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Equal opportunity and poverty reduction: how should aid be allocated?

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Abstract

This paper analyses a model of aid allocation that aims to equalize the opportunity between recipient countries to reach a common poverty reduction goal. We propose a fair and efficient aid allocation based on a multi-criteria principle. The model considers structural handicaps in recipient countries in terms of lack of human capital and economic vulnerability, their initial poverty, and the natural gap between the growth rate required to reach a development goal and the observed one. We show that our proposed aid allocation favors poor and vulnerable countries with our multi-criteria principle. It substantially differs from the observed allocation. Analyses also shed light on the impact of the donors' aversion to the low natural growth gap in recipient countries on the optimal aid allocation and the marginal efficiency of aid.

Keywords: Development Aid; Efficiency; Equity; Growth Deviation; Poverty Reduction, Vulnerability

JEL Classification: D63; F35; I30; O19

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1 Introduction

Developing countries, particularly the most vulnerable and low-income countries, need foreign aid, which may help them build up favorable conditions for a generation of economic growth and attainment of sustainable development. One of the most relevant questions concerns the aid allocation and factors determining an efficient allocation. Several donors, such as World Bank's International Development Association, Asian Development Bank, the European Development Fund, etc., employ performance-based allocation systems, prioritizing the countries in need and those with absorption capacity.

Several empirical analyses on aid allocation (Easterly, 2007, Easterly and Pfutze, 2008, Knack *et al.*, 2011, etc.) emphasize two main characteristics in recipient countries: their need for assistance (low GDP per capita, low IDH, high child mortality, or post-conflict country), and their ability to use aid effectively (high government effectiveness index, high institutional performance, etc.). Other analyses underline the link between aid allocation and donors' preferences represented by colonial ties and language homogeneity between aid organizations and recipients (Berthelemy and Tichit, 2004; Maiden and Brockway, 2018). Donors' interests (strategic allies, commercial allies) are potential criteria influencing donors' decisions. For instance, Couharde *et al.* (2019) underline the role of oil on bilateral aid policy, while in Nunnenkamp and Öhler (2011), donor strategic interests are reflected by the recipient's relative importance as a donor's export market and by the degree of recipient UN voting coincidence with a donor.

From a normative point of view, many issues are under debate regarding the optimal choice for aid allocation (Collier and Dollar (2001, 2002), Wood (2008), Llavador and Roemer (2001), Cogneau and Naudet (2007), Carter (2014), etc.) For instance, Collier and Dollar (2001, 2002) adopt a utilitarian vision by maximizing a social welfare function, the sum of aid-recipient countries' utilities. A country's utility is measured in terms of the number of poor, which is a decreasing aid function. Following Collier and Dollar (2001, 2002), an optimal allocation of aid should maximize the reduction of the poor in recipient countries. According to the effectiveness principle, the optimal aid allocation proposed by Collier and Dollar is determined by the initial deprivation of recipient countries, institutional quality, and policy quality. In other words, compared to the observed allocation of aid, the Collier and Dollar's allocation gives more aid to the poorest countries implementing the highest policy quality (high CPIA). In the same vein, Wood (2008) includes an intertemporal aspect in his analysis and considers initial poverty and future poverty in aid donors' objective function.

This approach of Collier and Dollar is criticized for its lack of consideration for fairness. In this sense, Llavador and Roemer (2001) propose an alternative way of calculating the optimal allocation of aid based on the Rawlsian principle. They analyze how aid can be distributed to equalize recipient countries' growth opportunities. Therefore, aid donors should give an allocation that compensates countries for bad initial circumstances so that the final differences in outcomes between countries will be only attributed to differences in their efforts, not to their initial circumstances.¹ According to Cogneau and Naudet (2007), the optimal aid allocation of Llavador and Roemer (2001) is paradoxically in favor of countries with high macroeconomic performances. They propose another method

¹In Llavador and Roemer (2001), the effort variable is defined by economic management, the weighted average of three macroeconomic markers: budget surplus relative to GDP, inflation, and trade openness. The initial circumstances or initial disadvantages of country i are defined as the component of the growth rate, which is not explained by effort or aid.

including equal opportunity but separating effort and circumstances of recipient countries. Their aid allocation shares poverty risk more fairly among the world's population, and their results show that donors should give more aid to the poorest countries than the observed aid allocation.

Recently, Carter (2014) proposed an aid allocation rule that maximizes recipient countries' welfare rather than economic growth and considers recipient countries' absorptive capacity (measured by the World Bank's Country Performance Rating). Donors target a range of development outcomes by putting more weight on aid-funded consumption and less weight on economic growth. The division of aid between consumption and investment maximizes households' utility in recipient countries. In this setting, the objective of maximizing welfare in recipient countries may lead to an optimal allocation giving more aid to countries that are least able to stimulate economic growth.

The debate on foreign aid allocation in developing countries is still lively today. In this vein, our paper aims to design an efficient and fair distribution of aid based on a multi-criteria principle and within a utilitarian framework where aid donors maximize the sum of recipient countries' utilities. Our goal is not to dichotomize fairness and efficiency as two different aid allocation criteria. On the contrary, we show that it is possible to determine a fair allocation, which is also efficient. The difference between our paper and Collier and Dollar (2001,2002), Llavador and Roemer (2001), Cogneau and Naudet (2007) stems from three major points.

First, aid policy should address uneven economic conditions between countries and compensate them with foreign aid. Therefore, as in McGillivray and Pham (2017) and Guillaumont et al. (2017), our analysis considers structural growth handicaps in recipient countries. We introduce economic vulnerability and lack of human capital in the growth equation. Our study assumes that a country with low human capital and a high economic vulnerability may encounter difficulties in formulating high-quality economic and social policies, inducing, therefore, a low possibility of achieving its development goal. It is fair to consider the lack of human capital and economic vulnerability in recipient countries.

Second, unlike previous studies, we focus on structural factors, mainly structural economic vulnerability, as essential elements determining aid effectiveness. Indeed, according to Guillaumont and Chauvet (2001), aid is growth-enhancing in countries with a high economic vulnerability. Accounting for economic vulnerability in recipient countries may be viewed as compatible with an aid effectiveness principle.

Third, aid policy could be fair. However, unlike Llavador and Roemer (2001) and Cogneau and Naudet (2007), which adopt the Rawlsian principle, we propose an alternative way to model this fairness. We assume that donors are sensitive to the natural growth deviation or gap in recipient countries. Their goal is to equalize the opportunity between recipient countries to reach a common poverty reduction goal. To formulate this assumption, we posit the utility of country i depending on the gap between its current growth rate (depending on received aid and structural handicaps) and its expected (or targeted) growth rate. The latter represents the growth rate that a country i has to reach if it wants to achieve a specific development goal. Hence, an efficient and fair allocation of aid should reduce poverty in recipient countries by considering the particular conditions (such as structural handicaps and poverty rate) and the natural growth deviation or gap in these countries.

Our optimal aid allocation with poverty reduction objective is then based on a multi-criteria principle that incorporates initial poverty, lack of human capital, economic vulnerability, and natural growth deviation in recipient countries. Our analysis is implemented

in two steps. The first step corresponds to estimating a growth equation depending on factors such as lack of human capital, economic vulnerability, and received aid amount. The second step uses the computed growth rates in recipient countries, obtained from the first step, to perform a simulation exercise showing a substantial difference between the optimal and observed allocation. We also indicate the meaningful impact of the donors' aversion to low growth deviation or gap in recipient countries on the optimal aid allocation.

The rest of the paper is structured as follows. Section 2 presents the theoretical model. Section 3 reports estimation results concerning the economic growth equation. Section 4 discusses the efficient and fair allocation of aid, as well as the marginal efficiency of aid. Section 5 concludes. Other details are presented in the Appendix.

2 A model of efficient and fair allocation of aid

This section proposes a theoretical model to determine aid allocation, equalizing countries' opportunities to reach a development goal. We take as a retrospective example the Millennium Development Goal (MDG), proposing to reduce by half the poverty by 2015 compared to 1990. It is all about approaching the most possible to the MDG by giving each recipient country the same probability of lifting out of poverty by half. We need to define an expected growth rate required to reach each recipient country's millennium goal and eventually compensate for the difference between this one and the effective growth rate. This difference can be used as an argument, among others, to justify the aid allocated. This principle involves considering both effectiveness and fairness in designing the optimal aid allocation. For this purpose, we assume that the utility of recipient country i , U_i , which corresponds to the number of poor that can be reduced by economic growth, is defined by

$$U_i [g_i(A_i)] = -\eta_i h_i N_i \left[\alpha u(g_i) + (1 - \alpha) v \left(\frac{g_i}{g_i^*} \right) \right] \quad (1)$$

where h_i is a measure of poverty (such as the percentage of country i 's population living below 2 dollars (in PPP) per day), $\eta_i = \frac{\partial h_i}{\partial y_i} \frac{y_i}{h_i}$ is the elasticity of poverty reduction with respect to per capita income y_i , assumed to be a negative constant in Collier and Dollar (2001, 2002), and N_i is the population size.

Country i 's utility is a function of its growth rate of per capita income, $u(g_i)$ with $u' > 0$ and $u'' \leq 0$, and a function of the ratio between the observed growth rate and the growth rate expected to achieve the MDG, $v(g_i/g_i^*)$ with $v' > 0$ and $v'' \leq 0$. Parameter $\alpha \in [0, 1]$ represents the weight associated to the growth objective (α called as growth-weight), and $1 - \alpha$ is the weight relative to 'natural growth deviation' from the expected (or targeted) growth rate g_i^* ($1 - \alpha$ called as growth gap-weight). When $\alpha = 1$ and $u(g_i) = g_i$ we exactly recover the utility function of Collier and Dollar (2001, 2002) where $U_i = -\eta_i h_i N_i g_i$. Thus, this expression gives the number of the poor that can be reduced by economic growth. However, this utility function, which is linear in the growth rate, implies that the marginal utility of growth U_g (also interpreted as the marginal reduction of poverty) is constant. In this respect, the specification in (1) appears more general as it allows for a non-constant marginal reduction of poverty. More precisely, we assume that each country's utility is increasing and concave with respect to the economic growth rate

g_i . Its first and second derivatives are given respectively by

$$U_g = \frac{\partial U_i}{\partial g_i} = -\eta_i h_i N_i \left[\alpha u'(g) + (1 - \alpha) v' \left(\frac{g_i}{g_i^*} \right) \frac{1}{g_i^*} \right] > 0, \quad (2)$$

$$U_{gg} = \frac{\partial^2 U}{\partial g_i^2} = -\eta_i h_i N_i (\alpha u''(g) + (1 - \alpha) v'' \left(\frac{g_i}{g_i^*} \right) \frac{1}{g_i^{*2}}) \leq 0. \quad (3)$$

We observe that marginal utility of growth, U_g , is decreasing with the ratio g_i/g_i^* . In other words, the marginal effect of growth is stronger in countries where the natural growth deviation is lower (i.e., lower g_i/g_i^*). This decreasing effect is more important if the curvature of v is higher (or the relative risk aversion of v is higher).

We also assume that the targeted growth rate g_i^* is independent of aid. It can be determined as follows. Adopting the MDG with the number of the poor reduced by half between 1990 and 2015 means that the cumulated objective of poverty variation is -50% in 25 years. Let x denote the annual reduction rate of poverty, hence

$$h_i N_i (1 - 0.5) = h_i N_i (1 - x)^{25}. \quad (4)$$

We can easily find that x is equal to 0.0273. As $g_i^* \eta_i = -x$, the targeted growth rate for country i , g_i^* , depends on the objective of annual poverty reduction rate (x_i) and the elasticity of poverty reduction with respect to per capita income (η_i),

$$g_i^* = -x/\eta_i. \quad (5)$$

Therefore, if $\eta_i = -2$ as in Collier and Dollar (2001, 2002), we obtain $g_i^* = 0.0273/2 = 0.01365$.

