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A Multi-Criteria Optimization Proposal for Aid Allocation: Combining Donor and Recipient Interests

Una propuesta de optimización multicriterio para la asignación de la ayuda oficial al desarrollo: combinando los intereses de los donantes y de los receptores

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Abstract

It is well known that donors pursue different objectives (altruistic objectives or those based on recipient, and donor interests) in granting their aid. This study proposes an innovative tool that enables a combination of both types of objectives, allowing each donor (bilateral or multilateral) to better understand, optimise and target the distribution of its ODA according to the interests of both parties to the transaction (donor and recipient). This tool uses concentration curves and Suits' indices to determine an optimal distribution of aid through the development of a constrained optimisation program that encompasses all of its purposes. Furthermore, used at the aggregate level, this tool could facilitate donor coordination to achieve international development goals.

Keywords:Official Development Assistant, Donor country interest, Recipient country interest, Foreign aid allocation, Multicriteria optimization.

Resumen

Es bien sabido que los donantes persiguen diferentes objetivos al conceder su ayuda oficial al desarrollo (objetivos altruistas, basados en los intereses de los receptores, pero también basados en los suyos propios). Este estudio propone una herramienta que posibilita combinar ambos tipos de objetivos, permitiendo a cada donante (bilateral o multilateral) comprender, optimizar y orientar mejor la distribución de su AOD en función de los intereses de ambas partes de la transacción (donante y receptor). Dicha herramienta utiliza curvas de concentración e índices de Suits para determinar una distribución óptima de la ayuda mediante el desarrollo de un programa de optimización restringido que incluya todos los objetivos perseguidos. Además, utilizada a nivel agregado, esta herramienta podría facilitar la coordinación de los donantes para alcanzar los objetivos internacionales de desarrollo.

Palabras clave: Ayuda Oficial al Desarrollo, intereses donante, intereses receptor, distribución geográfica de la ayuda, optimización multi-criterio.

JEL Classification / Clasificación JEL: F31.

Introduction

The eradication of poverty has been and continues to be the main objective of the international development cooperation agenda. It has been explicitly included as the first item in the Millennium Development Goals (MDGs) of the Millennium Declaration (United Nations, 2000): "*To eradicate extreme poverty and hunger*". It is currently a top priority in the 2030 Agenda for Sustainable Development (United Nations, 2015), as it is also Goal 1 of the Sustainable Development Goals (SDGs): "*End poverty in all its forms everywhere* ". Therefore, if it is a priority for the international development cooperation agenda, it must also be a priority for one of its main instruments - official development assistance (ODA). According to the Development Assistance Committee's definition ODA is government aid designed to promote the economic development and welfare of developing countries (excluding loans and credits for military purposes).

Although the effectiveness of ODA has been questioned on numerous occasions, much of the current literature finds that aid can be effective in promoting growth, and by implication, in reducing poverty (Hansen and Tarp, 2000; Collier and Dollar, 2002; Alvi and Sembeta, 2012; Addison *et al.*, 2015; Woldekidan 2015). This fact, together with the promulgation of the aforementioned objectives, would justify the priority allocation of donor aid to the least developed countries (LDCs). However, analysis of the geographical distribution of donor aid reveals patterns of allocation that, in many cases, respond to criteria other than poverty or recipient needs (RNs). As an example of these other criteria, we note the effectiveness of the aid, which motivates the demand for good governance by aid recipient countries, (Burnside and Dollar, 2000; Knack, 2001; Faust, 2011) or the donor's own political or economic interests (Berthélemy, 2006; Sotillo, 2011; Hoeffler and Outram, 2011; Muñoz and Torres, 2014; Briggs, 2017; Bickenbach *et al.*, 2018; Weiler *et al.*, 2018).

Despite this, some studies have revealed a certain change in the direction of aid flows towards the poorest countries since the end of the 20th century (Claessens *et al.*, 2009). This can be largely explained by the adoption of important international agreements with specific objectives to eradicate poverty (such as MDGs and SDGs). Similarly, there has been great proliferation of scientific and academic studies on the allocation of aid, which provides "visibility" and demands "transparency" regarding how donors act (Claessens *et al.*, 2009; Collins *et al.*, 2009; Ghosh and Kharas, 2011; McGee, 2013;

Hedlin, 2017). In these circumstances, donors may feel more pressured to prioritise the interests of the aid beneficiary over their own.

In summary, donors' criteria for their ODA distribution can be grouped into two categories: criteria that consider the characteristics of the recipient (such as poverty levels and need for aid or governance capability) and criteria related to the donor's own interests (political, commercial, etc.). However, it is difficult to find pure allocation models that apply only one set of criteria. In practice, aid allocation usually follows a hybrid model that includes the interests of both parties (Feeny and McGillivary; 2008; Hoeffler and Outram, 2011; Weiler *et al.*, 2018). Therefore, one of the main contributions of this study is the proposal of a realistic tool for assessing the geolocation of aid that includes all the interests considered by donors in allocating aid - both altruistic interests that focus on the recipient's benefits and donors' own interests.

