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Equal Opportunity and Poverty Reduction: How Aid Should Be Allocated?*

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Abstract

This paper proposes a model of aid allocation which aims to equalize the opportunity between recipient countries to reduce the poverty. The model takes into account the natural growth deviation which is defined by the gap between the growth rate required to reach a development goal and the growth rate observed in the recipient countries. The resulting optimal aid allocation is computed using the estimation of a growth equation. Said equation includes effects of aid and structural handicaps to growth in recipient countries (which are represented by the economic vulnerability index and lack of human capital). To illustrate the interest of our approach, we perform a simulation which shows a substantial difference between the aid allocation obtained with our multi-criteria principle and the observed allocation. Moreover, we also shed light on the impact of the donors' sensitivity with respect to the natural growth deviation on the optimal aid allocation.

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1 Introduction

This papers fits in the debate on allocation of foreign aid in developing countries. We use a normative approach to determine an efficient and fair allocation of aid in the line of few existing studies such as Collier and Dollar (2001, 2002), Wood (2008), Llavador and Roemer (2001), and Cogneau and Naudet (2007), Carter (2014), etc.[1]

In their seminal papers, Collier and Dollar (2001, 2002) adopt a utilitarian vision by maximizing a social welfare function which is the sum of utilities of aid-recipient countries. A country's utility is measured in terms of number of poor which is a decreasing function of aid. More precisely, Collier and Dollar (2001, 2002) estimate the aid allocation that maximizes the reduction of number of poor in recipient countries. The reduction of poverty depends on several factors such as economic growth, initial poverty, and growth elasticity of poverty reduction. Economic growth is in turn influenced by aid (with a decreasing marginal effect), institutional quality, and policy quality. Consequently, the aid allocation reducing the poverty is determined by the initial poverty of recipient countries, their institutional quality, and their policy quality. The latter two factors (institutional and policy quality) are usually assimilated to the effectiveness principle. 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 not only initial poverty but also future poverty in aid donors' objective function.

This utilitarian approach of Collier and Dollar, merely corresponding to the minimization of the total number of poor people in recipient countries, is criticized for its lack of consideration for fairness. Indeed, Llavador and Roemer (2001) and Cogneau and Naudet (2007) proposed an alternative way in calculating the optimal allocation of aid based on the Rawlsian principle. Both studies define an aid allocation satisfying the objective of equal opportunities. They analyze how aid can be distributed in order to equalize growth opportunities of recipient countries. 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 imputed to differences in their efforts, not to their initial circumstances.[2]

The study of Cogneau and Naudet (2007) devises a way of allocating aid that also includes the equal opportunity by using another method. The authors criticize the aid allocation of Llavador and Roemer (2001) which is paradoxically in favor of countries with high macroeconomic performances such as South Korea, Indonesia, and Thailand (low inflation, small budget deficit, and major open trade) to the detriment of countries with bad circumstances such as Nicaragua and Zambia. The Cogneau and Naudet analysis separates effort and circumstances of recipient countries as in Llavador and Roemer (2001), but using the same framework than Collier and Dollar. Their aid allocation however shares out poverty risks more fairly among the world's population, and their results show that donors should give more aid to poorest countries than the currently observed aid

[1]Other empirical analysis of aid allocation rules emphasizes two main characteristics in recipient countries: their need for assistance (measured by their income per capita) and their absorption constraint (i.e. their ability to use aid effectively, measured by the World Bank's Country Performance Rating). See for example, Easterly (2007), Easterly and Pfutze (2008), Knack, Rogers and Eubank (2011), etc.

[2]In Llavador and Roemer (2001), the effort variable is defined by economic management which is 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.

allocation.

Recently, Carter (2014) proposes an aid allocation rule that maximizes welfare of recipient countries rather than economic growth and takes into account the absorptive capacity of recipient countries (measured by the World Bank's Country Performance Rating). Donors target a range of development outcomes by putting more weight to aid-funded consumption and less weight to economic growth. The division of aid between consumption and investment results from the maximization of 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 which are least able to stimulate economic growth.

Our paper aims to design an optimal allocation of aid based on a multi-criteria principle, and within a utilitarian framework where aid donors maximize the sum of recipient countries' utilities. The difference between our paper and Collier and Dollar (2002), Llavador and Roemer (2001), and Cogneau and Naudet (2007), stems from two major points.

