such considerations in order to focus on the basics of optimal aid allocation. The approach taken here of studying the optimal rules-based allocation of aid to multiple recipients, via numerical simulation, could be extended in many directions.

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