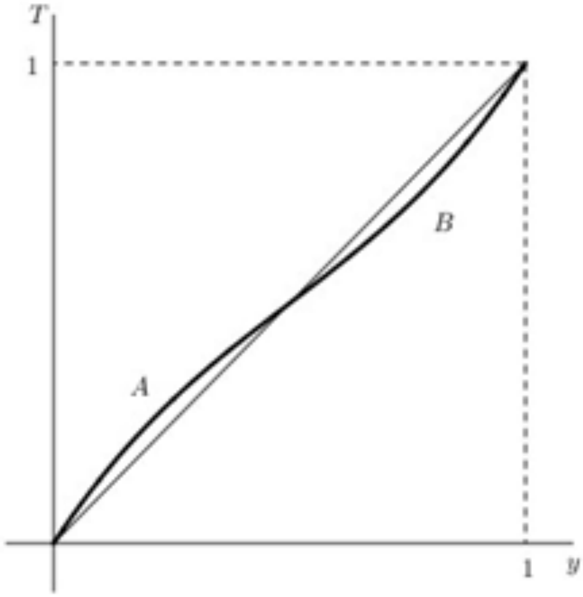
This study proposes an allocation model that can be placed in the prescriptive category (Tezanos, 2008), i.e. among those that propose donor specialisation criteria to increase aid effectiveness by applying geographical allocation optimisation models (Tezanos, 2009). It is a multi-objective regulatory model (McGillivray and White, 1994; McGillivray *et al.*, 2002) that aims to optimise ODA allocation by simultaneously addressing various objectives, such as recipient needs (RNs) and different donor interests (DIs). Specifically, an evaluation tool is proposed that pursues three objectives: i) to make each individual donor aware of how aid is actually distributed according to the pursued objectives; i.e., the extent to which it is responding to the intended sectoral and/or geographical objectives (using concentration curves and Suit indices); ii) Optimise ODA distribution, the tool focuses on determining the "optimal" distribution curve for each donor (by developing a restricted optimisation program that includes all its purposes), and iii) the tool compares the two curves to show the donor how the actual aid distribution deviates from the intended objectives and how plan future aid distributions to better align with the objectives. The remainder of this article is organised as follows. The second section presents the methodology and the mathematical formulation of the problem. The third section presents the application of the proposed optimisation model to the actual distribution of aid of some international donors. The fourth section demonstrates the flexibility of the model, indicating the modifications that could be made to adapt it to other circumstances. Last, the fifth section presents the main conclusions of the study, its limitations, and future lines of research.

1. Methodology

The proposed methodology is based on measuring the concentration of aid distribution using concentration curves and its statistical counterpart, the Suits index. Both methodologies originated in the field of taxation and have been used by many authors in the aid distribution arena (Mosley, 1987; Clark, 1991; McGillivray and White, 1994; Baulch 2006; Tezanos, 2010; Muñoz and Torres, 2014; Baulch and Le, 2015; Tezanos and Quiñones, 2016). Specifically, these tools have been applied to analyse the geographical distribution of donors' international aid flows by measuring the progressivity or regressivity of this distribution. Inspired by the Lorenz curve, the concentration curves represent the accumulated percentage of the distributed amount (on the vertical axis) and the accumulated percentage of the population receiving this amount (on the horizontal axis), arranged according to the desired criterion. In this case, the amount distributed refers to ODA that has been granted bilaterally by donor countries to recipients. According to DAC's definition, ODA is government aid designed to promote the economic development and welfare of developing countries (excluding loans and credits for military purposes). Aid includes grants, "soft" loans (where the grant element is at least 25% of the total) and technical assistance. The OECD maintains a list of developing countries and territories; only the aid distributed to these countries counts as ODA. The list is periodically updated and currently contains over 150 countries or territories with per capita incomes below USD 12,276 in 2010. The data source used was the Development Assistance Committee's (DAC) on-line database, Creditor Reporting System, CRS (OECD, 2017). The horizontal axis, which displays the cumulative percentage of the population pertaining to the recipient countries (excluded from the analysis are countries with no data) is arranged according to previously established criterion, in this case, according to the RNs. This arrangement of the values on the horizontal axis enables the concentration curves (unlike the Lorenz curve) to run below the bisector of the first quadrant (see Figure 1). This bisector is an equidistributed sequence because the proportion of aid distributed coincides with the proportion of the recipient population. If the populations of the most needy countries (at the beginning of the horizontal axis) receive proportionally more aid than the populations of the least needy countries (at the bottom), the curve runs above the diagonal, implying a progressive distribution of aid (area A of Figure 1). Conversely, if the populations of the most needy countries receive proportionally less aid than the more developed countries, the curve runs below the diagonal, indicating a regressive distribution (area B of Figure 1).

Interpreting the concentration curve is not always easy, especially when it crosses the diagonal more than once. The Suits index (1977) is used to overcome this difficulty, as this index measures the progressivity or regressivity of the distribution with only one data point. This index can range between -1 and +1. The values at the extremes represent two undesirable situations. A value of -1 indicates that all aid is allocated to the poorest country (thereby eliminating other poor and needy countries from receiving some aid). At the other extreme, a value of +1 means that all aid is directed to the least needy country. In principle, a zero value means that the concentration curve would be close to the bisector and, therefore would indicate a balanced distribution of aid to all countries, without considering any measure of need (which does not seem appropriate). We cannot declare exactly what the optimal Suits index value should be, but we believe that it should be negative. We also believe

Figure 1. Example of a concentration curve (own elaboration)



that neither extreme is appropriate (more detailed information about the computation and characteristics of this index can be seen in Suits, 1977).