Firstly, we think that aid policy should include uneven economic conditions between countries and then to compensate for them with foreign aid. Therefore, as in McGillivray and Pham (2017), our analysis considers structural growth handicaps in recipient countries. More precisely, we introduce economic vulnerability and lack of human capital in the growth equation. Our study relies on the assumption that a country with a low human capital and/or a strong economic vulnerability may encounter some difficulties to formulate high quality economic and social policies, inducing a low possibility to achieve its development goal. Moreover, accounting for economic vulnerability in recipient countries may be viewed as compatible with an effectiveness principle of aid. Indeed, according to Guillaumont and Chauvet (2001), aid is more efficient in terms of growth in countries with a high economic vulnerability.

Secondly, we believe that aid policy could be determined in a fair way. However, unlike the works of 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 in recipient countries, and their goal is to equalize the opportunity between recipient countries to reduce the poverty. To formulate this assumption, we posit the utility of country i as a function of 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 country i has to reach if it wants to achieve a certain development goal. Hence, an efficient and fair allocation of aid should have the purpose to reduce the poverty in recipient countries by considering the specific conditions (such as structural handicaps) and the natural growth deviation in these countries.

Our optimal aid allocation with poverty reduction objective is then based on a multi-criteria principle which incorporates initial poverty, lack of human capital, economic vulnerability as well as natural growth gap in recipient countries. Our analysis is implemented in two steps. The first step corresponds to the estimation of a growth equation depending on different 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 which shows a substantial difference between the optimal allocation and the observed allocation. We also shed light on the impact of the donors' sensitivity with respect to growth deviation 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 about the economic growth equation. Section 4 discusses the efficient and fair allocation of aid as well as the marginal effect of aid. Section 5 concludes.

2 A model of efficient and fair allocation of aid

In this section we propose a theoretical model to determine the aid allocation which equalizes the opportunity between countries to reach a development goal. Taking as 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 to each recipient country the same probability to lift out of the poverty by half.[3] This leads to consider the growth rate required to reach this millennium goal for each recipient country and eventually to compensate 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. Such a principle involves the consideration of 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

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

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 and $1-\alpha$ is the weight relative to 'natural growth deviation' from the expected (or targeted) growth rate g_i^*. When $\alpha = 1$ and $u(g_i) = g_i$ we exactly recover the utility function of Collier and Dollar (2001, 2002) where $U_i = -\eta_i h_i N_i g_i$. This expression gives thus 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 marginal reduction of poverty) is constant. In this respect, the specification in (1) appears more general as it allows for a nonconstant marginal reduction of poverty. More precisely, we assume that each country's utility is increasing and concave with respect to economic growth rate g_i. Its first and second derivative are given respectively by

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

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

We observe that marginal utility of growth, U_g, is decreasing with the ratio g_i/g_i^*. In

[3] We leave the possibility to consider other goals or other deadlines in a further study.

others 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 haft 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 the poverty, hence

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

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),

$$g_i^* = -x/\eta_i. \tag{5}$$

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,

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

s.t.

$$\begin{aligned} \sum_i^n A_i y_i N_i &= \bar{A} && (6) \\ A_i &\geq 0, \ \forall i && (7) \end{aligned}$$

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 allocated to all recipient countries is equal to the total amount of available aid.

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

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

where λ and μ_i, $i = 1, ..., n$ 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 $\hat{A} \equiv (\hat{A}_1, ..., \hat{A}_n)$, and multipliers $\hat{\lambda}$, and $\hat{\mu}_i$ must satisfy the following first order conditions (FOC), $\forall i = 1, ..., n$:

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

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

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

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, which is 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 $\hat{A}_i \geq 0$, and $\hat{\mu}_i > 0$ if $\hat{A}_i = 0$. Hence, for country i such that $\hat{A}_i \geq 0$, equation (9) gives $U_g(A_i)g_A(A_i) = \hat{\lambda} y_i N_i$ because $\hat{\mu}_i = 0$. Combining this with condition (11) will gives 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. $\hat{\mu}_j = \hat{\lambda} y_j N_j - U_g(0)g_A(0)$. 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.[4]

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) $\hat{A}_i = 0$ *if* $U_g(\hat{A}_i)g_A(\hat{A}_i) = \hat{\lambda} y_i N_i - \hat{\mu}_i$ *and* $\hat{\mu}_i > 0$,

(ii) $\hat{A}_i > 0$ *if* $U_g(\hat{A}_i)g_A(\hat{A}_i) = \hat{\lambda} y_i N_i$ *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 to the positiveness of aid and* $\hat{\lambda}$ *is the multiplier (or shadow value) associated to the total amount of 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