As the growth rate g_i depends on the amount of aid A_i , let us consider the following optimization program, which consists in choosing an aid allocation maximizing the sum of utilities of n countries under constraints on the total amount of aid, on the one hand, and the positiveness of aid, on the other hand,

$$\max_{\{A_i\}_{i=1}^n} \sum_i^n U_i(g_i(A_i)) \quad (P1)$$

s.t.

$$\sum_i^n A_i y_i N_i = \bar{A} \quad (6)$$

$$A_i \geq 0, \forall i \quad (7)$$

where y_i is per capita income, A_i the amount of aid (measured as a percentage of total GDP of i), and \bar{A} the total amount of aid available for allocating among all recipient countries. The constraint in equation (6) indicates the sum of aid given to all recipient countries is equal to the total amount of available aid.

The Lagrangian of problem (P1) can be written as follows.

$$L(A) = \sum_i^n U_i(g_i(A_i)) + \lambda \left(\bar{A} - \sum_i^n A_i y_i N_i \right) + \sum_{i=1}^n \mu_i A_i, \quad (8)$$

where λ and μ_i , $i = 1, \dots, n$ correspond respectively to the Lagrange multipliers of the constraint on the total available amount of aid and the positiveness of aid. The vector of candidates $\hat{A} \equiv (\hat{A}_1, \dots, \hat{A}_n)$, and multipliers $\hat{\lambda}$, and $\hat{\mu}_i$ must satisfy the following first order conditions (FOC), $\forall i = 1, \dots, n$:

$$\frac{\partial L(\hat{A})}{\partial \hat{A}_i} = U_g(\hat{A}_i)g_A(\hat{A}_i) - \hat{\lambda}y_iN_i + \mu_i = 0 \quad (9)$$

$$\hat{A}_i \geq 0, \hat{\mu}_i \geq 0, \quad \hat{\mu}_i \hat{A}_i = 0 \quad (10)$$

$$\sum_i^n \hat{A}_i y_i N_i = \bar{A} \quad (11)$$

where g_A is the marginal effect of aid on the growth rate and U_g the marginal effect of growth on country i 's utility, given by equation (2).

Condition (10) is about the complementarity between \hat{A}_i and $\hat{\mu}_i$, i.e. $\hat{\mu}_i = 0$ if $\hat{A}_i > 0$, and $\hat{\mu}_i > 0$ if $\hat{A}_i = 0$. Hence, for country i such that $\hat{A}_i > 0$, equation (9) gives $U_g(\hat{A}_i)g_A(\hat{A}_i) = \hat{\lambda}y_iN_i$ because $\hat{\mu}_i = 0$. Combining this with condition (11) will give the values for $\hat{A}_i > 0$ and $\hat{\lambda}$. Finally, given $\hat{A}_i > 0$ and $\hat{\lambda}$, $\hat{\mu}_j$ can be recovered from equation (9), which only applies to country j such that $\hat{A}_j = 0$, i.e. $\hat{\mu}_j = \hat{\lambda}y_jN_j - U_g(0)g_A(0)$. This sketch about the solution of these FOCs appears simple. However, its implementation is cumbersome because it needs some combinatory calculations. Fortunately, certain softwares can help us to solve this problem.²

Given the discussion above, we can state the following proposition:

Proposition 1 *Considering the optimization program (P1) where each country's utility is increasing and concave with economic growth (i.e., conditions (2) and (3)), the optimal (efficient and fair) allocation of aid $\{\hat{A}_i\}_{i=1}^n$ must verify the following conditions:*

$$(i) \hat{A}_i = 0 \text{ if } U_g(\hat{A}_i)g_A(\hat{A}_i) = \hat{\lambda}y_iN_i - \hat{\mu}_i \text{ and } \hat{\mu}_i > 0,$$

$$(ii) \hat{A}_i > 0 \text{ if } U_g(\hat{A}_i)g_A(\hat{A}_i) = \hat{\lambda}y_iN_i \text{ and } \hat{\mu}_i = 0,$$

$$(iii) \sum_i^n \hat{A}_i y_i N_i = \bar{A},$$

where $\hat{\mu}_i \geq 0$ is the multipliers associated with the positiveness of aid and $\hat{\lambda}$ is the multiplier (or shadow value) associated to the total aid.

It should be noted that the multiplier λ can be viewed as the *marginal efficiency of aid* as in Collier and Dollar (2001, 2002). We observe from point (ii) of Proposition 1 that for any country i which receives a strictly positive amount of aid (i.e. $\hat{A}_i > 0$), we have

$$\hat{\lambda} = \frac{U_g(\hat{A}_i)g_A(\hat{A}_i)}{y_iN_i}. \quad (12)$$

In terms of our specification, this expression is equivalent to

$$\hat{\lambda} = \frac{-\eta_i h_i N_i (\alpha u' + (1 - \alpha)v'/g_i^*) g_A(\hat{A}_i)}{y_i N_i}. \quad (13)$$

²For the simulation of the optimal aid allocation (based on estimation results of the growth equation and a parametrization of the theoretical model) in the next section, we use Matlab (function `fmincon`) and R (package `Rsolnp`) to find the solution of the optimization problem. The implementation of these different packages generally give the same results.

In the case of the Collier and Dollar' (2001, 2002) model, i.e. $\alpha = 1$ and $u(g_i) = g_i$, this multiplier becomes

$$\hat{\lambda}_{CD} = \frac{-\eta_i h_i N_i g_A(\hat{A}_i)}{y_i N_i}. \quad (14)$$

Collier and Dollar (2001, 2002) precisely defined this quantity as the number of the poor reduced by an increase of the total amount of aid by one unit.

From equation (13), we can compute for our model the equivalent number of the poor in country i that can be reduced by an increase of the total amount of aid by one unit (here in millions of dollars) as

$$\hat{\lambda}_i = \frac{\hat{\lambda}}{\alpha u' + (1 - \alpha)v'/g_i^*}. \quad (15)$$

We observe that while $\hat{\lambda}$ is constant (i.e., there is a unique solution for this, see also Proposition 1) $\hat{\lambda}_i$ is different between countries receiving a positive amount of aid (because of different values of $\alpha u' + (1 - \alpha)v'/g_i^*$). The only case for which the marginal efficiency of aid is the same for every recipient countries corresponds to the Collier-Dollar utility function, i.e., $\alpha = 1$ and $u(g_i) = g_i$ implying $\hat{\lambda}_i = \hat{\lambda} = \hat{\lambda}_{CD}, \forall i$.

We now turn to sufficient conditions for the optimization program's solution (P1). As the constraint is linear, the sufficient conditions for $\{\hat{A}_i\}_{i=1}^n$ being the solution of the optimization problem (P1) are that the objective function is concave with $\{\hat{A}_i\}_{i=1}^n$. In other words, the second-order matrix

$$\begin{pmatrix} \frac{\partial^2 U^2}{\partial A_1^2} & \frac{\partial^2 U^2}{\partial A_1 \partial A_2} & \cdots & \frac{\partial^2 U^2}{\partial A_1 \partial A_n} \\ \frac{\partial^2 U^2}{\partial A_2 \partial A_1} & \frac{\partial^2 U^2}{\partial A_2^2} & \cdots & \frac{\partial^2 U^2}{\partial A_2 \partial A_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial^2 U^2}{\partial A_n \partial A_1} & \frac{\partial^2 U^2}{\partial A_n \partial A_2} & \cdots & \frac{\partial^2 U^2}{\partial A_n^2} \end{pmatrix}$$

must be negative semi-definite. We observe that this matrix is diagonal, and its diagonal elements are given by

$$\frac{\partial^2 U(\hat{A})}{\partial \hat{A}_i^2} = U_{gg}(\hat{A}_i) g_A^2(\hat{A}_i) + U_g(\hat{A}_i) g_{AA}(\hat{A}_i) \quad (16)$$

Hence, the negative semi-definiteness of this matrix corresponds to the negativity of (16) or equivalently

$$\frac{g_{AA}(\hat{A}_i)}{g_A^2(\hat{A}_i)} \leq -\frac{U_{gg}(\hat{A}_i)}{U_g(\hat{A}_i)}, \quad \forall i. \quad (17)$$

The right-hand side term $(-U_{gg}/U_g)$, which is always positive, represents the utility function's curvature with respect to the growth rate. It is also known as the coefficient of absolute risk aversion at g . The left-hand side term (g_{AA}/g_A^2) corresponds to the curvature of the growth rate with respect to aid. This inequality merely means that the absolute risk aversion of the objective function at g should be sufficiently high to warranty that $\{\hat{A}_i\}_{i=1}^n$ is the solution of the maximization problem. Hence, we can state the following proposition on the sufficient condition:

Proposition 2 *If the absolute risk aversion of the utility function with respect to the*

growth rate is sufficiently high as given by equation (17) (i.e. $g_{AA}(\hat{A}_i)/g_A^2(\hat{A}_i) \leq -U_{gg}(\hat{A}_i)/U_g(\hat{A}_i)$, $\forall i$) the allocation of aid $\{\hat{A}_i\}_{i=1}^n$ defined in Proposition 1 corresponds to the maximum of the optimization program (P1).

We remark that Proposition 2 automatically holds if $g_{AA}(\hat{A}) \leq 0$. It also holds even with some positive g_{AA} as long as condition (17) is satisfied.

3 Estimation of the growth equation

3.1 Foreign aid and economic growth

There is a consensus that aid rarely has a direct effect on the growth rate. Its impact on the recipients' economic growth, if significant, is often conditional on performance factors in recipient countries such as institutional quality, political stability, macroeconomic environment (Boone, 1996; Burnside and Dollar, 2000; Easterly, 2003; Moyo, 2009, Mosley, 2015, Temple and Van de Sijpe, 2017, Maruta et al., 2019, etc.). Collier and Dollar (2001, 2002) underline that the growth effect of aid positively depends on recipient policy performance measured by CPIA. Such an analysis implies that countries with high performance in economic policies and institutions will receive more aid than others. Such studies focusing on the performance ignore the initial disadvantages of recipient countries and the stabilizing impact of aid. Indeed, aid may lead to higher growth rates in countries with high structural vulnerability (Guillaumont and Chauvet, 2001; Chauvet and Guillaumont, 2004, 2009; Guillaumont and Le Goff, 2010; Guillaumont and Wagner, 2012, Chauvet et al., 2019).

From a development perspective, it is necessary to make aid fairer, without losing the effectiveness goal, by considering structural handicaps to the growth of recipient countries, particularly their economic vulnerability and lack of human capital. Indeed, as underlined in Guillaumont et al. (2017), a country with a low human capital level is likely to have a low-performance score despite its great efforts. It may encounter difficulties to formulate a high quality of economic and social policies to achieve the objective of poverty reduction during their development process. Therefore, allocating more aid to countries suffering from low human capital and high economic vulnerability might be an excellent way to compensate for their initial disadvantages.

In the same line as Guillaumont and Chauvet (2001) and Guillaumont et al. (2017), we assume that the growth rate depends on structural handicaps represented by the degree of economic vulnerability and the lack of human capital. More precisely, the growth rate of country i in period t is a function of the degree of economic vulnerability (V_{it}), lack of human capital (H_{it}), level of aid relative to GDP (A_{it}), its squared term (A_{it}^2) and the interaction of aid with economic vulnerability.