1.1. Approach and formulation of the problem

The starting point for developing the model is the actual distribution of ODA by a particular donor (country or institution) to recipient countries over a given period. In other words, once the aid has been distributed, the corresponding concentration curve can be drawn to indicate how the donor's aid has actually been distributed (progressively or regressively) to its partner countries. At this stage therefore, donors *know* how they have distributed their ODA according to their objectives.

Based on this actual distribution, the model proposes a "redistribution" of the aid that meets all of the criteria (without exception) intended by the donor. For example, if the criterion were the recipient's level of need, the proposed aid redistribution would enforce the criterion that no country with greater need will receive less aid per capita than another country in better circumstances. The model will produce an individual "optimal" concentration curve for each donor. This curve will be the result of the progressive reallocation closest to the donor's actual initial allocation (because the initial allocation presumably reflects the donor's objectives, even if some deviations have occurred). Therefore, in this second stage, donors optimise their ODA distribution according to their objectives.

Thus, a donor can understand how its actual aid distribution deviates from its purported interests and can establish corrective measures with a view to future aid allocations. So, in this third phase, donors can orient better their performance. However, an a priori evaluation model can also be applied to a planning of a donor's ODA distribution prior to implementation, which would enable the donor to take corrective measures beforehand.

The mathematical formulation of the proposed evaluation tool is described below.

Consider a donor who has distributed a total amount $\boldsymbol{A}$ over a specific time period (a calendar year, in this case) to address a specific need that affects part of the populations of $\boldsymbol{N}$ recipient countries that we will arrange in descending order according to need.

Let $\boldsymbol{P_n}$ be the affected population in the $\boldsymbol{n}$ -th recipient country, $\boldsymbol{A_n}$ be the aid allocated to this country, and $\boldsymbol{a_n}$ be the per capita aid allocated to the recipient country.

$$a_n = \frac{A_n}{P_n} \tag{1}$$

The total amount distributed is given by $\boldsymbol{A}$:

$$A = \sum_{n=1}^{N} a_n P_n \tag{2}$$

where N is the total number of recipients and P is the recipient population.

The objective of this model is to determine the per capita redistribution $z_1, \dots, z_N$ that should be made so that:

1. the total amount distributed is still $\boldsymbol{A}$, as this is the amount that the donor has decided to distribute as ODA during the period of analysis;
2. the new distribution is not regressive; that is, a recipient with a lower level of poverty (and therefore is further to the right on the horizontal axis) does not receive a greater amount of per capita ODA than any recipient to its left on this axis; and
3. the adjustments between the initial and the revised distribution are minimal, in order to adhere (as much as possible) to the donor initial distribution, which is considered representative of its foreign aid policy guidelines.

With these three conditions, the simplest approach is to pose this as a restricted optimisation problem, with the third condition as the objective and the first two conditions acting as model restrictions.

A feasibility analysis will be conducted first because otherwise, the whole approach will be meaningless. Let $z = (z_1, \dots, z_N)$ be any possible reallocation of per capita resources anddefined analogously to the current allocation.

The first condition regarding the total amount of aid can be expressed as:

$$\sum_{n=1}^{N} z_n P_n = A \tag{3}$$

For the second condition, because recipients are arranged in descending order according to need (as measured by the selected indicator), the condition of non-regressivity implies that each inhabitant of a recipient country must receive at least what an inhabitant from the next country (just below it in terms of need) would receive, and the allocated ODA can never have a negative value, therefore:

$$z_1 \geq \cdots \geq z_N \geq 0 \tag{4}$$

Of course, this is probably not a desirable progressive condition, but to formulate it would require some strict constraints. From a programming (including decision-making) perspective, this is only possible if minimum required differentials between recipients are established, which is a very subjective issue. However, these can be incorporated into the model if a decision has been made, as will be seen in a later section.

Returning to the treatment of the constraint, it must be broken down into a set of $\boldsymbol{N}$ constraints:

$$z_n \geq z_{n+1} \quad n = 1, \ldots . N\text{-}1 \qquad z_N \geq 0 \tag{5}$$

Once these have been collected, it must be demonstrated that the feasible set $\boldsymbol{F_z}$ is not empty:

$$F_z = \{z\text{:}\ \textstyle\sum_{n=1}^{N} z_n P_n = A \quad z_N \geq 0 \quad z_n \geq z_{n+1} n = 1, \ldots, N\text{-}1\} \tag{6}$$

For this, it is sufficient to consider that $(\bar{a}, \ldots, \bar{a}) \in F_z$, with $\boldsymbol{a}$ being the global average amount of per capita aid:

$$\bar{a} = \frac{A}{\sum_{n=1}^{N} P_n} \tag{7}$$

As far as the objective is concerned, the function to be minimised would be the distance between the distribution made and each element of $\boldsymbol{F_z}$

$$min \quad d(a, z) \tag{8}$$

From the infinite number of choices for this distance, we have selected the weighted Euclidean distance, using the relative population of each recipient as the weighting factor.

$$p_n = \frac{P_n}{\sum_{j=1}^{N} P_j} \tag{9}$$

The reasons for these choices are as follows:

1. The Euclidean distance leads to a quadratic optimisation program, which, as can be seen, has a unique solution that is easily calculated with conventional optimisation tools.
2. Regarding the weighting, because the final subjects of the aid distribution are people, it seems more than reasonable for the differences to be weighted according to the number of people affected.