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

In terms of our specification, this expression is equivalent to

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

[4]For 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

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

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 total amount of aid by one unit (here in millions of dollars) as

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

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

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

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

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

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

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

The right-hand side term $(-U_{gg}/U_g)$, which is always positive, represents the curvature of the utility function 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 in order 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 Econometric specification

This section describes the estimation of the growth equation, which serves as the basis for simulating the optimal aid allocation in the next section. Let us turn to the growth equation. Collier and Dollar (2001, 2002) consider that economic growth depends on policy quality and aid with decreasing marginal effects. This implies that countries with high performance in economic policies and institutions will receive more aid than others. However, such a studies ignore initial disadvantages of recipient countries. Those who are under poverty line because of their bad institutional qualities, economic vulnerability, and economic policies are unfairly taken into account. In order to avoid this drawback, it is then necessary, from a development perspective, to make aid fairer by considering structural handicaps to growth of recipient countries, in particular their economic vulnerability and their 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 score of performance in spite of 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 with a low human capital and a strong economic vulnerability might be a good way to compensate for their initial disadvantages.

The growth equation is estimated by using a panel data framework (see, e.g., Islam, 1995, Caselli et al., 1996, Durlauf et al., 2005). We assume that the growth rate depends not only on aid, policy quality, but also 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. 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

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

where $\ln y_{it}$ is the log real GDP per capita in international prices PPP 2005. The set of covariates includes 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.[5]

[5]We also include a variable representing the quality of policies, Polity 4 (as in the existing literature), and its interaction with aid. However, they add nothing to the results as they are statistically not significant.

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 Economic Vulnerability Index of the FERDI.[6] The WDI database provides information on aid, GDP, population, etc. Aid and GDP are expressed in terms of real dollars, international prices PPP 2005, measured in millions 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, which is 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 compute $H = (100 - HAI)/100$. The economic vulnerability index (V), which is is 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 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 comprised between 0 and 1.

Our data are an unbalanced panel data sample covering 92 countries and period 1983-2011. As in the existing literature we use data with some time span interval in order to avoid business cycle effects. We adopt the 4-year interval ($\tau = 4$) as in 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 in total 8 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 to capture the common trend that can exist between variables and to ensure no cross-country correlation in the model residuals. Definition and descriptive statistics on variables are summarized in Table 1.

Table 1 here

3.3 Estimation results

The equation above is a dynamic panel data model which can be estimated by 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.[7] Results of the within fixed effects estimator are also reported for comparison

[6] Data and estimation codes are available on request from the authors.

[7] The 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

purpose.[8] 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 has a positive effect on the current level of GDP per capita, which prove the usefulness of the dynamic setting. The linear term of aid has no effect whereas the effect of its squared term is negative. While economic vulnerability has a negative effect on income, its interaction term with aid has a significant and positive effect. This finding means that aid and economic vulnerability are complementary in the growth equation. In other words, when vulnerability of a country 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 computed from the estimated coefficients of equation (18) as follows:

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

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 allocation of aid. 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

In order to assess the theoretical allocation, we need an analytically tractable model. For simplicity'sake, we specify $u(g_i) = g_i$ and $v(g_i/g_i^*) = (g_i/g_i^*)^\gamma$ with $\gamma > 0$. We observe 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 2018 sample encounter this situation. A reduction in γ, represented by an increase of the curvature of the function, means that aid donors are more sensitive to natural growth deviation. In other words, donors are more averse to a low ratio g_i/g_i^*.

the system GMM, all strictly exogenous regressors are used as instrument 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) in order to reduce the bias that can happen in small samples with increased number of instruments.

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

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 here

We use the estimation results of the growth equation above to simulate the amount of aid resulted from our theoretical model. We also compare these simulations with the observed data in 2008 which cover more than 90 countries.[9] The growth-aid relation for the 2008 data, based on the previous estimated coefficients, is presented in Figure 2. This relations has an increasing pattern.

Figure 2 here

Our simulations cover both the optimal allocations of aid obtained without ($\alpha = 1$) and with natural growth deviation ($\alpha < 1$). 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 also remark that when $\alpha = 1$, the donors' objective function, focusing on the poverty reduction, depends only on economic growth obtained in recipient countries thanks to aid. We consider the following assumptions about parameters for two models: (i) the headcount poverty rate based on two types of poverty line, 2 dollars per day and 1.25 dollars per day, which correspond to two sets of countries, 93 and 91 respectively, (ii) the elasticity of poverty reduction with respect to income per capita is the same for all countries, $\eta = -2$ (like Collier and Dollar, 2002).