The growth equation is estimated using a panel data framework (see, e.g., Islam, 1995, Caselli et al., 1996, Durlauf et al., 2005). Following the literature (Islam 1995, Caselli et al. 1996, Durlauf et al. 2005, etc.), the growth equation can be expressed in a panel data framework as

$$\begin{aligned} \ln y_{it} = & \rho \ln y_{i,t-\tau} + \beta_V V_{it} + \beta_{AV} A_{it} V_{it} + \beta_H H_{it} + \\ & + \beta_A A_{it} + \beta_{AA} A_{it}^2 + \mu_i + \nu_t + \varepsilon_{it} \end{aligned} \quad (18)$$

where $\ln y_{it}$ is the log real GDP per capita in international prices PPP 2005. The set of covariates includes the ratio of aid to GDP (A), its squared term (A^2), economic

vulnerability (V), lack of human capital (H), interaction of aid with V . The terms μ_i represents the country fixed effects. The term ν_t represents the time effects, which are treated as time dummies.³

3.2 Data

The data employed to assess equation (18) are collected from the World Development Indicators of the World Bank, the Human Assets Index (HAI), and the FERDI Economic Vulnerability Index.⁴ The WDI database provides information on aid, GDP, population, etc. Aid and GDP are expressed in real dollars, international prices PPP 2005, and measured in millions of dollars. These series are employed to compute GDP per capita (y) and the share of aid in GDP (A). We use the series on HAI , a composite index of education and health (see Closset et al., 2014), to compute H as a measure of lack of human capital. For this purpose, we simply calculate $H = (100 - HAI)/100$. The economic vulnerability index (V), one of several criteria retained by the United Nations Committee for Development Policy in identifying the least developed countries, was proposed by the FERDI (see Cariolle, 2011, for more details). Following Cariolle (2011), the vulnerability index encompasses the main determinants of structural vulnerability that can harm economic growth and poverty reduction in developing countries. The principal components entering then in the definition of economic vulnerability index are (1) population, (2) share of agriculture, forestry, and fisheries in GDP, (3) exports concentration, (4) remoteness from main world markets, adjusted for landlockness, (5) instability of exports receipts, (6) instability of agricultural production, and (7) homelessness due to natural disasters. Values of lack of human capital H and economic vulnerability V are between 0 and 1.

Our data are an unbalanced panel data sample covering 92 countries and the 1983-2011 period. As in the existing literature, we use data with some time span intervals to avoid business cycle effects. We adopt the 4-year interval ($\tau = 4$) as Collier and Dollar (2002). More precisely, following Caselli et al. (1996) and Durlauf et al. (2005), among others, y_{it} (and then $y_{i,t-\tau}$) correspond to GDP per capita observed in 1983, 1987, 1991, 1995, 1999, 2003, 2007, and 2011. Variables A , V , and H are defined as the averages over the 4 years preceding t , i.e., 1983-1986, 1987-1990, 1991-1994, 1995-1998, 1999-2002, 2003-2006, 2007-2010. There are eight waves of 4-year interval: 1983-1986, 1987-1990, ..., 2007-2010. Hence, as our model deals with a relatively small time dimension ($T=8$), the issue of nonstationarity is not crucial here. Furthermore, following the recommendation by Bond et al. (2010), the treatment of time effects as time dummies (one for each 4-year period) in our regressions allows capturing the common trend between variables and ensures no cross-country correlation in the model residuals. Definition and descriptive statistics on variables are summarized in Table 1.

Table 1 here

³We also include a variable representing the quality of policies, Polity 4 (as in the existing literature), and its interaction with aid. However, the system-GMM estimation results using this variable show that coefficient of Polity 4 and the interaction term are insignificant. At the same time, the sample size is much reduced.

⁴Data and estimation codes are available on request from the authors.

3.3 Econometric specification and estimation results

Equation (18) is a dynamic panel data model that can be estimated using the system-GMM method of Blundell and Bond (1998). We note that this model considers two sets of regressors: (i) strictly exogenous regressors (including time dummies) and (ii) predetermined regressors (including $\ln y_{i,t-\tau}$, A , V , and H). Outliers are excluded from the estimations. The estimation results by using the system GMM are reported in Table 2.⁵ Results of the within fixed effects estimator are also reported for comparison purposes.⁶ Specification tests (Arellano-Bond tests for AR(1) and AR(2) in the regression residuals, Sargan and Hansen overidentifying restrictions tests) and tests for exogeneity of instruments are generally verified.

Table 2 here

We observe that results given by system GMM and within FE estimators are comparable. More precisely, the lagged term of GDP per capita is highly significant and positively affects the current GDP per capita level, which proves the usefulness of the dynamic setting. The linear term of aid has no effect, whereas its squared term has a negative effect. While economic vulnerability negatively affects income, its interaction term with aid has a significant and positive impact. This finding means that aid and economic vulnerability are complementary in the growth equation. In other words, when a country's vulnerability is high, aid is more efficient in terms of growth. The same result is found in Guillaumont and Chauvet (2001). Finally, lack of human capital is a handicap for growth as its coefficient is statistically significant and negative.

As the average annual growth rate of country i between periods $t - \tau$ and t is given by $(1/\tau)(\ln y_{it} - \ln y_{i,t-\tau})$, it can therefore be computed from the estimated coefficients of equation (18) as follows:

$$g_{it} \equiv (1/\tau)(\ln y_{it} - \ln y_{i,t-\tau}) = ((\hat{\rho} - 1)/\tau) \ln y_{i,t-\tau} + W'_{it} \hat{\beta} / \tau, \quad (19)$$

where W includes all right-hand side variables of equation (18), except $y_{i,t-\tau}$. This is the growth rate we will use in the subsequent simulations of efficient and fair aid allocation. We remark that the negative coefficient associated to A^2 in the growth equation (see Table 2) confirms the sufficient conditions of our optimization problem (i.e. $g_{AA} \leq 0$).

4 Simulation of the optimal aid allocation

To assess the theoretical allocation, we need an analytically tractable model. For simplicity's sake, we specify $u(g_i) = g_i$ and $v(g_i/g_i^*) = (g_i/g_i^*)^\gamma$ with $\gamma > 0$. We observe

⁵The difference-GMM method of Arellano and Bond (1991) was also considered but proved less satisfactory than the system GMM through specification tests. As noted in Roodman (2009), when performing the system GMM, all strictly exogenous regressors are used as instruments in both transformed equation and levels equation. Predetermined regressors are also valid instruments for the levels equation since they are assumed to be uncorrelated with the contemporaneous error term. Moreover, we use all available lags of the predetermined variables in levels as instruments for the transformed equation and the contemporaneous first differences as instruments in the levels equation. Finally, following Roodman (2009), we specify one instrument for each variable and lag distance (rather than one for each time period, variable, and lag distance) to reduce the bias in small samples with an increased number of instruments.

⁶We do not present the GLS random effects estimator here as it is dominated by the within fixed effects estimator according to the Hausman test.

that $\gamma > 0$ measures the curvature of v with respect to ratio g_i/g_i^* . This ratio, named as natural growth deviation, may be interpreted as natural growth deficit in case of $g_i < g_i^*$ or natural growth excess in case of $g_i > g_i^*$. In this formulation, $1 - \gamma$ represents the relative ‘risk’ aversion to growth deviation. It should be noted that we do not exclude the case where $g_i > g_i^*$ as it is quite possible that g_i^* is low enough. Actually, many countries in our 2008 sample encounter this situation. A reduction in γ , represented by an increase of the function’ curvature, means that aid donors are more sensitive to natural growth deviation. In other words, a reduction in γ means that donors are more averse to a low ratio g_i/g_i^* . This implies that aid donors give more weight to countries with a ratio g_i/g_i^* lower than other countries, all else being equal.

We think that the case $\gamma > 1$ should be excluded as it is not fair to favour the countries with a high ratio g_i/g_i^* to the detriment of the countries with a low ratio g_i/g_i^* . With $\gamma \in (0, 1)$, function $v(g_i/g_i^*)$ is then increasing and concave with respect to g_i/g_i^* . Figure 1 describes the behavior of function v following different values of γ .

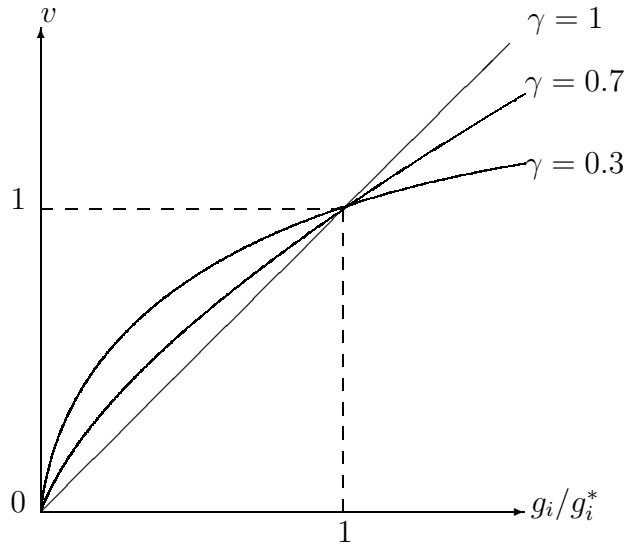


Figure 1: Behavior of $v(g_i/g_i^*) = (g_i/g_i^*)^\gamma$ with different values of γ ($0 < \gamma < 1$). A lower value of γ corresponds to a higher aversion to low natural growth deviation.

We use the estimation results of the growth equation above to simulate the amount of aid resulting from our theoretical model. We also compare these simulations with the observed data in 2008, which covers more than 90 countries.⁷ The growth-aid relation for the 2008 data, based on the previously estimated coefficients, is presented in Figure 2. This relation has an increasing pattern.

Our simulations cover both the optimal allocations of aid obtained without the weighting scheme in the donors’ objective (i.e., $\alpha = 1$) and with the weighting scheme taking into account natural growth deviation (i.e., $\alpha < 1$). Recall that both allocations, either with $\alpha = 1$ or $\alpha < 1$, rely on the same set of estimates obtained from the growth equation presented above (which focuses on the structural handicaps to growth in recipient countries). We consider the following assumptions for two models: (i) the headcount poverty rate is based on two types of the poverty line, 2 dollars/day and 1.25 dollars/day, which correspond to two sets of countries, 93 and 91 respectively, (ii) for comparison with Collier and Dollar (2002), we assume that the growth elasticity of poverty reduction η is the same

⁷We use the 2008 data because that contains a much higher number of countries than other years.

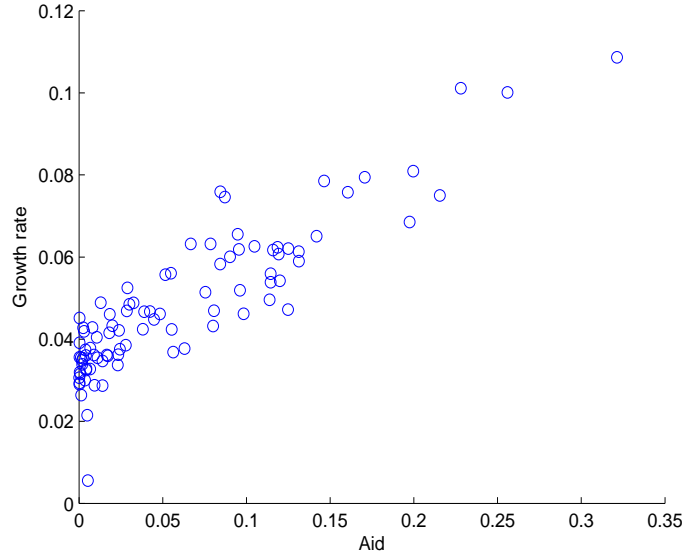


Figure 2: The estimated relation between growth and aid for the 2008 data.

for all countries and $\eta = -2$. Complementary simulations are also done with elasticity varying with five groups of countries. Detailed simulations of optimal allocations are given in Appendix G (with constant elasticity) and F (with elasticity at the regional level).

The model without natural growth deviation corresponds to $\alpha = 1$ (in this case, the value of γ does not affect the results). This situation corresponds to the donors' objective function depending only on economic growth obtained in recipient countries, as in Collier and Dollar (2002). However, differently from Collier and Dollar (2002) focusing on policy factors, we estimate growth function focusing on aid recipients' structural handicaps (lack of human capital and economic vulnerability). As mentioned previously, aid may be growth-enhancing in countries suffering structural handicaps. The aid effectiveness principle should conduce the donors to give aid to such countries in high need. In this sense, the effectiveness principle is not necessarily incompatible with fairness. Regarding the model with natural growth deviation (i.e. $\alpha < 1$), we consider two parameterizations: (i) $\alpha = 0.7$, $\gamma = 0.7$ and (ii) $\alpha = 0.7$, $\gamma = 0.3$. Recall that case (ii) with $\gamma = 0.3$ means that donors are more sensitive to natural growth deviation compared to the case (i) with $\gamma = 0.7$. Moreover, our model requires the value of the targeted growth rate g^* related to η as shown previously in Section 2. With the assumption that $\eta = -2 \forall i$, we get $g^* = 0.01365$, $\forall i$. Our results are manifold.