However, these choices can be left to the person applying the tool because flexibility and versatility are some of its main features (as mentioned in the introduction).

By regrouping the objective function and constraints, the problem can be posed as follows:

$$\min \sum_{n=1}^{N} (a_n\text{-}z_n)^2 p_n \qquad (10)$$
$$s.a. \qquad z \in F_Z$$

To solve the problem, a new variable $d = a\text{-}z$ is defined. Thus, the problem can be expressed as:

$$\min \sum_{n=1}^{N} d_n^2 p_n \qquad (11)$$
$$s.a. \qquad d \in F_d$$

being

$$F_d = \{d\colon\ \textstyle\sum_{n=1}^{N} d_n\, p_n = 0 \quad d_N \leq a_N \quad d_n\text{-}d_{n+1} \leq a_n\text{-}a_{n+1} n = 1, \ldots, N\text{-}1\} \qquad (12)$$

This variable change enables the simplification of the objective function, on one hand, and on the other hand, the problem is now written in standard form, expressing the constraints of the feasible set as "≤" inequalities.

Regarding the interpretation, the new variable measures the optimum difference between the initial and new distributions and, therefore, measures the successful allocations ($d_n = 0$), over-allocations ($d_n > 0$), and under-allocations ($d_n < 0$) of the situation being evaluated.

As for the existence of this optimum, it has already been proven that the feasible set is not empty and that it is also closed (it is determined by non-strict inequalities and equalities of linear functions of the decision variables). As the objective function is quadratic with a diagonal and positive matrix ($p_n > 0$), it is a strictly convex objective, which means that there is a strict and unique minimum for the function. We will call this solution d^*.

Therefore, given the initial distribution, it is possible to ensure the existence and uniqueness of an alternative based on the initial distribution that is not regressive and that is the most similar to the actual distribution. Because of how the variables have been defined, their value will be:

$$z^* = a\text{-}d^* \qquad (13)$$

The previously described vector z^* contains the reallocation of resources to be carried out, which formally solves the proposed problem. However, it seems appropriate to define an indicator of the degree of inefficiency of the initial distribution in relation to its optimum, which uses a single measure to provide an idea of the validity of the initial distribution.

To that end, *I* is defined as:

$$I = -\frac{\sum_{d_n^*<0} d_n^* p_n}{A} \qquad (14)$$

which, as will be explained next, represents the proportion of misallocated resources.

By definition, it is clear that $I \geq 0$. In addition, it will have a maximum value of one because:

$$-\sum_{d_n^*<0} d_n^* P_n = \sum_{d_n^*<0} (z_n^* - a_n) P_n \leq \sum_{d_n^*<0} z_n^* P_n \leq A \Rightarrow I = -\frac{\sum_{d_n^*<0} d_n^* P_n}{A} \leq I \quad (15)$$

Because the numerator indicates the system's total under-allocations (recipients who have been allocated less than the optimum) and the denominator indicates the total amount allocated, *I*, represents the proportion of misallocated resources.

Naturally, it follows from the $\sum d_n^* P_n = 0$ condition that the result would have been the same if over-allocations had been measured instead of under-allocations.

However, this index has at least one limitation, as it does not identify the area in which recipients have been unduly harmed due to misallocated resources. This is an important question for further research along these lines.

In effect, the *I* numerator value does not consider the rankings of the recipients; therefore, if two countries have the same deficiency, then their contribution is the same regardless of their level of need.

To address this deficiency, at least in part, the following two potential solutions are considered:

1. Assign weights to each country when calculating the indicator so that the neediest are more influential (remember that the indicator rises with inefficiency). Unfortunately, any allocation is arbitrary; therefore, any correction to the allocation would eliminate the real meaning of the index.
2. Calculate, by groups of countries with common characteristics, the percentage of misallocation that occurs in their respective areas. This partitioning could be by deciles, quartiles, tertiles, etc. or by some less arbitrary criterion. For example, if the countries were divided into three groups (high need, average need, and low need), and the tertiles of the misallocation were equal to 0.25, 0.25 and 0.5, respectively, then this would indicate that half of the under-allocation falls on the low-need third, and the other half is equally distributed between the first two-thirds of recipients. This is clearly less unfair than a distribution of 0.5, 0.25 and 0.25 for the same value of *I*.

The second solution has been chosen for this study. The countries have been classified according to the groups established by the Human Development Index (HDI), and this criterion has been applied to the real cases analysed. Therefore, in the models, the groups of countries with low, medium, high and very high HDI[1] scores have been differentiated by the population percentages corresponding to each group.