The model without natural growth deviation corresponds to $\alpha = 1$ (in this case, the value of γ has no effect on the results). This situation corresponds to the utility function proposed by Collier and Dollar (2002). Regarding the model with natural growth deviation, we consider two parameterizations: (i) $\alpha = 0.7$, $\gamma = 0.7$ and (ii) $\alpha = 0.7$, $\gamma = 0.3$. Moreover, our model requires the value of the targeted growth rate g^* which is related to η as shown previously in Section 2. With the assumption that $\eta = -2\ \forall i$, we get $g^* = 0.01365$, $\forall i$. The full set of simulation results on optimal allocation is reported in Tables A1-A4 in Appendix. Our results are manifold.

1. Our first result concerns the number of countries receiving aid to development. 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), the optimal allocation shortlists only around one third of them. This optimal choice is based on a multi-criteria principle including initial poverty, natural growth deviation, and structural handicaps to growth of recipient countries.

   We remark that initial poverty in recipient countries is one of the key elements which justifies a large aid flow. Tables 3 and 4 report the observed and the optimal allocations for 10 countries with the highest poverty rates (based on 1.25$/day

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

and 2$/day poverty lines, respectively). Compared to the observed allocation, our optimal allocations with or without natural growth deviation propose higher aid amounts to these poor countries.

Tables 3 and 4 here

2. The second result relates to the difference between the allocation without natural growth deviation ($\alpha = 1$) and the allocation with natural growth deviation ($\alpha < 1$). The latter allocation covers more countries than the former. More precisely, with the case of the 2 dollars per day poverty line (see Tables A1-A2 in Appendix), the solution without natural growth deviation (i.e. $\alpha = 1$) only cover 33 countries. When taking into account the natural deviation from a targeted growth rate (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 dollars per day poverty line is considered (see Tables A3-A4 in Appendix). Indeed, while the number of countries receiving a positive aid is 30 for the solution with $\alpha = 1$, it increases to 32 countries for $\alpha = 0.7, \gamma = 0.7$ and 34 countries for $\alpha = 0.7, \gamma = 0.3$, respectively.

3. The third result is linked to the second. As a result of the increase in the number of countries receiving aid, for most of them, the optimal allocation with natural growth deviation may propose an aid amount lower than the case without natural growth deviation. Nevertheless, we can identify countries that take advantage of our multi-criteria principle compared to the case based on the Collier-Dollar utility function.

Table 5 here

Table 5 identifies 12 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 $\alpha = 1$. Yemen is added to this list when $\alpha = 0.7, \gamma = 0.3$. Moreover, given $\alpha = 0.7$, we observe that the difference in terms of aid amount between the 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.[10] When using the 1.25$ poverty line, the figures corresponding to $\gamma = 0.7$ and $\gamma = 0.3$ are respectively 8 countries (Angola, Bangladesh, Congo Republic, Ethiopia, Guinea, Lao PDR, Papua New Guinea, and Tanzania) and 10 countries (the previous 8 countries plus Mauritania and Senegal). More details are provided in Table 6.

Table 6 here

[10]Other 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 ($g_i/g_i^* = 2.53$).

This result stresses that taking into account the donors' sensitivity with respect to natural growth deviation will significantly modify the aid allocation favouring countries with a low ratio g_i/g_i^* (to the detriment of others).

4. We can compute the marginal efficiency of aid, i.e. number of the poor reduced by increasing the total aid amount of 1 million dollars. It is shown that the optimal allocation with natural growth deviation ($\alpha < 1$) gives a higher marginal efficiency than the optimal allocation without natural growth deviation ($\alpha = 1$). Considering the 2$/day poverty line, the figures for the optimal allocation without natural deviation ($\alpha = 1$) is 131.78 people per million dollars. Regarding the optimal allocation with natural growth deviation (where $\alpha = 0.7$), this quantity (denoted as $\hat{\lambda}_i$, see also Section 2) varies among countries that receive a positive amount of aid. The last column of each of Tables A1-A2 in Appendix reports details on this. The average values of these $\hat{\lambda}_i$ are 140.96 for $\gamma = 0.7$ and 151.89 people per million dollars for $\gamma = 0.3$. Figures 3a-b give a full picture about the distribution of $\hat{\lambda}_i$.