1. Our first result concerns the number of countries receiving development aid. While in 2008, the observed allocation of aid proposed a positive amount of aid (in GDP share) to all countries considered in our exercises (93 countries with the 2\$/day poverty line and 91 countries with the 1.25\$/day poverty line), our optimal allocation shortlists only around one-third of them.

Tables 3 and 4 here

Tables 5 and 6 here

Tables 3 and 4 report simulation results following 5 different regions, while Tables 5 and 6 following four income groups. The optimal choice is based on a multi-criteria principle, including initial poverty, natural growth deviation, and structural handicaps to the growth of recipient countries (lack of human capital and vulnerability). Values reported in these tables represent the average amount for each region (Tables 3-4) or each income group (Tables 5-6). We remark that compared to the observed allocation, on average, our optimal allocation proposes to increase aid for Sub-Saharan Africa (Tables 3 and 4) and low-income countries (Tables 5 and 6).

2. We observe that initial poverty in recipient countries is one of the key elements which justifies a large aid flow. Tables 7 and 8 report the observed aid allocation and the optimal aid allocation for ten countries with the highest poverty rates (based on 1.25\$/day and 2\$/day poverty lines, respectively). Compared to the observed allocation, our optimal allocations with ($\alpha = 1$) or without natural growth deviation ($\alpha < 1$) favor these developing countries and propose higher aid amounts to them. Note that all countries (except Haiti) that should receive a more significant aid amount belong to Sub-Saharan Africa.

Tables 7 and 8 here

3. The third result relates to the difference between the allocation without natural growth deviation in Collier and Dollar ($\alpha = 1$) and the allocation with natural growth deviation ($\alpha < 1$). The latter allocation covers more countries than the former. More precisely, with the 2\$/day poverty line (Table 3 or 5), the solution without growth deviation-weight (i.e., $\alpha = 1$) only covers 33 countries. With the weighting scheme in the donors' objective (i.e., $\alpha = 0.7$), the number of countries receiving a positive aid increases to 38 and 39 for $\gamma = 0.7$ and $\gamma = 0.3$, respectively. A similar result can be found when the 1.25\$/day poverty line is considered (Table 4 or 6).
4. The fourth finding is linked to the previous one. As a result of the increase in the number of countries receiving aid, for most of them, the optimal allocation with the weighting scheme (i.e., $\alpha = 0.7$) may propose an aid amount lower than the case without (i.e., $\alpha = 1$). Nevertheless, we can identify countries that take advantage of our multi-criteria principle compared to the case without this weighting scheme.

Tables 9 and 10 here

Table 9 identifies 12 “winning” countries (Angola, Bangladesh, Cambodia, Congo Republic, Ethiopia, Ghana, Guinea, Mauritania, Papua New Guinea, Senegal, Sudan and Tanzania) which would receive a higher aid amount in the case of $\alpha = 0.7, \gamma = 0.7$ compared to the case of $\alpha = 1$ (considering all criterion: lack of human capital, economic vulnerability, poverty rate and natural growth deviation). Yemen is added to this list when $\alpha = 0.7, \gamma = 0.3$. Moreover, given $\alpha = 0.7$, we observe that the difference in aid between two cases $\gamma = 0.7$ and $\gamma = 0.3$ is relatively important for countries with a low natural growth deviation (i.e., a low ratio g_i/g_i^*). Angola is a striking example. With only g_i/g_i^* equal to 1.27, this country receives an aid flow

of 0.0131% of GDP when $\gamma = 0.7$. If donors are more sensitive to low natural deviation, i.e., $\gamma = 0.3$, then the aid flow increases to 0.0495% of GDP.⁸ When using the 1.25\$ poverty line, the figures corresponding to $\gamma = 0.7$ and $\gamma = 0.3$ are respectively eight “winning” countries (Angola, Bangladesh, Congo Republic, Ethiopia, Guinea, Lao PDR, Papua New Guinea, and Tanzania) and 10 “winning” countries (the previous 8 countries plus Mauritania and Senegal).

Our analysis stresses that the optimal aid allocation is biased in favour of countries with a low ratio g_i/g_i^* (given other factors such as economic vulnerability, lack of human capital, and poverty rate) when donors are more sensitive to the natural growth deviation in recipient countries.

5. We also compute the marginal efficiency of aid, i.e., the number of the poor reduced by increasing the total aid amount of 1 million dollars. It is shown that the optimal allocation with the weighting scheme in donors’ objective (i.e., $\alpha = 0.7$) gives higher marginal efficiency than the optimal allocation without this weighting scheme (i.e., $\alpha = 1$). Considering the 2\$/day poverty line, the reduction corresponds to 131.78 people per million dollars when $\alpha = 1$. Regarding the optimal allocation when $\alpha = 0.7$, this quantity (denoted as $\hat{\lambda}_i$, see also Section 2) varies among countries that receive a positive amount of aid. The average values of these $\hat{\lambda}_i$ for the whole sample are 140.96 for $\gamma = 0.7$ and 151.89 people per million dollars for $\gamma = 0.3$ (Table 11). Figures 3a-b give a full picture of the distribution of $\hat{\lambda}_i$ for the whole sample.

For the case with the 1.25\$ poverty line, the number of people lifting from poverty in the optimal allocation when $\alpha = 1$ is 88.85. When $\alpha = 0.7$, the mean values of these $\hat{\lambda}_i$ are respectively 96.42 and 102.59 people for $\gamma = 0.7$ and $\gamma = 0.3$ (Table 12) and Figures 3c-d).⁹

Tables 11 and 12 here

Figure 3 here

We observe that aid is more efficient in terms of poverty reduction in recipient countries with a high economic vulnerability. Indeed, the number of people lifted from poverty per million dollars of aid is higher than the average number for these countries.¹⁰

⁸Other countries widely benefit from the donors’ sensitivity with respect to natural growth deviation are Congo Republic ($g_i/g_i^* = 2.51$), Senegal ($g_i/g_i^* = 2.69$), Yemen ($g_i/g_i^* = 2.53$).

⁹We remark that Angola is the country where aid is the lowest efficient among countries receiving a positive amount of aid. The numbers of people lifted from poverty (regarding the 2\$ poverty line) are 77 and 70 for $\gamma = 0.7$ and $\gamma = 0.3$ respectively. If the poverty line is 1.25\$/day, these numbers are respectively 58 people and 53 people for $\gamma = 0.7$ and $\gamma = 0.3$. In contrast, Burundi is the country where aid is the most efficient. Indeed, for the 2\$ poverty line, there are 167 people (in the situation of $\gamma = 0.7$) and 205 people ($\gamma = 0.3$) that can escape poverty. When using the 1.25\$ poverty line, these figures are respectively 112 people and 137 people per million dollars.

¹⁰For the case of 2\$ dollars poverty line, $\lambda = 0.7, \gamma = 0.3$, this number is 193.83 for Timor-Leste, 203.44 for Malawi, 184.5 for Zambia, 192.14 for Guinea-Bissau, 205.17 for Burundi, 199.01 for Comoros, 179.85 for Chad, 177.88 for the Gambia, which are considerably higher than the average level (151.89).

6. Finally, a reduction in the value of γ , equivalent to an increase in the donors' aversion to low natural deviation ($1 - \gamma$), significantly impacts the optimal aid allocation and raises the average marginal efficiency of aid. In other words, by giving more priority to countries with a low ratio of g_i/g_i^* , aid donors choose an efficient and fair allocation that can help lift more people from poverty. For the 2\$ poverty line, the average number of people increases from 140.96 to 151.89, and for the 1.25\$ poverty line, this number is from 96.42 to 102.59 (Tables 11 and 12).

Our model adopts the same growth elasticity of poverty reduction for all countries in our sample, $\eta = -2$. This choice is mainly motivated by the purpose of comparison with Collier and Dollar (2001,2002). We remark that the values of this elasticity may vary with the poverty-related measures (poverty headcount, poverty gap, poverty line) and the changes in income measures (GDP per capita or survey mean income) (Ram, 2006, Amini and Dan Bianco, 2016) and differs among countries (Bourguignon 2002, Bourguignon and Platteau 2017). This elasticity also depends on macroeconomic activity (expansion, recession), as Aiyemo (2020) shows. This author reported that it is -2.5% during positive economic activity while it is -2.2% during recessions. These values are not far from the assumption of $\eta = -2$. However, they reported estimates for the GEB neither at the regional level nor at the country level.

Ram (2006) is the only study that provided the growth elasticity at the regional levels, for the period 2002-2015. This elasticity is estimated with a value equal to -0.9 for East Asia and Pacific, -1.35 for Europe and Central Asia, -0.95 for Latin America and Caribbean, -1.6 for Middle East and North Africa, -0.81 for South Asia, and -0.72 for Sub-Saharan Africa.

In line with this literature and for comparison purposes, we also run simulations using Ram (2006)'s regional values. However, it should be noted that these calculations were based on the 1\$ poverty line. Subsequently, Lenagala and Ram (2010) and Ram (2011, 2013) provided some updates and estimations based on other poverty lines (1.25\$, 2\$, and 2.5\$) but they did not cover all the regions above. More precisely, there were no updates for countries from Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, East Asia (except China), South Asia (except India) whereas the estimate for Sub-Saharan Africa based on the 2\$ poverty rate is very close, -0.73 (Ram, 2013). As the period studied by Ram (2006) is close to our study, we think it is reasonable to use Ram's (2006) estimates in our simulations based on both the 1.25 and 2 poverty lines.

Our simulations on the optimal allocation of aid using the five different values of η are presented in Appendix F. Comparing these results with that given in Appendix G using the same elasticity for all regions, we can observe that the results mentioned above remain. Mainly, Table 13 and 14 indicate that countries with the highest poverty rate always take advantage of our principle, compared to the current allocation. Optimal allocations of aid in case of elasticity of poverty reduction at the regional levels give an aid flow slightly lower than allocations using $\eta = -2$. This difference is obtained because all five values of η are lower than 2 (absolute value).

5 Conclusion

In this study, we propose a model of aid allocation which aims to equalize the opportunity between recipient countries to reach a given common goal of poverty reduction. Based

on a multi-criteria principle, our optimal allocation is fair and efficient. The modeling accounts for the natural deviation or gap between the growth rate required to reach a specific target and the actual growth rate observed in the recipient countries. To maximize poverty reduction in all recipient countries, we consider their structural handicaps to growth in terms of lack of human capital, economic vulnerability, initial poverty, and natural growth deviation.

This paper takes the Millennium Development Goal (MDG) as a retrospective example, proposing to reduce poverty by half by 2015 compared to 1990. It is all about approaching the MDG by giving to each recipient country the same probability of lifting itself out of poverty by half. We calculate the required growth rate from this goal, which is considered as given since it does not depend on foreign aid.

Our proposed aid allocation substantially differs from the observed allocation. In particular, poor and vulnerable countries are "winners" as they should receive higher aid following our multi-criteria principle. Our analysis shows that it is possible to design a fair allocation of aid, which is also an efficient one since we observe that aid may be more efficient in poverty reduction in recipient countries with a high economic vulnerability. In addition, our results shed light on the impact of the weighting scheme in the donors' objective on the allocation of aid in favor of countries with a low natural growth deviation. We also show the meaningful impact of the donors' aversion to natural growth deviation on the optimal allocation of aid and its marginal efficiency. By giving more priority to countries with a low natural growth deviation or gap, aid donors can help to lift more people from poverty.

It is undeniable that performance (i.e., good governance, good macroeconomic policy in recipient countries, etc.) is the most frequent argument to explain aid allocation decided by several multilateral development banks. Our study proposes that the performance approach could be improved by considering the vulnerable initial situation in recipient countries to obtain the same initial opportunities for development. This fairness focus is not necessarily incompatible with the effectiveness principle one. Further extensions are needed to check the robustness of our results. The theoretical analysis can also be extended to include the dynamic aspect of aid allocation as official development aid may result from a dynamic interaction between donor and recipient countries. It is also promising to have other time horizons and targeted growth rates to achieve different development goals.

