Supplementary Material Appendix

Measuring inequalities

To measure inequalities we used concentration curves and concentration indices[1–3] – standard measures used in this type of analysis in the health economics literature.[4] The concentration curve plots the cumulative share of the population ranked by living standards (proxied by GDP per capita in our analysis), against the cumulative share of the financing variable (funding per capita in our analysis) to provide a representation of the relative inequality between relative frequencies of the two variables. If every country receives an amount of funding proportional to their GDP, the concentration curve will be represented as a 45° line – the 'Equality line'. Inequality is represented by the relative position of the concentration curve for the financing variable with respect to the Equality line. If the concentration curve lies above the Equality line, the funding is concentrated more among the worse-off (*pro-poor* inequality). The farther the line is above the Equality line, the greater the inequality in favor of the poorer countries (*pro-poor* inequality). By contrast, if the curve lies below the equality line, there is *pro-rich* (for countries) inequality in funding.

Analogously, the inequality in the distribution of health is represented by the relative position of the concentration curve for the health indicator with respect to the Equality line. However, the number of people at risk of malaria (TotalPAR), the health indicator used, is an undesirable outcome. Hence, a concentration curve that lies above the 45 degree line indicates inequalities disfavoring poor countries i.e. disease burden is concentrated among the worse-off (*pro-poor* inequality).

Since the concentration curves do not provide a measure of the magnitude of inequality, we measure these magnitudes by estimating the concentration index (*CI*) measured as twice the area between the concentration curve and the Equality line. The concentration indices are also more informative in cases where the concentration curve crosses the Equality line leading to inconclusive results regarding the level and direction of inequalities, in particular whether the funding is concentrated towards poor countries (*pro-poor* inequality) or concentrated towards rich countries (*pro-rich* inequality).

The concentration index is defined as:

$$CI = 1 - 2\int_0^1 L_f(p)dp \qquad (1)$$

where $L_f(p)$ is the concentration curve that captures the distribution of the funding variable by income. The concentration index is then twice the area between $L_f(p)$ and the Equality line. The index is bounded between -1 and 1 (negative for *pro-poor* inequality and positive for *pro-rich* inequality). The *CI* in (1) can be obtained from a 'convenient regression' of a transformation of the funding variable of interest on the fractional rank of the GDP distribution[2,3]

$$2\sigma_r^2\left(\frac{f}{\mu}\right) = \alpha + \beta r_i + \varepsilon_i \qquad (2)$$

Where σ^2 is the variance of the fractional rank in the GDP distribution (r). The *CI* is then given by an ordinary least squares (OLS) estimate of β.[3] To test whether these indices are different from zero, we adopted the inference methods developed by Kakwani *et al*., and described in O'Donnell *et al*.[2,3]

Horizontal Equity of Malaria funding

The notion of horizontal equity refers to equal treatment for equal need. In our context it measures whether, countries with equal malaria burden receive equal funding regardless of their income, i.e. malaria funding is distributed in proportion of need.

The inequalities observed through the concentration curves and indices described above must not be directly interpreted as inequity. Variation in disbursements due to differences in healthcare need is a legitimate source of inequality. Those countries with greater burden of disease legitimately ought to be entitled to higher disbursements compared to those with a lower disease burden. Therefore, to determine the extent of inequity a comparison needs to be made between the distributions of need (malaria burden) and expenditure in malaria across income deciles. The concentration curves in this context plot the cumulative proportion of countries ranked by living standards (proxied by GDP per capita) against the cumulative proportion of need (proxied by TotalPAR) and expenditure in malaria (proxied by per capita funding). Comparison of the two concentration curves (need and healthcare expenditure) then provides an indication of inequity. If funding is allocated across income groups in proportion of their share of need, the two curves would coincide. If poorer countries receive lower (higher) than the fair share

of funding compared to the richer countries, the funding concentration curve will lie below (above) the health need curve.

The extent of horizontal inequity is therefore assessed by measuring the *horizontal inequity index* that is computed as the difference between the concentration index for healthcare expenditure (used as a proxy for healthcare) and that for need.[1] This index compares each income group's share of need and its share of healthcare. The relative position of the concentration curves of need and funding determine the direction and level of horizontal inequity. In particular, if the need curve lies above (below) the funding curve then there is horizontal inequity favoring the better-off (worse-off) with the higher income countries obtaining a higher (lower) share of funding than their share of need, and then will result in an unequal *pro-rich* (*pro-poor*) distribution of malaria funding across countries.

Vertical Equity of Malaria funding

We also assess vertical inequity, i.e. the extent to which countries with unequal ability to finance malaria control and elimination receive appropriately unequal funding from international donors. More specifically, the concept of vertical equity helps to identify whether a particular source of funding is 'progressive' (i.e. *pro-poor* and *pro-burden*), regressive (*pro-rich* and favoring countries with lower burden) or proportional (aligned to economic status and burden).

While a straightforward way to measure vertical equity is to compare the share of funding received across the different income deciles, a drawback of this approach is that it cannot quantify the degree of progressivity or regressivity. Hence, it cannot answer the question of how much more progressive or regressive one source of funding is compared to another source of funding, nor how progressivity changes over time. Therefore, to measure progressivity we estimate the Kakwani Index (KI) that is the most widely used measure of progressivity in financing of a health system.[1,3]

The Kakwani Index is defined as 'twice the area between the financing concentration curve and the Lorenz Curve' and can be estimated as the difference between the concentration index for the financing source and the concentration index for income (as measured by the Gini coefficient[3]).

The Kakwani Index ranges from –2 to 1. It is negative (positive) if the concentration curve dominates (is dominated by) the Lorenz curve, i.e. there is progressivity (regressivity) in funding. In the case in which the concentration curve lies on top of the Lorenz curve, the Kakwani Index is zero (proportionality in funding) . Note that, when assessing sources of financing for a health system, such as taxation, a negative Kakwani Index indicates regressivity, a positive value indicates progressivity, and the index is zero for the case of proportionality.[2] In our analysis, however, we are evaluating the progressivity of funding received and, therefore, a negative value for Kakwani Index indicates progressivity while a positive value indicates regressivity.

Dominance testing

Finally, we test for statistical dominance of the concentration curves. The statistical significance of the differences between concentration curves, and those with the equality line, can be inferred using dominance testing[2]. We used the decision rule "*intersection union principle"* that has been theoretically presented and empirically used to infer statistically significant differences between concentration curves. This rule requires statistically significant difference between ordinates at all quantile points in order to assign dominance and reduces the probability of erroneously rejecting non-dominance at the cost of reducing the power of detecting dominance when true[2].

References (in Supplementary Material Appendix)

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