   Figure 3 here

   For the case with 1.25$ poverty line, the numbers of people lifting from poverty in the optimal allocation without natural deviation is 88.85. The mean values of these $\hat{\lambda}_i$ for this poverty line are respectively 96.42 and 102.59 people per million dollars for $\gamma = 0.7$ and $\gamma = 0.3$ (see Figures 3c-d for more details).[11]

   We observe that aid is more efficient in terms of poverty reduction in recipient countries with a high economic vulnerability. Indeed, for these countries, the number of people lifted from poverty per million dollars of aid is higher than the average number.[12]

5. Finally, a reduction in value of γ, which is equivalent to an increase in the 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 g_i/g_i^*, aid donors choose an efficient and fair allocation which can help lifting more people from poverty, the average number of people increases from 140.96 to 151.89 for the case of 2$ poverty line, and from 96.42 to 102.59 for the case of 1.25$ poverty line.

5 Conclusion

In this study, we propose a model of aid allocation which aims to equalize the opportunity between recipient countries to reduce the poverty. The modeling accounts for the natural

[11]We 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.

[12]For 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 Gambia, which are considerably higher than the average level (151.89).

deficit or natural deviation between the growth rate required to reach a certain target and the actual growth rate observed in the recipient countries. Based on a multi-criteria principle, our optimal allocation is fair and efficient. To maximize the poverty reduction in all recipient countries, we take into consideration their structural handicaps to growth in terms of lack of human capital, economic vulnerability, their initial poverty as well as their natural growth deviation.

This paper takes the Millennium Development Goal (MDG) as an example, proposing to reduce poverty by half by 2015 compared to 1990. It is all about approaching the MDG by giving the same probability to each recipient country to lift itself out of the poverty by half. From this goal, we calculate the required growth rate which is considered as given since it does not depend on different factors such as aid or initial poverty, etc.

We show that our proposed aid allocation substantially differs from the observed allocation. Moreover, our results shed light on the impact of the donors' sensitivity with respect to growth deviation on the allocation of aid. More precisely, compared to an allocation without this sensitivity, our allocation is favorable to countries with a low natural growth deviation. We also show the meaningful impact of the aversion to growth deviation on the marginal efficiency of aid. Giving higher weights to countries with a low growth deviation (or a high growth deficit) can help lifting more people from poverty.

Further extensions are needed to check the robustness of our results. We can generalize the simulation to the case where the elasticity of poverty reduction with respect to income differs among countries (Bourguignon 2002, Bourguignon and Platteau 2017). The theoretical analysis can be also 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 include other deadlines and other targeted growth rates to achieve different development goals.

References

[1] Alesina A. and Dollar D. (2000) "Who gives foreign aid to whom and why?" *Journal of Economic Growth* 5(1), 33-63.

[2] Arellano M. and Bond S. (1991), "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *Review of Economic Studies* 58, 277-97.

[3] Berthélemy J.-C. and Tichit A.(2004), "Bilateral donors' aid allocation decisions: A three-dimentional panel analysis," *International Review of Economics and Finance* 13(3), 253-274.

[4] Blundell R. and Bond S. (1998), "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics* 87, 115-143.

[5] Bond S., Hoeffler A. and Temple J. (2001), "GMM estimation of empirical growth models", CEPR Discussion Papers no.3048.

[6] Bourguignon F. (2002), "The growth elasticity of poverty reduction: explaining heterogeneity across countries and time series". In Eichler T. and Turnovsky S. (eds), *Growth and Inequality*, MIT Press, chapter 1.

[7] Bourguignon F. and Platteau J.-P. (2017), "Aid effectiveness: Revisiting the trade-off between needs and governance,"CEPR Discussion Paper DP12277.

[8] Burnside C. and Dollar D. (2000), "Aid, policies and growth", *American Economic Review* 90(4), 409-435.

[9] Cariolle J. (2011), "The economic vulnerability index: 2010 updated", FERDI Working Papers no.9.

[10] Carter, P., Postel-Vinay F. and Temple, J.R.W (2013), "Dynamic aid allocation", *Discussion Paper* 5696, CEPR

[11] Carter, P. (2014), "Aid allocation rules", *European Economic Review* 71, 132-151.

[12] Caselli F., Esquivel G., and Lefort F. (1996), "Reopening the convergence debate: A new look at cross-country growth empirics," *Journal of Economic Growth* 1(3), 363-389.