This paper examines the choice from the donors' point of view and discusses criteria and conditions for an optimal aid allocation, taking into account recipient characteristics and donors' preferences. However, the aid effectiveness relies not only on aid forms and donors' decisions but also on the recipient countries' circumstances and how aid is used. Several internal factors of a country determining its economic development are not included in the donors' aid allocation decisions. The normative approach adopted by our analysis should be completed by asking why the same amount of aid is efficient in one country and not in another one. Moreover, the question related to the conditions under which a recipient country can get out of poverty should be deeply analyzed in parallel with our normative approach. In brief, analyses on the effectiveness and allocation of aid are perfectly complementary.

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Tables and Figures

Table 1: Definition of variables and descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min.	Max.
Growth rate of GDP per capita (g)	838	1.618	4.543	-28.546	27.271
log GDP per capita ($\ln y$)	971	7.969	0.958	4.6134	10.051
Economic vulnerability index (V)	923	0.413	0.123	0.130	0.730
Lack of human capital (H)	1007	0.428	0.243	0.012	0.965
Aid (A , in GDP share)	958	0.091	0.125	0	1.451
Poverty headcount, 1.25\$/day	759	0.193	0.223	0	0.926
Poverty headcount, 2\$/day	759	0.325	0.287	0	0.985

Table 2: Estimation results of the growth equation

Variable	Within FE		System GMM	
	Coefficient	Std. Err.	Coefficient	Std. Err.
$\ln y_{i,t-\tau}$	0.683**	0.024	0.943**	0.020
Aid	-0.219	0.392	-0.883	0.620
Squared aid	-1.019*	0.620	-1.324**	0.496
Vulnerability	0.101	0.115	-0.206**	0.087
Aid \times Vulnerability	1.503**	0.740	2.455*	1.263
Lack of human capital	-0.527**	0.141	-0.259**	0.074
Period 87-90	-0.085**	0.029	-0.032*	0.018
Period 91-94	-0.099**	0.025	-0.029	0.022
Period 95-98	-0.087**	0.023	-0.020	0.016
Period 99-02	-0.058**	0.020	0.003	0.014
Period 03-06	-0.067**	0.016	-0.025*	0.013
Period 07-10	0.026*	0.014	0.062**	0.010
Intercept	2.740**	0.227	0.704**	0.195
Number of observations		700		693
Number of countries		109		109
Existence of fixed effects, $F(108, 572)$		4.50**		
Hausman test, random vs. fixed effects, $\chi^2(12)$		151.12**		
Arellano-Bond test, AR(1)				-4.80**
Arellano-Bond test, AR(2)				-1.44
Sargan test of overid. restrictions, $\chi^2(50)$				130.63**
Hansen test of overid. restrictions, $\chi^2(50)$				64.35*
Difference-in-Hansen tests of exogeneity				
Hansen test excluding group, $\chi^2(44)$				54.38
Difference, $\chi^2(6)$				9.97

Notes. Dependent variable: $\ln y_{it}$. Results obtained with the within fixed effects estimator and the one-step system GMM estimator of Blundell and Bond (1998) using robust standard errors. * and ** denote significance at the 10% and 5% levels, respectively. Strictly exogenous regressors include time dummies. Predetermined regressors are $\ln y_{i,t-\tau}$, Aid, Vulnerability, Lack of human capital.

Appendix A: List of countries

Sub-Saharan Africa: Angola, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Rep., Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Swaziland, Benin, Mozambique

Middle East and North Africa: Algeria, Djibouti, Egypt Arab Rep., Iran, Iraq, Jordan, Morocco, Syrian Arab Rep., Timor-Leste, Tunisia, Yemen

Latin America and Caribbean: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay, Venezuela, St. Lucia, Belize, El Salvador, Bolivia, Mexico

East-Asia and Pacific: Cambodia, China, Fiji, Indonesia, Lao PDR, Papua New Guinea, Philippines, Vietnam, Malaysia

South and Central Asia: Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka, India, Turkey

Appendix B: Optimal allocations of aid

Table 3: Observed and optimal allocations of aid for 5 regions (based on the 2\$/day poverty line, 2008 data)

Region	Observed aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$, $\gamma = 0.3$
Sub-Saharan Africa	0.10	0.1588	0,151	0.1431
Middle East and North Africa	0.0386	0.0279	0.0245	0.0259
Latin America and Caribbean	0.0233	0.0113	0.0011	0.0097
East-Asia and Pacific	0.0283	0.0192	0.0198	0.0195
South and Central Asia	0.0276	0.0195	0.0193	0.0186
# recipients	93	33	38	39

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. Our sample contains 93 countries: 41 countries in Sub-Saharan Africa, 11 countries in Middle East and North Africa, 24 countries in Latin America and Caribbean, 9 countries in East-Asia and Pacific, and 8 countries in South and Central Asia

Table 4: Observed and optimal allocations of aid for 5 regions (based on the 1.25\$/day poverty line, 2008 data)

Region	Observed aid (%GDP)	Optimal aid	Optimal aid	Optimal aid
		(%GDP)	(%GDP)	(% GDP)
		$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
			$\gamma = 0.7$	$\gamma = 0.3$
Sub-Saharan Africa	0.10	0.1553	0,1469	0.1366
Middle East and North Africa	0.0386	0.0226	0.0186	0.0153
Latin America and Caribbean	0.0233	0.0121	0.0115	0.0109
East-Asia and Pacific	0.0332	0.0084	0.0116	0.0125
South Asia	0.0312	0.0124	0.0132	0.0134
# recipients	91	30	31	35

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. Our sample contains 91 countries: 41 countries in Sub-Saharan Africa, 11 countries in Middle East and North Africa, 24 countries in Latin America and Caribbean, 8 countries in East-Asia and Pacific, and 7 countries in South Asia

Table 5: Observed and optimal allocations of aid for 4 income groups (based on the 2\$/day poverty line, 2008 data)

Group	Observed aid (%GDP)	Optimal aid	Optimal aid	Optimal aid
		(%GDP)	(%GDP)	(% GDP)
		$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
			$\gamma = 0.7$	$\gamma = 0.3$
Low income	0.1289	0.2416	0.2186	0.2149
Low middle income	0.0555	0.0462	0.0449	0.0439
Upper middle income	0.0169	0	0	0
High income	0.00425	0	0	0
# recipients	93	33	38	39

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. Our sample contains 93 countries: 24 low income countries, 35 low middle income countries, 30 upper middle income countries, and 4 high income countries.

Table 6: Observed and optimal allocations of aid for 4 income groups (based on the 1.25\$/day poverty line, 2008 data)

Group	Observed aid (%GDP)	Optimal aid	Optimal aid	Optimal aid
		(%GDP)	(%GDP)	(% GDP)
		$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
			$\gamma = 0.7$	$\gamma = 0.3$
Low income	0.1289	0.2351	0.223	0.2117
Low middle income	0.0555	0.0406	0.0382	0.0366
Upper middle income	0.0180	0	0	0
High income	0.0043	0	0	0
# recipients	91	30	31	35

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. Our sample contains 91 countries: 24 low income countries, 35 low middle income countries, 28 upper middle income countries, and 4 high income countries.

Table 7: Observed and optimal allocations of aid of 10 countries with highest poverty rate (based on the 1.25\$/day poverty line, 2008 data)

Country	Poverty rate	Observed aid (%GDP)	Optimal aid	Optimal aid	Optimal aid
			(%GDP)	(%GDP)	(%GDP)
			$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
				$\gamma = 0.7$	$\gamma = 0.3$
Central African Rep.	0.6283	0.1312	0.3229	0.3128	0.3022
Haiti	0.6358	0.1419	0.2909	0.2760	0.2611
Zambia	0.6627	0.0843	0.3570	0.3298	0.3030
Nigeria	0.6646	0.0066	0.1679	0.1591	0.1510
Tanzania	0.6676	0.1138	0.1294	0.1303	0.1302
Malawi	0.6734	0.2280	0.4103	0.3914	0.3716
Rwanda	0.6766	0.1996	0.3339	0.3163	0.2984
Madagascar	0.7162	0.0902	0.2902	0.2775	0.2644
Burundi	0.8058	0.3214	0.4773	0.4660	0.4540
Congo Dem. Rep.	0.8615	0.1707	0.3888	0.3843	0.3794

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation.

Table 8: Observed and optimal allocations of aid of 10 countries with highest poverty rate (based on the 2\$/day poverty line, 2008 data)

Country	Poverty rate h	Observed aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$
Central African Rep.	0.8017	0.1312	0.3108	0.2990	0.2861
Zambia	0.8104	0.0843	0.3294	0.2978	0.2666
Mozambique	0.8187	0.2155	0.3009	0.2883	0.2746
Nigeria	0.8411	0.0066	0.1341	0.1283	0.1216
Rwanda	0.8482	0.1996	0.3159	0.2954	0.2739
Tanzania	0.8741	0.1138	0.1133	0.1149	0.1145
Malawi	0.8755	0.2280	0.4000	0.3785	0.2550
Madagascar	0.8943	0.0902	0.2735	0.2586	0.2427
Burundi	0.9321	0.3214	0.4652	0.4507	0.4346
Congo Dem. Rep.	0.9449	0.1707	0.3805	0.3743	0.3672

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries.

Appendix C: “Winning” countries

Table 9: “Winning” countries when accounting for natural growth deviation (g_i/g_i^*). Optimal allocations of aid. Headcount poverty rate based on the 2\$/day poverty line, 2008 data.

Country	H	h	V	g_i/g_i^*	Optimal aid	Optimal aid	Optimal aid
					(%GDP)	(% GDP)	(% GDP)
					$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
						$\gamma = 0.7$	$\gamma = 0.3$
Angola	0.69	0.72	0.47	1.27	0	0.0131	0.0495
Bangladesh	0.43	0.79	0.22	3.26	0.0336	0.0412	0.0452
Cambodia	0.41	0.54	0.37	3.06	0	0.0156	0.0255
Congo Republic	0.38	0.74	0.42	2.51	0	0.0001	0.0211
Ethiopia	0.64	0.69	0.25	3.42	0.1140	0.1174	0.1188
Ghana	0.32	0.47	0.33	3.61	0.0125	0.0165	0.0162
Guinea	0.58	0.69	0.26	3.41	0.0960	0.1004	0.1023
Mauritania	0.47	0.48	0.49	3.06	0	0.0335	0.0439
Papua New Guinea	0.43	0.64	0.42	3.63	0.0681	0.0717	0.0710
Senegal	0.54	0.50	0.35	2.69	0	0.0270	0.0436
Sudan	0.45	0.45	0.48	3.29	0.0174	0.0383	0.0411
Tanzania	0.52	0.87	0.27	3.64	0.1133	0.1149	0.1145
Yemen	0.43	0.46	0.44	2.53	0	0	0.0121

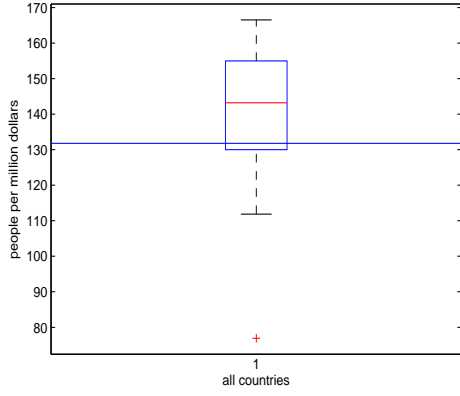
Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors’ sensitivity with respect to growth deviation in recipient countries. H : lack of human capital; h : poverty line; V : economic vulnerability index; g_i/g_i^* : natural growth deviation

Table 10: “Winning” countries when accounting for natural growth deviation (g_i/g_i^*). Optimal allocations of aid. Headcount poverty rate based on the 1.25\$/day poverty line, 2008 data.