1 The Human Development Index ranks countries as low, medium, high and very high without using a fixed level for each group. It uses levels calculated annually from actual index data (for the current year) for all countries.

1.2. Performance evaluation measures

Based on the initial allocation $\boldsymbol{a}$, the corrected allocation $\boldsymbol{z}^*$, the difference $d^* = a\text{-}z^*$, index $\boldsymbol{I}$ and its subdivided parts (I_1, I_2 and I_3), the following model for presenting the results is proposed:

1. Cumulative Allocations Chart: This chart displays the cumulative aid allocations (for both $\boldsymbol{a}$ and $\boldsymbol{z}^*$) on the vertical axis and the cumulative relative population (based on vector $\boldsymbol{p}$) on the horizontal axis.
   The result will be two polygonal lines that both start at the origin and reach point $(1,1)$, corresponding to one of the two allocations (initial and corrected). In each segment, the slope will align with the associated value of the individual allocated aid (*a*) or theoretical aid (*z*), and the slope difference in a segment will therefore indicate the gap between the actual aid allocated and the optimal allocation of aid. If the initial allocation is not regressive, both lines will align.
2. Under-allocations Chart: This is a bar graph in which "under-allocations" are represented by vertical bars below the horizontal axis. The chart also includes two vertical lines corresponding to the population group boundaries according to the HDI.
3. Indicators: The charts include the index values and their breakdown by each aid distribution group.

2. Results from applying the model to the ODA distributions of major bilateral donors

To apply the proposed model to real cases, we used the concentration curves for three donor countries. These countries were selected using the following criteria: (i) a major international donor (specifically, the country must be among those that account for 80% of all ODA granted in the period analysed); (ii) geographically distant, assuming that the donor's aid-related interests (historical, commercial, political, etc.) will therefore be different (three countries from three continents were chosen); and iii) the geographical distributions of their ODA were different; i.e., they had significantly different concentration curves, which would allow the model to reveal how it works in very disparate situations.

The countries selected were the United States (the largest international donor), the Netherlands (one of the most progressive curves), and Japan (the most regressive curve).

The curves proposed by the allocation model and the graphs of under-allocations[2] between the actual and proposed curves are presented in the annex (Figure 2).

2 The grey lines divide the graph into segments. The HDI segments are as follows: 40.2% of the population is in countries with a low HDI; between 40.2% and 93.7% (53.5%) is in countries with a medium HDI; and between 93.7% and 100% (6.3%) is in countries with a high or very high HDI.

As shown in Figure 2, the model for the United States (Suits index = -0.19) proposes a curve very close to the original one to correct the under-allocations. The under-allocations chart shows that most of them happen in the first two groups (low and medium HDI). Concretely, countries as Congo, Ethiopia and Nigeria are the main under-allocated in the group of the lowest HDI, followed by Ghana and India in the second group (medium HDI). All of this is reflected in the inefficiency indicator of 51%, virtually half (52%) belongs to the poorest group, and slightly fewer (43.9%) is associated with medium HDI countries.

Notably, the least populous countries have the most favourable aid allocations. This confirms what other authors have previously demonstrated: ODA is biased in favour of smaller countries (Snyder, 1993; Arvin *et al.,* 2001; Martinsen *et al.,* 2018). However, many of the most populous countries are below the bisector, this is the case of India and China, the countries with the greatest under-allocations. The main countries over-allocated by the United States are South Sudan, Afghanistan, Syria, Kenya, Bangladesh and Jordan.

The Netherlands seems to have the most progressive original curve, with a -0.38 Suits index, which means that the optimal curve in some segments is below the original curve. However, the under-allocations chart shows an inefficiency indicator (52%) very similar to that reached by the United States (51%). This is due to the significant number of under-allocated countries that belong to the low-HDI group, such as Niger, Burkina Faso, Congo, Sudan and Nigeria. These countries accumulate 71.4% of the inefficiency rate of Netherlands. Among the over-allocated countries of this group are Burundi, Mozambique, Mali, Ethiopia, Afghanistan, Benin, and Rwanda. Over allocations dominate, mainly, in the second and the third group of countries (HDI medium and high). This is the case of Kenia, Bangladesh, Iraq and Jordan. The exceptions are once more India and China, which are the main under-allocated due to their huge population.

Japan has the most regressive curve, with a Suits index of 0.44. The model's proposed curve practically aligns with the diagonal. Its differences graph illustrates that most of the countries in the first segment are under-allocated, with this figure inverted for most countries by the end of the distribution. With an inefficiency index of 66% (of misallocated aid), low- and medium-HDI countries are equally under-allocated (29 and 31%), including the Democratic Republic of Congo, Ethiopia, Nigeria, and India. Meanwhile, the over-allocated countries in the medium-HDI group are mostly Asian countries, such as Bangladesh, the Philippines, Vietnam, Indonesia, Thailand, Egypt, and Ukraine.