[13] Chauvet L. and Guillaumont P. (2009), "Aid, volatility, and growth again: When aid volatility matters and when it does not," *Review of Development Economics* 13(3), 452-463.

[14] Closset M., Feindouno S., and Goujon M. (2014), "Human Assets Index Retrospective series: 2013 update," Ferdi Working Papers no.110.

[15] Cogneau D. and Naudet J.-D. (2007) "Who deserves aid? Equality of opportunity, international aid, and poverty reduction," *World Development* 35(1), 104-120.

[16] Collier P. and Dollar D. (2001), "Can the world cut poverty in half? How policy reform and effective aid can meet intrenational development goals," *World Development* 29(11), 1787-1802.

[17] Collier P. and Dollar D. (2002), "Aid allocation and poverty reduction," *European Economic Review* 46, 1475-1500.

[18] Durlauf S.N., Johnson P.A., and Temple J.R.W. (2005), "Growth econometrics". In Aghion P. and Durlauf S.N. (eds), *Handbook of Economic Growth*, Elsevier, volume 1, part A, chapter 8.

[19] Easterly, W (2007), "Are aid agencies improving," *Economic Policy* 22 (52), 633-678.

[20] Easterly, W and Pfutze, T. (2008), "Where does the money go? Best and worst pratices in foreign aid," *Journal of Economic Perspectives* 22 (2), 29-52.

[21] Guillaumont P. and Chauvet L. (2001), "Aid and performance: A reassessment," *Journal of Development Studies*, 37(6), 6-92.

[22] McGillivray M. and Pham T.K.C. (2017), "Reforming performance based aid allocation pratice," *World Development*, 90, 1-5.

[23] Guillaumont P., McGillivray M., and Wagner L. (2015), "Performance assessment, vulnerability, human capital and the allocation of aid among developing countries," *World Development*, 90, 17-26.

[24] Islam N. (1995), "Growth empirics: A panel data approach", *Quarterly Journal of Economics* 110, 1127-1170.

[25] Knack, S., Rogers, F.H. and Eubank, N. (2011), "Aid quality and donor rankings", *Journal of Development Economics*, 82(2), 315-347.

[26] Llavador H.G. and Roemer J. E. (2001), "An equal-opportunity approach to the allocation of international aid", *Journal of Development Economics* 64, 147-171.

[27] Roodman D. (2009), "How to do xtabond2: An introduction to difference and system GMM in Stata", *Stata Journal* 9(1), 86-136.

[28] Wood A. (2008), "Looking ahead optimally in allocating aid", *World Development* 36(7), 1135-1151.

Appendix

Table A1: Actual and optimal allocations of aid, headcount poverty rate based on 2$ per day poverty line, $\alpha = 0.7$, $\gamma = 0.7$

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.7$
Algeria	0.0019	0	0	0
Angola	0.0052	0	0.0134	76.91
Argentina	0.0004	0	00	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

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Table A1 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.7$
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	0.1140	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

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Table A1 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7, \gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7, \gamma = 0.7$
Mauritania	0.1251	0	0.0335	121.61
Mexico	0.0001	0	0	0
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

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Table A1 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.7$
Togo	0.1048	0.2361	0.2209	147.70
Tunisia	0.0088	0	0	0
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 $\alpha = 0.7$, $\gamma = 0.7$, $g^* = 0.01365$, $\forall i$. 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 A2: Actual and optimal allocations of aid, headcount poverty rate based on 2$ per day poverty line, $\alpha = 0.7$, $\gamma = 0.3$

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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

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Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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

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Table A2 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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

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Table A2 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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 $\alpha = 0.7$, $\gamma = 0.3$, $g^* = 0.01365$, $\forall i$. 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 A3: Actual and optimal allocations of aid, headcount poverty rate based on 1.25$ per day poverty line, $\alpha = 0.7$, $\gamma = 0.7$

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7, \gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7, \gamma = 0.7$
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
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

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Table A3 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.7$
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
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

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Table A3 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7, \gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7, \gamma = 0.7$
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
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

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Table A3 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.7$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.7$
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: 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 $\alpha = 0.7$, $\gamma = 0.7$, $g^* = 0.01365$, $\forall i$. 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 A4: Actual and optimal allocations of aid, headcount poverty rate based on 1.25$ per day poverty line, $\alpha = 0.7$, $\gamma = 0.3$

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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

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Table A4 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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

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Table A4 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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

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Table A4 – continued from previous page

Country	Actual aid (%GDP)	Optimal aid (%GDP) $\alpha = 1$	Optimal aid (%GDP) $\alpha = 0.7$, $\gamma = 0.3$	Marginal efficiency $\hat{\lambda}_i$ (people/$ million) $\alpha = 0.7$, $\gamma = 0.3$
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
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: 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 $\alpha = 0.7$, $\gamma = 0.3$, $g^* = 0.01365$, $\forall i$. 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 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

	Within FE		System GMM	
Variable	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 × 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*

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.