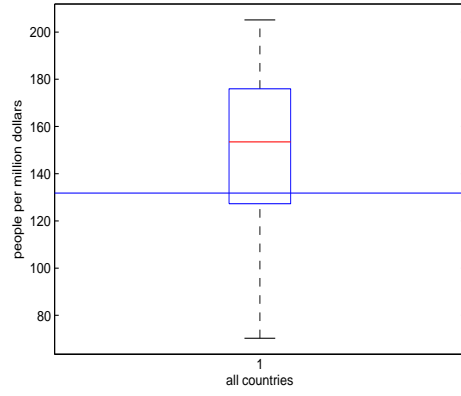
Country	H	h	V	g_i/g_i^*	Optimal aid (% GDP) $\alpha = 1$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$
Angola	0.69	0.56	0.47	0.85	0	0.0274	0.0642
Bangladesh	0.43	0.47	0.22	3.06	0.0101	0.0220	0.0296
Congo Republic	0.38	0.53	0.42	2.39	0	0.0145	0.0332
Ethiopia	0.64	0.32	0.25	3.10	0.0600	0.0698	0.0746
Guinea	0.58	0.42	0.26	3.31	0.0820	0.0883	0.0925
Lao PDR	0.35	0.34	0.44	3.30	0.0073	0.0238	0.0296
Papua New Guinea	0.43	0.42	0.42	3.60	0.0634	0.0690	0.0706
Tanzania	0.52	0.67	0.27	3.73	0.129	0.1303	0.1302
Mauritania	0.47	0.23	0.49	2.13	0	0	0.0004
Senegal	0.54	0.25	0.35	2.05	0	0	0.0022

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors’ sensitivity with respect to growth deviation in recipient countries. H : lack of human capital; h : poverty line; V : economic vulnerability index; g_i/g_i^* : natural growth deviation

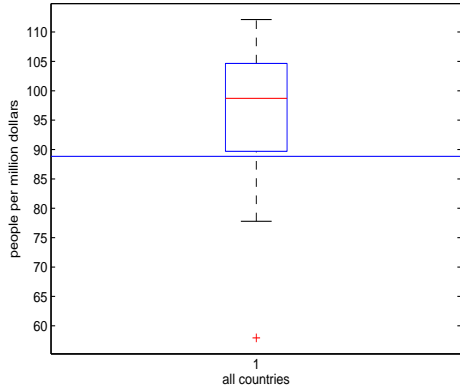
Appendix D: Marginal efficiency $\hat{\lambda}$



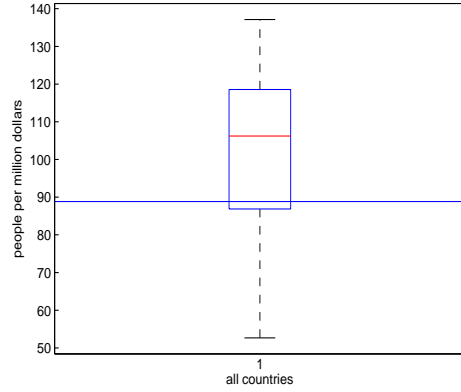
(a)



(b)



(c)



(d)

Figure 3: Marginal efficiency of aid, $\hat{\lambda}_i$. (a) poverty line = 2\$/day, $\gamma = 0.7$, (b) poverty line = 2\$/day, $\gamma = 0.3$, (c) poverty line = 1.25\$/day, $\gamma = 0.7$, (d) poverty line = 1.25\$/day, $\gamma = 0.3$. The horizontal lines correspond to the Collier-Dollar utility function, $\hat{\lambda}_{CD} = 131.78$ for poverty line = 2\$ per day and = 88.85 for poverty line = 1.25\$/day.

Table 11: Marginal Efficiency $\hat{\lambda}$. Headcount poverty rate based on the 2\$/day poverty line, 2008 data.

Region	Average $\hat{\lambda}$		
	$\alpha = 1$	$\alpha = 0.7$	$\alpha = 0.7$
		$\gamma = 0.7$	$\gamma = 0.3$
Sub-Saharan Africa	131.78	141.48	154.66
Middle East and North Africa	131.78	162.98	150.1
Latin America and Caribbean	131.78	148.81	166.52
East-Asia and Pacific	131.78	130.1	130.58
South Asia and Central Asia	131.78	132.75	135.5
Whole sample average	131.78	140.96	151.89
# recipients	33	38	39

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. The marginal efficiency value corresponds to the average value of 31 recipients over 41 countries in Sub-Saharan Africa; 1 recipient over 11 countries in Middle East & North Africa (and 2 recipients when $\gamma = 0.3$); one recipient over 24 countries in Latin America & Caribbean, 3 recipient over 9 countries in East-Asia and Pacific; 2 recipient over 8 countries in South Asia and Central Asia.

Table 12: Marginal Efficiency $\hat{\lambda}$. Headcount poverty rate based on the 1.25 \$/day poverty line, 2008 data.

Region	Average $\hat{\lambda}$		
	Average value	Average value	Average value
	$\alpha = 1$	$\alpha = 0.7$ $\gamma = 0.7$	$\alpha = 0.7$ $\gamma = 0.3$
Sub-Saharan Africa	88.85	96.87	100.27
Middle East and North Africa	88.85	106.82	122.06
Latin America and Caribbean	88.85	100.79	112.82
East-Asia and Pacific	88.85	86.26	85.4
South Asia	88.85	87.51	87.12
Whole sample average	88.85	96.03	102.59
# recipients	30	31	35

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita) and $g^* = 0.01365$, $\forall i$. The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The last two columns correspond to the model with natural growth deviation, a lower value of γ means a higher donors' sensitivity with respect to growth deviation in recipient countries. The marginal efficiency value corresponds to the average value of 29 recipients over 41 countries in Sub-Saharan Africa; 1 recipient over 11 countries in Middle East & North Africa; 1 recipient over 24 countries in Latin America & Caribbean, 2 recipient over 8 countries in East-Asia and Pacific; 2 recipient over 7 countries in South Asia.

Appendix E: Detailed simulations with constant growth elasticity of poverty reduction

Table 13: Observed and optimal allocations of aid of 10 countries with highest poverty rate, based on the \$1.25/day poverty line (2008 data) and growth elasticity of poverty reduction following regions.

Country	Poverty rate	Observed aid (%GDP)	$\eta = -2$			Regional η		
			Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$
Central African Rep.	0.6283	0.1312	0.3229	0.3128	0.3022	0.3123	0.2951	0.2964
Haiti	0.6358	0.1419	0.2909	0.2760	0.2611	0.3057	0.3035	0.2928
Zambia	0.6627	0.0843	0.3570	0.3298	0.3030	0.3386	0.3010	0.2981
Nigeria	0.6646	0.0066	0.1679	0.1591	0.1510	0.1399	0.1150	0.1293
Tanzania	0.6676	0.1138	0.1294	0.1303	0.1302	0.1122	0.1001	0.1122
Malawi	0.6734	0.2280	0.4103	0.3914	0.3716	0.3999	0.3751	0.3709
Rwanda	0.6766	0.1996	0.3339	0.3163	0.2984	0.3199	0.2938	0.2931
Madagascar	0.7162	0.0902	0.2902	0.2775	0.2644	0.2775	0.2566	0.2579
Burundi	0.8058	0.3214	0.4773	0.4660	0.4540	0.4712	0.4563	0.4537
Congo Dem. Rep.	0.8615	0.1707	0.3888	0.3843	0.3794	0.3855	0.3787	0.3783

Notes: The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The columns with $\alpha = 0.7$ correspond to the model with natural growth deviation.

Table 14: Observed and optimal allocations of aid of 10 countries with highest poverty rate, based on the \$2/day poverty line (2008 data) and growth elasticity of poverty reduction following regions.

Country	Poverty rate h	Observed aid (%GDP)	$\eta = -2$			Regional η		
			Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$	Optimal aid (% GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$
Central African Rep.	0.8017	0.1312	0.3108	0.2990	0.2861	0.2970	0.2745	0.2751
Zambia	0.8104	0.0843	0.3294	0.2978	0.2666	0.2961	0.2560	0.2524
Mozambique	0.8187	0.2155	0.3009	0.2883	0.2746	0.2791	0.2623	0.2630
Nigeria	0.8411	0.0066	0.1341	0.1283	0.1216	0.0872	0.0698	0.0880
Rwanda	0.8482	0.1996	0.3159	0.2954	0.2739	0.2939	0.2634	0.2618
Tanzania	0.8741	0.1138	0.1133	0.1149	0.1145	0.0864	0.0754	0.0888
Malawi	0.8755	0.2280	0.4000	0.3785	0.2550	0.3828	0.3556	0.3496
Madagascar	0.8943	0.0902	0.2735	0.2586	0.2427	0.2573	0.2290	0.2297
Burundi	0.9321	0.3214	0.4652	0.4507	0.4346	0.4546	0.4354	0.4312
Congo Dem. Rep.	0.9449	0.1707	0.3805	0.3743	0.3672	0.3722	0.3652	0.3641

Notes: The model without consideration for natural growth deviation corresponds to $\alpha = 1$. The columns with $\alpha = 0.7$ correspond to the model with natural growth deviation.

Table 15: Actual and optimal allocations of aid, headcount poverty rate based on \$2/day poverty line, $\alpha = 0.7$, $\gamma = 0.7$, and $\eta = -2$

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million) $\alpha = 0.7, \gamma = 0.7$
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.7$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0134	76.91
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0336	0.0412	125.93
Belize	0.0199	0	0	0
Benin	0.0961	0.1575	0.1496	137.24
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.2199	0.2094	141.15
Burundi	0.3214	0.4652	0.4507	166.55
Cambodia	0.0755	0	0.0156	122.21
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Rep.	0.1312	0.3108	0.2990	149.62
Chad	0.0631	0.3545	0.3216	156.39
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3741	0.3361	165.38
Congo, Dem. Rep.	0.1707	0.3805	0.3743	157.56
Congo, Rep.	0.0553	0	0.0001	111.86
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0	0	0
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0

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Table 15 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1140	0.1174	127.95
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia	0.0948	0.2812	0.2171	158.77
Ghana	0.0515	0.0125	0.0165	130.01
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0960	0.1004	127.73
Guinea-Bissau	0.1605	0.3781	0.3478	161.61
Guyana	0.0872	0	0	0
Haiti	0.1419	0.2694	0.2523	148.81
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.1045	0.0905	137.81
Lesotho	0.0667	0.1696	0.1405	147.81
Madagascar	0.0902	0.2735	0.2586	150.28
Malawi	0.2280	0.4000	0.3785	166.12
Malaysia	0.0007	0	0	0
Maldives	0.0301	0	0	0
Mali	0.1144	0.2466	0.2356	144.05
Mauritania	0.1251	0	0.0335	121.61
Mexico	0.0001	0	0	0

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Table 15 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.3009	0.2883	149.73
Namibia	0.0244	0	0	0
Nepal	0.0549	0.1227	0.1135	139.59
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2831	0.2746	144.70
Nigeria	0.0066	0.1341	0.1283	135.10
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0681	0.0717	130.29
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3159	0.2954	154.99
Sao Tome & Principe	0.2559	0.0684	0.0516	137.62
Senegal	0.0801	0	0.0270	116.57
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2981	0.2858	147.66
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.0174	0.0383	125.41
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Rep.	0.0030	0	0	0
Tanzania	0.1138	0.1133	0.1149	130.24
Timor-Leste	0.0844	0.3070	0.2700	162.98
Togo	0.1048	0.2361	0.2209	147.70
Tunisia	0.0088	0	0	0

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Table 15 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid	Optimal aid	Marginal efficiency $\hat{\lambda}_i$
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	(people/\$ million) $\alpha = 0.7, \gamma = 0.7$
Turkey	0.0015	0	0	0
Uganda	0.1159	0.1804	0.1682	142.37
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen	0.0172	0	0	0
Zambia	0.0843	0.3294	0.2978	158.32
		$\hat{\lambda}_{CD}=131.78$	$\hat{\lambda}=1450.95$	average $\{\hat{\lambda}_i\}=140.96$

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.7, g^* = -0.0273/\eta = 0.01365, \forall i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$) and our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 16: Actual and optimal allocations of aid, headcount poverty rate based on \$2/day poverty line, $\alpha = 0.7$, $\gamma = 0.3$, and $\eta = -2$