A significant conclusion emerging from the comparative analysis of concentration curves (with their different Suits, progressive, and regressive indices) and differences charts is that the evaluation of the appropriateness (based on level of need) of aid allocations should be done in segments[3]. In other

3 Remember that although it is called a "curve", it is actually a series of attached segments with horizontal distances that measure the needy population percentages of each country. The vertical distances measure the ODA percentage allocated to a country to cover the need.

words, the evaluation of the suitability of the aid allocated to a country must be based on its level of need and not derived from the distance between the curve and the bisector. This analysis is necessary because an under-allocation to a country may cause the curve to run below the bisector for the entire next segment because it was mistakenly categorised as regressive overall, even though aid allocations have been adapted to the level of need in the other cases. The opposite is also possible if there is significant over-allocation in one of the first countries. Therefore, the degree of progressivity (high or low) is actually indicated by the differences chart in such a way that a country will be progressive if it over-allocates to the first segments (not by individual countries) or if the difference curve runs very close to zero (i.e., very close to the optimal curve).

3. Model flexibility: modification of the initial hypotheses

Although the initial model starts by proposing an optimal curve based on the criterion of RN only (without including any other consideration), this model can be “modified” so that it complies with various relevant constraints. For example, one could force the aid to always be degressive, to give priority to a particular country or, on the contrary, avoid giving aid to a country that has been “sanctioned” for some reason by the donor, limit or mandate a certain amount of aid for a specific target, etc.

Below are some possible modifications to the initial theoretical approach:

1. The distance does not have to be a Euclidean distance:

$$\sum(a_n\text{-}z_n)^2 p_n \rightarrow \sum f(a_n\text{-}z_n)p_n \tag{16}$$

2. A certain minimum aid differential between successive countries may be required. The differential threshold is zero in the current function:

$$d_n\text{-}d_{n+1} \geq \varepsilon_n \tag{17}$$

3. There may be a requirement that a country cannot receive more than a certain amount. This can be generalised to a group of countries:

$$\sum d_n \leq q \tag{18}$$

Similarly, a minimum quantity could be required for a group.

4. In general, any linear constraint on allocations could be included.
5. Weights can be ascribed to the index values to make country differences more prominent.

4. Practical example of modifying the model: Japan

To provide an example of how the initial optimal curve proposal can be modified, we will use Japan, the most regressive of the major donors, as an illustration. In fact, the proposed optimal curve almost completely aligns with the diagonal, which is characteristic of regressive curves. However, the differences chart allows a qualification of this conclusion. Although it does penalise several low-HDI countries and prioritises others with acceptable coverage circumstances (like Thailand or Ukraine), the remaining difference values are very close to the horizontal axis. This indicates that the individual country allocations are very close to the proposed optimal curve, even more than other countries identified as progressive.

This is "logical" because a per capita allocation of ODA to India would amount to a very large amount of aid that would have to be diverted from other targets. For this reason and to illustrate ways of extending the model, the India variable has been excluded from the minimum optimum allocation constraint, thereby "forcing" the actual amount allocated by Japan to India. Furthermore, Thailand was also removed from the minimum allocation constraint. There is favourable bias in Japan's ODA allocation to Thailand, which is obvious considering the significant amount of aid Thailand receives despite its acceptable level of development. According to a report by the International Development Centre of Japan (2015), Thailand is one of five countries in the Mekong Region that have long-standing, socio-cultural, political and economic ties with Japan. Therefore, the economic development and stability of this region is also important for Japan's economic stability. We therefore consider it desirable to leave Japan's allocation to Thailand untouched. Thus, in the annex (Figure 3), we can compare the difference in the new curve that is based on the fundamental constraints and the donor interest constraints.

A clear change in the proposed optimal curve can be observed that is much closer to the actual curve in the modified case, although potential modifications to the allocations are still being proposed that will be better suited to the RNs even when considering the demands of the donor countries. The overall inefficiency index logically improves, going from 66% of "poorly" allocated aid to 43%, which becomes an opportunity for improvement, especially in low-HDI countries that suffered from the comparison effect.

5. Conclusions

The geographical distribution of ODA is an issue that has always been of concern and interest to international development cooperation. At present, considering the objectives of the 2030 Agenda for Sustainable Development, the eradication of poverty demands the aid of the most developed countries for those in worse circumstances. The decision of where to deliver ODA is crucial for attaining this objective. Many factors are considered by donors (bilateral and multilateral) in making that decision, including the characteristics of the recipient but also the donor's own interests. This is an undeniable reality that the international community should assume and accept. However, despite the substantial number of research studies analysing this issue, there is no evidence of the use of tools that try to reconcile the interests of donors and recipients. This is precisely one of the main contributions of this article because the proposed evaluation model incorporates the interests of both parties to the transaction (donor and recipient), which imbues the evaluation with practicality and makes the tool more useful.

In addition, the model makes other important contributions that are noteworthy. On one hand, it enables an understanding of the deviations between actual or planned ODA distributions and their desired or intended distributions. This understanding facilitates the incorporation of corrective or improvement measures. On the other hand, if the model is used at an aggregate level, including international development objectives, it could facilitate donor coordination, which is essential for improving aid effectiveness (Ashoff, 2004; Bigsten and Tengstam, 2015; Aldasoro *et al.*, 2010; Adison *et al.*, 2015).