Table 3: 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 (%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
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 4: 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.

Table 5: 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 (%GDP) $\alpha = 1$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.7$	Optimal aid (% GDP) $\alpha = 0.7$ $\gamma = 0.3$
Angola	0.69	0.72	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.

Table 6: 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.

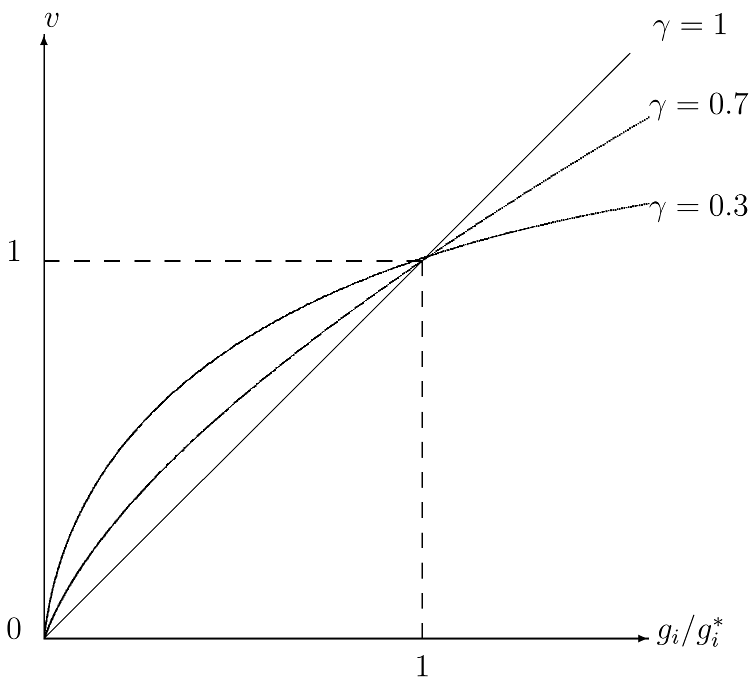

Figure 1: Behavior of $v(g_i/g_i^*) = (g_i/g_i^*)^\gamma$ with different values of γ $(0 < \gamma < 1)$.

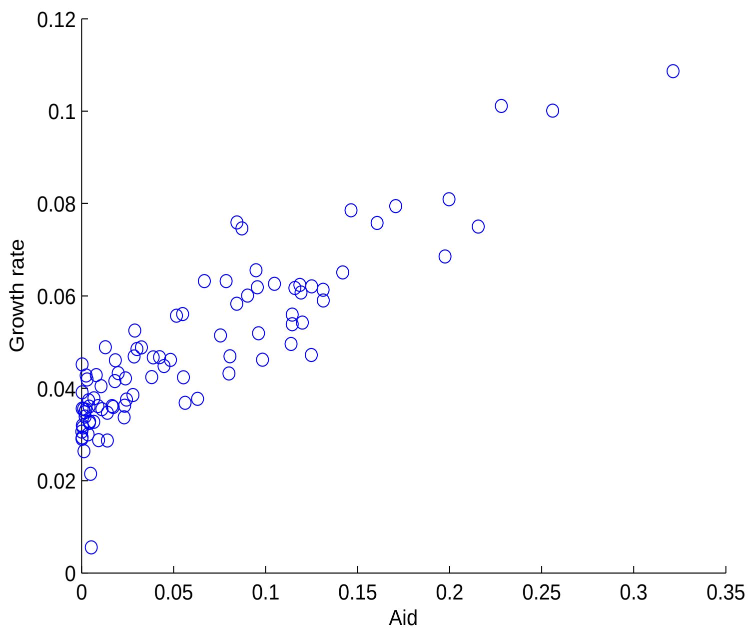

Figure 2: The estimated relation between growth and aid for the 2008 data.