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0495	70.28
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0336	0.0452	122.89
Belize	0.0199	0	0	0
Benin	0.0961	0.1575	0.1410	143.20
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.2199	0.1981	151.18
Burundi	0.3214	0.4652	0.4346	205.17
Cambodia	0.0755	0	0.0255	118.51
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Rep.	0.1312	0.3108	0.2861	169.25
Chad	0.0631	0.3545	0.2901	179.85
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3741	0.2980	199.01
Congo, Dem. Rep.	0.1707	0.3805	0.3672	186.69
Congo, Rep.	0.0553	0	0.0211	105.87
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0	0	0
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0

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Table 16 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1140	0.1188	126.32
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia	0.0948	0.2812	0.1717	177.88
Ghana	0.0515	0.0125	0.0162	130.14
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0960	0.1023	125.99
Guinea-Bissau	0.1605	0.3781	0.3168	192.14
Guyana	0.0872	0	0	0
Haiti	0.1419	0.2694	0.2346	166.52
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.1045	0.0792	142.67
Lesotho	0.0667	0.1696	0.1159	161.34
Madagascar	0.0902	0.2735	0.2427	170.16
Malawi	0.2280	0.4000	0.3550	203.44
Malaysia	0.0007	0	0	0
Maldives	0.0301	0	0	0
Mali	0.1144	0.2466	0.2236	157.40
Mauritania	0.1251	0	0.0439	118.66
Mexico	0.0001	0	0	0

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Table 16 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.3009	0.2746	169.37
Namibia	0.0244	0	0	0
Nepal	0.0549	0.1227	0.1035	148.06
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2831	0.2651	159.28
Nigeria	0.0066	0.1341	0.1216	138.94
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0681	0.0710	130.57
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3159	0.2739	179.40
Sao Tome & Principe	0.2559	0.0684	0.0403	141.55
Senegal	0.0801	0	0.0436	110.16
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2981	0.2723	164.95
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.0174	0.0441	123.64
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Rep.	0.0030	0	0	0
Tanzania	0.1138	0.1133	0.1145	130.62
Timor-Leste	0.0844	0.3070	0.2334	193.83
Togo	0.1048	0.2361	0.2049	164.47
Tunisia	0.0088	0	0	0

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Table 16 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP)	(%GDP)	
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Turkey	0.0015	0	0	0
Uganda	0.1159	0.1804	0.1555	153.46
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen	0.0172	0	0.0121	106.38
Zambia	0.0843	0.3294	0.2666	184.52
		$\hat{\lambda}_{CD}=131.78$	$\hat{\lambda}=440.18$	average $\{\hat{\lambda}_i\}=151.89$

Notes: Simulations are run under the assumption $\eta = -2$ (elasticity of poverty reduction with respect to income per capita). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.3, g^* = -0.0273/\eta = 0.01365, \forall i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$) and our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 17: Actual and optimal allocations of aid, headcount poverty rate based on \$1.25 per day poverty line, $\alpha = 0.7, \gamma = 0.7$, and $\eta = -2$

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP)	(%GDP)	
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.7$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0274	57.94
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0102	0.0220	83.45
Belize	0.0199	0	0	0
Benin	0.0961	0.1373	0.1317	91.19
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0

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Table 17 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Burkina Faso	0.1199	0.2058	0.1959	94.30
Burundi	0.3214	0.4773	0.4660	112.13
Cambodia	0.0755	0	0	0
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Rep.	0.1312	0.3229	0.3128	100.87
Chad	0.0631	0.3423	0.3089	104.58
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3830	0.3472	111.53
Congo, Dem. Rep.	0.1707	0.3888	0.3843	105.99
Congo, Rep.	0.0553	0	0.0145	77.79
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0	0	0
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.0601	0.0699	83.72
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia	0.0948	0.2369	0.1776	103.58
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0820	0.0883	85.25
Guinea-Bissau	0.1605	0.3663	0.3346	108.23
Guyana	0.0872	0	0	0

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Table 17 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Haiti	0.1419	0.2909	0.2760	100.79
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.0073	0.0238	85.22
Lesotho	0.0667	0.1684	0.1400	99.34
Madagascar	0.0902	0.2902	0.2775	101.50
Malawi	0.2280	0.4103	0.3914	111.90
Maldives	0.0301	0	0	0
Mali	0.1144	0.2429	0.2321	96.73
Mauritania	0.1251	0	0	0
Mexico	0.0001	0	0	0
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.3076	0.2961	100.84
Namibia	0.0244	0	0	0
Nepal	0.0549	0.0767	0.0705	91.57
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2689	0.2598	96.90
Nigeria	0.0066	0.1679	0.1591	92.80
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0634	0.0690	87.31
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0

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Table 17 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	(people/\$ million) $\alpha = 0.7, \gamma = 0.7$
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3339	0.3163	104.74
Sao Tome & Principe	0.2559	0	0	0
Senegal	0.0801	0	0	0
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2933	0.2809	99.14
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0	0	0
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Rep.	0.0030	0	0	0
Tanzania	0.1138	0.1294	0.1303	88.20
Timor-Leste	0.0844	0.2484	0.2048	106.82
Togo	0.1048	0.2093	0.1931	98.27
Tunisia	0.0088	0	0	0
Uganda	0.1159	0.1693	0.1575	95.24
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen	0.0172	0	0	0
Zambia	0.0843	0.3570	0.3298	107.50
		$\hat{\lambda}_{CD}=88.85$	$\hat{\lambda}=975.46$	average $\{\hat{\lambda}_i\}=96.42$

Notes: The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.7, g^* = -0.0273/\eta_i = 0.01365, \forall i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$) and our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 18: Actual and optimal allocations of aid, headcount poverty rate based on \$1.25/day poverty line, $\alpha = 0.7$, $\gamma = 0.3$, and $\eta = -2$

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0642	52.65
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0102	0.0296	80.01
Belize	0.0199	0	0	0
Benin	0.0961	0.1373	0.1262	93.49
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.2058	0.1864	99.53
Burundi	0.3214	0.4773	0.4540	137.14
Cambodia	0.0755	0	0	0
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Rep.	0.1312	0.3229	0.3022	113.48
Chad	0.0631	0.3423	0.2792	118.57
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3830	0.3123	133.67
Congo, Dem. Rep.	0.1707	0.3888	0.3794	124.50
Congo, Rep.	0.0553	0	0.0332	73.93
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0	0	0
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0

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Table 18 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	(people/\$ million) $\alpha = 0.7, \gamma = 0.3$
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.0601	0.0764	80.29
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia	0.0948	0.2369	0.1418	112.46
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0820	0.0925	82.94
Guinea-Bissau	0.1605	0.3663	0.3040	126.91
Guyana	0.0872	0	0	0
Haiti	0.1419	0.2909	0.2611	112.82
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.0073	0.0296	83.95
Lesotho	0.0667	0.1684	0.1175	107.66
Madagascar	0.0902	0.2902	0.2644	114.57
Malawi	0.2280	0.4103	0.3716	136.18
Maldives	0.0301	0	0	0
Mali	0.1144	0.2429	0.2212	104.63
Mauritania	0.1251	0	0.0004	64.15
Mexico	0.0001	0	0	0
Morocco	0.0166	0	0	0

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Table 18 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Mozambique	0.2155	0.3076	0.2841	113.29
Namibia	0.0244	0	0	0
Nepal	0.0549	0.0767	0.0645	94.23
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2689	0.2504	105.21
Nigeria	0.0066	0.1679	0.1510	96.46
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0634	0.0706	86.85
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3339	0.2984	121.00
Sao Tome & Principe	0.2559	0	0	0
Senegal	0.0801	0	0.0022	63.07
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2933	0.2683	109.57
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0	0	0
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Rep.	0.0030	0	0	0
Tanzania	0.1138	0.1294	0.1302	88.27
Timor-Leste	0.0844	0.2484	0.1679	122.06
Togo	0.1048	0.2093	0.1778	107.21
Tunisia	0.0088	0	0	0
Uganda	0.1159	0.1693	0.1464	101.30

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Table 18 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$
		(%GDP)		(people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	$\alpha = 0.7, \gamma = 0.3$
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen	0.0172	0	0	0
Zambia	0.0843	0.3570	0.3030	125.89
		$\hat{\lambda}_{CD}=88.85$	$\hat{\lambda}=293.10$	average $\{\hat{\lambda}_i\}=102.59$

Notes: The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.3, g^* = -0.0273/\eta = 0.01365, \forall i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$) and our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Appendix G: Detailed optimal allocations of aid with growth elasticity of poverty reduction at regional level

Table 19: Actual and optimal allocations of aid, headcount poverty rate based on \$2/day poverty line, $\alpha = 0.7$, $\gamma = 0.7$, and regional elasticity of poverty reduction

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.7$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0	0
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0240	0.0265	55.59
Belize	0.0199	0	0	0
Benin	0.0961	0.1189	0.0987	62.04
Bhutan	0.0806	0	-0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.1888	0.1686	63.92
Burundi	0.3214	0.4546	0.4354	73.19
Cambodia	0.0755	0	0.0321	52.23
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Republic	0.1312	0.2970	0.2745	67.30
Chad	0.0631	0.3159	0.2752	68.74
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3259	0.2964	72.16
Congo, Dem. Rep.	0.1707	0.3722	0.3652	70.21
Congo, Rep.	0.0553	0	0	0
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0

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Table 19 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Djibouti	0.1313	0.0786	0.1739	39.40
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1671	0.1887	37.34
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia, The	0.0948	0.2353	0.1476	67.69
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0740	0.0587	59.62
Guinea-Bissau	0.1605	0.3309	0.3117	70.99
Guyana	0.0872	0	0	0
Haiti	0.1419	0.2807	0.2805	57.29
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran, Islamic Rep.	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.1106	0.1182	56.66
Lesotho	0.0667	0.0525	0.0815	64.91
Madagascar	0.0902	0.2573	0.2290	67.38
Malawi	0.2280	0.3828	0.3556	72.91
Malaysia	0.0007	0	0	0
Maldives	0.0301	0	0	0

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Table 19 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Mali	0.1144	0.2189	0.2022	65.20
Mauritania	0.1251	0	0	0
Mexico	0.0001	0	0	0
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.2791	0.2623	67.30
Namibia	0.0244	0	0	0
Nepal	0.0549	0.1116	0.1042	59.73
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2682	0.2500	65.68
Nigeria	0.0066	0.0872	0.0698	60.69
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0786	0.0940	54.47
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.2939	0.2634	68.88
Sao Tome and Principe	0.2559	0	0	0
Senegal	0.0801	0	0	0
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2688	0.2568	66.53
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.2159	0.2768	42.07
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Republic	0.0030	0	0	0
Tanzania	0.1138	0.0864	0.0754	60.52

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Table 19 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid	Optimal aid	Marginal efficiency $\hat{\lambda}_i$
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	(people/\$ million) $\alpha = 0.7, \gamma = 0.7$
Timor-Leste	0.0844	0.3074	0.2961	63.45
Togo	0.1048	0.2029	0.1861	66.34
Tunisia	0.0088	0	0	0
Turkey	0.0015	0	0	0
Uganda	0.1159	0.1503	0.1266	64.27
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen, Rep.	0.0172	0.1406	0.2180	40.38
Zambia	0.0843	0.2961	0.2560	69.63
		$\hat{\lambda}_{CD}=57.10$	$\hat{\lambda}=324.61$	average $\{\hat{\lambda}_i\}=61.61$

Notes: Simulations are run under the following assumption about the regional values for growth elasticity of poverty reduction (η_i , cf. Ram, 2006): -0.90 (East Asia & Pacific countries), -0.95 (Latin America & Caribbean), -1.60 (Middle East & North Africa), -0.81 (South Asia & Central Asia), and -0.72 (Sub-Saharan Africa). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.7, g_i^* = 0.0273/\eta_i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$), our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 20: Actual and optimal allocations of aid, headcount poverty rate based on \$2/day poverty line, $\alpha = 0.7$, $\gamma = 0.3$, and regional elasticity of poverty reduction