Last, there is no doubt that the flexibility of the proposed evaluation model is one of the main advantages. The model has been applied in this study to assess the geographical distribution of ODA by some major bilateral donors. However, its potential use is much broader. Specifically, the flexibility of the proposed model is manifested in two ways: in its object and in its objective. Regarding the object, the model can be applied to the evaluation of any financial distribution, not just ODA, such as other types of aid (Jones, 2012) or investments, and by various donor types (countries, companies, or institutions). Regarding the objective, the model allows consideration of different criteria for evaluating distributions (included in the model as the objective function and constraints). Therefore, the proposed methodology's capacity for extrapolation to other completely different contexts than the one presented in this article increases the interest and scope of this study's contribution.

Thus, as potential lines of research for the future, the proposed model can be applied to the evaluation of ODA distributions by the major multilateral donors as well as for specific aid to CRS (Creditor Reporting System) sectors. In this type of study, the applied criteria and constraints must be related to the donor's objectives as well as those established in the international development agenda.

Therefore, we believe that the proposed methodology can be a useful tool for bilateral and multilateral donors, as well as policymakers, as it allows them to know how they are performing (in terms of ODA distribution in this case) and how improving it.

In conclusion, some comments on this study's limitations are necessary. Although the quality of the information from the international development cooperation data has improved considerably over the last few years, there is still little information on some recipient countries relevant to the study (because they are among the most disadvantaged). This led to their exclusion from the analysis. Therefore, if the achievement of the development goals proposed by the international community is to be measured rigorously and accurately, there must be an ongoing effort to collect and record information about the poorest countries.

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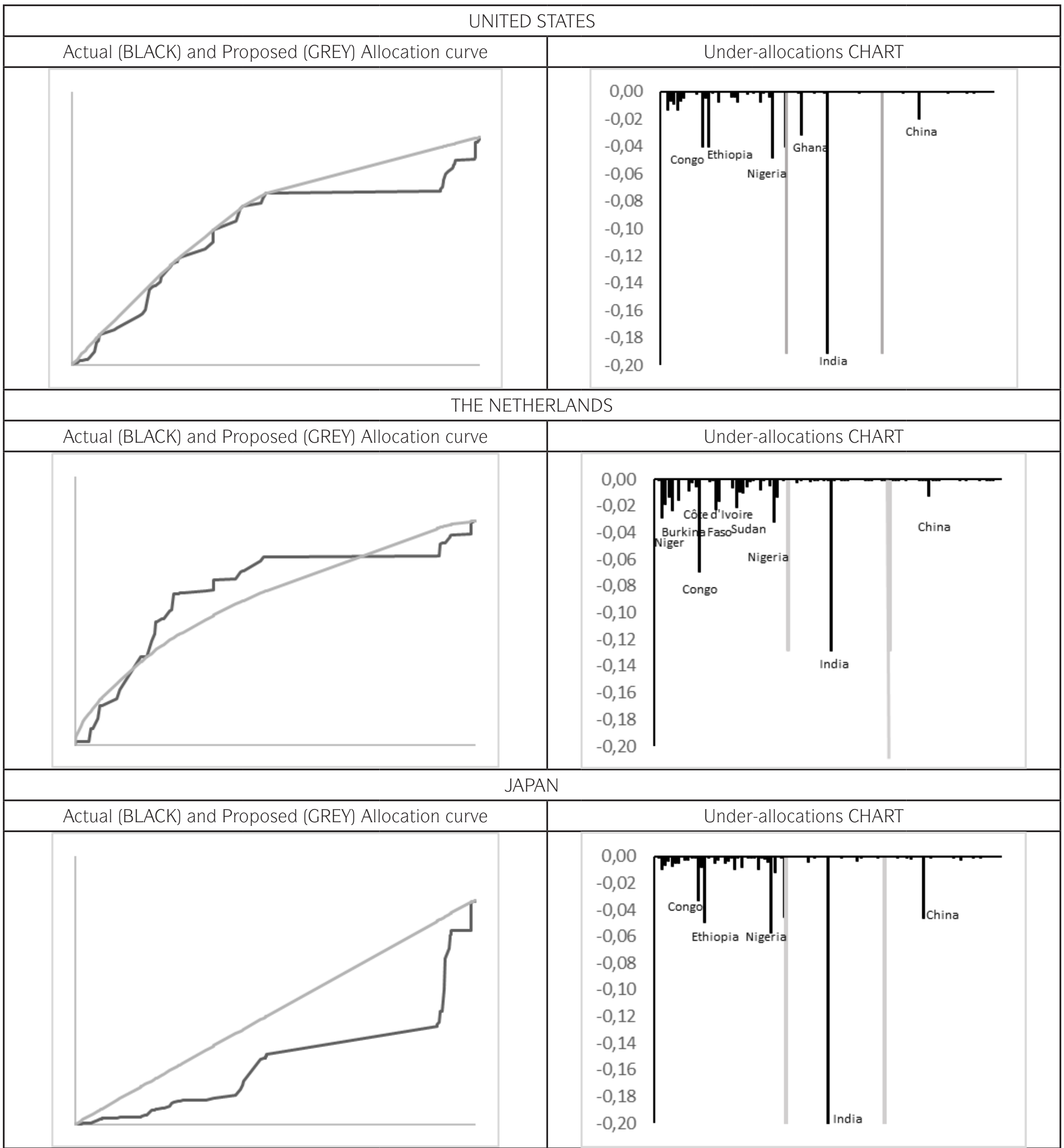
Annex