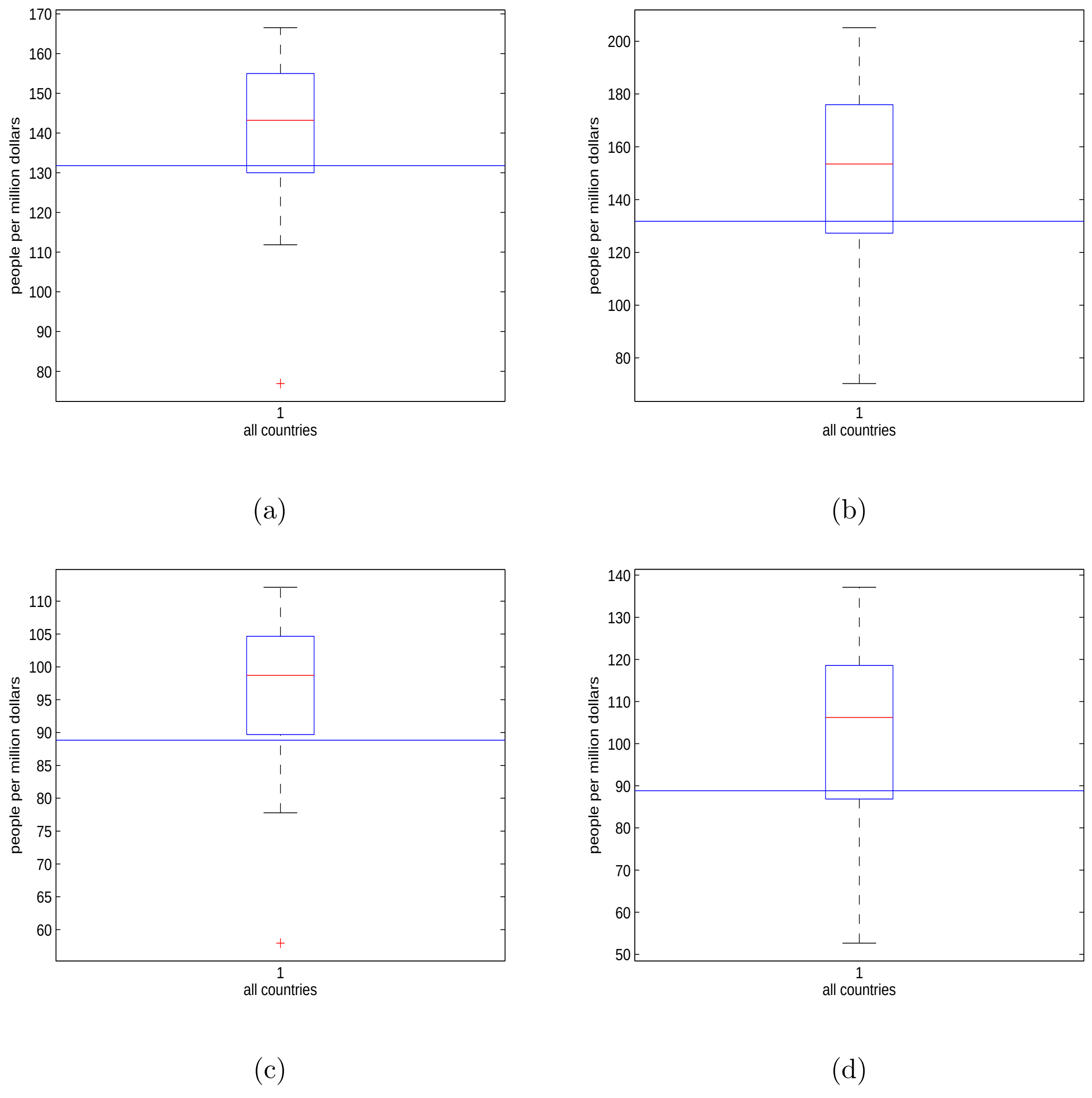

Figure 3: Marginal efficiency of aid, $\hat{\lambda}_i$. (a) poverty line = 2\$/day, $\gamma = 0.7$, (b) poverty line = 2\$/day, $\gamma = 0.3$, (c) poverty line = 1.25\$/day, $\gamma = 0.7$, (d) poverty line = 1.25\$/day, $\gamma = 0.3$. The horizontal lines correspond to the Collier-Dollar utility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

"Sur quoi la fondera-t-il l'économie du monde qu'il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l'ignore."

Pascal

Created in 2003 , the **Fondation pour les études et recherches sur le développement international** aims to promote a fuller understanding of international economic development and the factors that influence it.

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