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million) $\alpha = 0.7, \gamma = 0.3$
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0	0
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0240	0.0346	53.05
Belize	0.0199	0	0	0
Benin	0.0961	0.1189	0.1122	58.69
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.1888	0.1763	61.45
Burundi	0.3214	0.4546	0.4312	76.83
Cambodia	0.0755	0	0.0339	51.93
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Republic	0.1312	0.2970	0.2751	66.92
Chad	0.0631	0.3159	0.2733	69.28
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3259	0.2879	74.85
Congo, Dem. Rep.	0.1707	0.3722	0.3641	71.85
Congo, Rep.	0.0553	0	0	0
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0.0786	0.1138	50.05
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0

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Table 20 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1671	0.1770	48.06
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia, The	0.0948	0.2353	0.1481	67.61
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0740	0.0743	54.52
Guinea-Bissau	0.1605	0.3309	0.3060	73.00
Guyana	0.0872	0	0	0
Haiti	0.1419	0.2807	0.2666	63.89
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran, Islamic Rep.	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.1106	0.1049	59.23
Lesotho	0.0667	0.0525	0.0893	63.35
Madagascar	0.0902	0.2573	0.2297	67.06
Malawi	0.2280	0.3828	0.3496	76.31
Malaysia	0.0007	0	0	0
Maldives	0.0301	0	0	0
Mali	0.1144	0.2189	0.2066	63.45
Mauritania	0.1251	0	0	0
Mexico	0.0001	0	0	0

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Table 20 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.2791	0.2630	66.93
Namibia	0.0244	0	0	0
Nepal	0.0549	0.1116	0.1032	60.06
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2682	0.2527	64.21
Nigeria	0.0066	0.0872	0.0880	56.93
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0786	0.0882	55.56
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.2939	0.2618	69.55
Sao Tome and Principe	0.2559	0	0.0022	55.75
Senegal	0.0801	0	0	0
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2688	0.2587	65.65
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.2159	0.2137	57.48
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Republic	0.0030	0	0	0
Tanzania	0.1138	0.0864	0.0888	55.89
Timor-Leste	0.0844	0.3074	0.2730	72.19
Togo	0.1048	0.2029	0.1887	65.35
Tunisia	0.0088	0	0	0

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Table 20 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Turkey	0.0015	0	0	0
Uganda	0.1159	0.1503	0.1337	62.04
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen, Rep.	0.0172	0.1406	0.1593	53.13
Zambia	0.0843	0.2961	0.2524	70.74
		$\hat{\lambda}_{CD}=57.10$	$\hat{\lambda}=126.61$	average $\{\hat{\lambda}_i\}=62.94$

Notes: Simulations are run under the following assumption about the regional values for growth elasticity of poverty reduction (η_i , cf. Ram, 2006): -0.90 (East Asia & Pacific countries), -0.95 (Latin America & Caribbean), -1.60 (Middle East & North Africa), -0.81 (South Asia & Central Asia), and -0.72 (Sub-Saharan Africa). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7, \gamma = 0.3, g_i^* = 0.0273/\eta_i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$), our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 21: Actual and optimal allocations of aid, headcount poverty rate based on \$1.25/day poverty line, $\alpha = 0.7, \gamma = 0.7$, and regional elasticity of poverty reduction

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0	0
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0072	0.0111	35.82
Belize	0.0199	0	0	0
Benin	0.0961	0.1072	0.0846	39.95
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0

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Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.7$	
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.1828	0.1585	41.34
Burundi	0.3214	0.4712	0.4563	47.63
Cambodia	0.0755	0	0	0
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Republic	0.1312	0.3123	0.2951	43.88
Chad	0.0631	0.3155	0.2683	44.53
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3631	0.3166	47.13
Congo, Dem. Rep.	0.1707	0.3855	0.3787	45.64
Congo, Rep.	0.0553	0	0	0
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0
Djibouti	0.1313	0	0.0653	23.84
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1425	0.1720	24.20
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia, The	0.0948	0.1861	0.1154	42.85
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0592	0.0492	38.54

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Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.7$	
Guinea-Bissau	0.1605	0.3457	0.3026	46.00
Guyana	0.0872	0	0	0
Haiti	0.1419	0.3057	0.3035	37.37
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran, Islamic Rep.	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.0422	0.0554	35.22
Lesotho	0.0667	0.1342	0.0902	42.39
Madagascar	0.0902	0.2775	0.2566	44.04
Malawi	0.2280	0.3999	0.3751	47.49
Maldives	0.0301	0	0	0
Mali	0.1144	0.2255	0.2032	42.36
Mauritania	0.1251	0	0	0
Mexico	0.0001	0	0	0
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.2955	0.2760	43.84
Namibia	0.0244	0	0	0
Nepal	0.0549	0.0736	0.0644	38.17
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2546	0.2358	42.52
Nigeria	0.0066	0.1399	0.1150	40.59
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0912	0.0994	35.51

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Table 21 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.7$	
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3199	0.2938	45.05
Sao Tome and Principe	0.2559	0	0	0
Senegal	0.0801	0	0	0
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2781	0.2557	43.20
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.1174	0.2070	26.66
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Republic	0.0030	0	0	0
Tanzania	0.1138	0.1122	0.1001	39.71
Timor-Leste	0.0844	0.2669	0.2445	40.69
Togo	0.1048	0.1876	0.1583	42.68
Tunisia	0.0088	0	0	0
Uganda	0.1159	0.1461	0.1201	41.63
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen, Rep.	0.0172	0	0.0979	24.63
Zambia	0.0843	0.3386	0.3010	45.83
		$\hat{\lambda}_{CD} = 36.53$	$\hat{\lambda} = 210.85$	average $\{\hat{\lambda}_i\} = 40.03$

Notes: Simulations are run under the following assumption about the regional values for growth elasticity of poverty reduction (η_i , see Ram, 2006): -0.90 (East Asia & Pacific countries), -0.95 (Latin America & Caribbean), -1.60 (Middle East & North Africa), -0.81 (South Asia), and -0.72 (Sub-Saharan Africa). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The

last two columns correspond to our model with $\alpha = 0.7$, $\gamma = 0.7$, $g_i^* = 0.0273/\eta_i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$), our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).

Table 22: Actual and optimal allocations of aid, headcount poverty rate based on \$1.25/day poverty line, $\alpha = 0.7$, $\gamma = 0.3$, and regional elasticity of poverty reduction

Country	Actual aid (%GDP)	Optimal aid (%GDP)		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		$\alpha = 1$	$\alpha = 0.7, \gamma = 0.3$	
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0051	22.00
Argentina	0.0004	0	0	0
Bangladesh	0.0239	0.0072	0.0224	33.74
Belize	0.0199	0	0	0
Benin	0.0961	0.1072	0.1018	37.35
Bhutan	0.0806	0	0	0
Bolivia	0.0389	0	0	0
Botswana	0.0562	0	0	0
Brazil	0.0003	0	0	0
Burkina Faso	0.1199	0.1828	0.1688	39.30
Burundi	0.3214	0.4712	0.4537	49.57
Cambodia	0.0755	0	0	0
Cameroon	0.0234	0	0	0
Cape Verde	0.1464	0	0	0
Central African Republic	0.1312	0.3123	0.2964	43.33
Chad	0.0631	0.3155	0.2690	44.42
Chile	0.0006	0	0	0
China	0.0003	0	0	0
Colombia	0.0041	0	0	0
Comoros	0.0785	0.3631	0.3101	48.62
Congo, Dem. Rep.	0.1707	0.3855	0.3783	46.26
Congo, Rep.	0.0553	0	0	0
Costa Rica	0.0023	0	0	0
Cote d'Ivoire	0.0279	0	0	0

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Table 22 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Djibouti	0.1313	0	0.0176	27.28
Dominican Republic	0.0035	0	0	0
Ecuador	0.0044	0	0	0
Egypt, Arab Rep.	0.0106	0	0	0
El Salvador	0.0111	0	0	0
Ethiopia	0.1248	0.1425	0.1564	30.71
Fiji	0.0129	0	0	0
Gabon	0.0049	0	0	0
Gambia, The	0.0948	0.1861	0.1240	42.09
Ghana	0.0515	0	0	0
Guatemala	0.0140	0	0	0
Guinea	0.0983	0.0592	0.0675	34.86
Guinea-Bissau	0.1605	0.3457	0.2990	46.79
Guyana	0.0872	0	0	0
Haiti	0.1419	0.3057	0.2928	41.46
Honduras	0.0424	0	0	0
India	0.0017	0	0	0
Indonesia	0.0025	0	0	0
Iran, Islamic Rep.	0.0003	0	0	0
Iraq	0.1187	0	0	0
Jamaica	0.0067	0	0	0
Jordan	0.0326	0	0	0
Kenya	0.0448	0	0	0
Lao PDR	0.0955	0.0422	0.0524	35.52
Lesotho	0.0667	0.1342	0.0994	41.17
Madagascar	0.0902	0.2775	0.2579	43.59
Malawi	0.2280	0.3999	0.3709	49.31
Maldives	0.0301	0	0	0
Mali	0.1144	0.2255	0.2090	40.85

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Country	Actual aid (%GDP)	Optimal aid		Marginal efficiency $\hat{\lambda}_i$ (people/\$ million)
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	
Mauritania	0.1251	0	0	0
Mexico	0.0001	0	0	0
Morocco	0.0166	0	0	0
Mozambique	0.2155	0.2955	0.2775	43.26
Namibia	0.0244	0	0	0
Nepal	0.0549	0.0736	0.0675	37.61
Nicaragua	0.1192	0	0	0
Niger	0.1144	0.2546	0.2404	41.08
Nigeria	0.0066	0.1399	0.1293	38.26
Pakistan	0.0093	0	0	0
Panama	0.0013	0	0	0
Papua New Guinea	0.0381	0.0912	0.0952	36.04
Paraguay	0.0080	0	0	0
Peru	0.0038	0	0	0
Philippines	0.0003	0	0	0
Rwanda	0.1996	0.3199	0.2931	45.27
Sao Tome and Principe	0.2559	0	0	0
Senegal	0.0801	0	0	0
Seychelles	0.0140	0	0	0
Sierra Leone	0.1974	0.2781	0.2590	42.22
South Africa	0.0042	0	0	0
Sri Lanka	0.0184	0	0	0
St. Lucia	0.0181	0	0	0
Sudan	0.0483	0.1174	0.1365	34.42
Suriname	0.0286	0	0	0
Swaziland	0.0232	0	0	0
Syrian Arab Republic	0.0030	0	0	0
Tanzania	0.1138	0.1122	0.1122	36.52
Timor-Leste	0.0844	0.2669	0.2199	45.27

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Table 22 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid	Optimal aid	Marginal efficiency $\hat{\lambda}_i$
		(%GDP) $\alpha = 1$	(%GDP) $\alpha = 0.7, \gamma = 0.3$	(people/\$ million) $\alpha = 0.7, \gamma = 0.3$
Togo	0.1048	0.1876	0.1643	41.43
Tunisia	0.0088	0	0	0
Uganda	0.1159	0.1461	0.1296	39.78
Uruguay	0.0011	0	0	0
Venezuela	0.0002	0	0	0
Vietnam	0.0290	0	0	0
Yemen, Rep.	0.0172	0	0.0422	29.11
Zambia	0.0843	0.3386	0.2981	46.53
		$\hat{\lambda}_{CD}=36.53$	$\hat{\lambda}=81.41$	average $\{\hat{\lambda}_i\}=39.85$

Notes: Simulations are run under the following assumption about the regional values for growth elasticity of poverty reduction (η_i , see Ram, 2006): -0.90 (East Asia & Pacific countries), -1.35 (Europe & Central Asia), -0.95 (Latin America & Caribbean), -1.60 (Middle East & North Africa), -0.81 (South Asia), and -0.72 (Sub-Saharan Africa). The model of Collier and Dollar (2002) corresponds to $\alpha = 1$. The last two columns correspond to our model with $\alpha = 0.7$, $\gamma = 0.3$, $g_i^* = 0.0273/\eta_i$. The last row reports the marginal efficiency of aid of the Collier and Dollar' model ($\hat{\lambda}_{CD}$), our model ($\hat{\lambda}$ and the average of $\hat{\lambda}_i$).