Figure 2: Application of the donor reallocation model



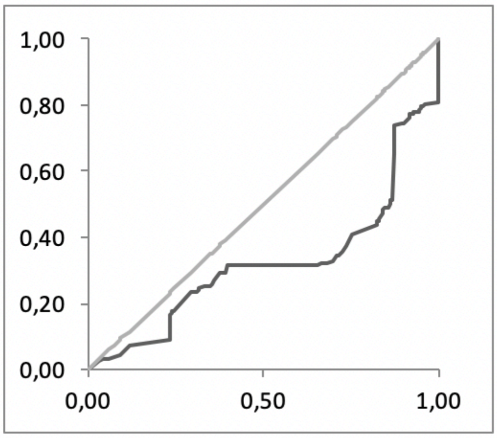
COUNTRY	SUITS INDEX	INEFFICIENCY INDICATOR	INEFFICIENCY INDICATOR BY GROUPS*		
			LOW HDI	MEDIUM HDI	HIGH AND VERY HIGH HDI
UNITED STATES	-0.19	51%	27% (52.9%)	22% (43.9%)	2% (3.9%)
THE NETHERLANDS	-0.38	52%	37% (71.4%)	14% (25.8%)	1% (2.8%)
JAPAN	0.44	66%	29% (44.9%)	31% (46.9%)	5% (8%)

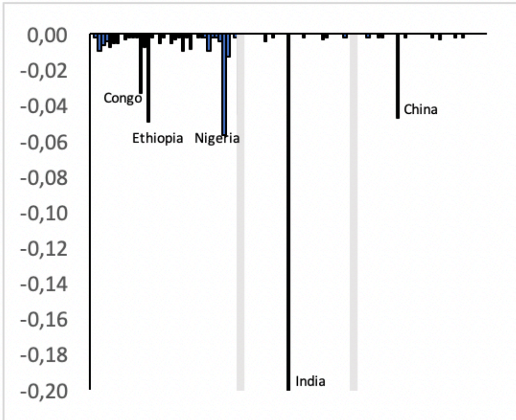
* The two values in each box indicate the following: the first percentage is the absolute portion of the global value, while the second (in parentheses) reflects the percentage that each group represents of the inefficient total. Therefore, summing each row of the first values (in the HDI groups) will equal the inefficiency indicator, and the sum of the second values will always be 100%. Source: own elaboration.

Figure 3: Application of the donor reallocation model to Japan: original versus modified situation

ORIGINAL JAPAN CASE

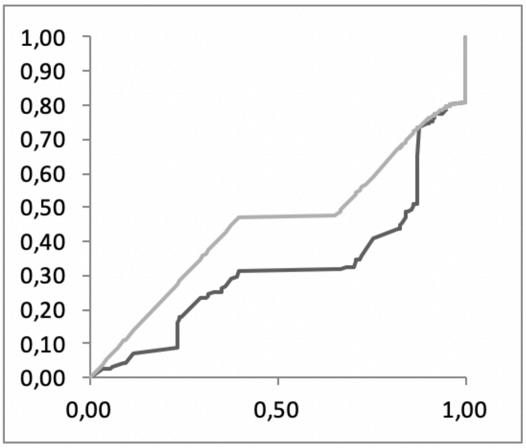
Actual (BLACK) and Proposed (GREY) Allocation curve	Under-allocations CHART

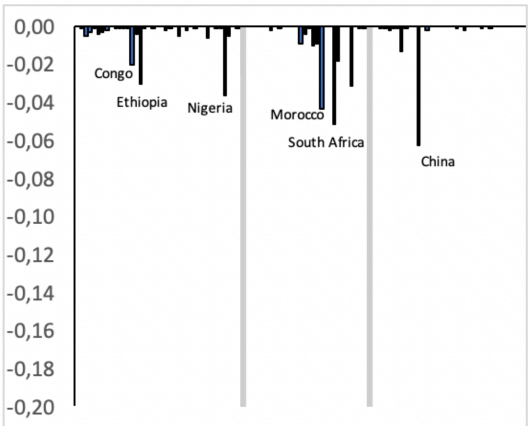




MODIFIED JAPAN CASE*

Actual (BLACK) and Proposed (GREY) Allocation curve	Under-allocations CHART





VALUATION INDICES

COUNTRY	Suits Index	INEFFICIENCY INDEX	INDEX		
			LOW HDI	MEDIUM HDI	HIGH AND VERY HIGH HDI
JAPAN – ORIGINAL	0.44	66%	29% (44.9%)	31% (46.9%)	5% (8%)
JAPAN - MODIFIED		43%	17% (38.3%)	18% (42.3%)	8% (19.4%)

* Not including the ODA-related constraints for India and Thailand.
Source: own elaboration.