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Method Article

Methods for testing the income-health relative hypothesis that the distribution of income in a society affects the distribution of health

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A B S T R A C T

Health and income relation analysis has been the subject of controversies on the absolute income hypothesis (the higher an individual's income, the better their health status) and the relative income hypothesis (individual health is affected by the distribution of income within society). In addition, the assumed relationship has been criticised as being a statistical artefact. To overcome these issues, we formulate the hypothesis that the distribution of health in a society is correlated with the distribution of income in that society and propose the analytical method framework. The method is focused on the calculation of Foster–Greer–Thorbecke (FGT) poverty indices using health and income outcomes. Econometric time series methods, particularly the autoregressive distributed lag (ARDL) cointegration bounds test and dynamic simulation, are complementary tools used to measure the relationship between the calculated indices. Applied to the sub-sample of countries below the poverty line, the method highlights the correlation between the gaps and inequalities in health outcomes and the gaps and inequalities in income outcomes, respectively.

• The Foster–Greer–Thorbecke (FGT) poverty indices are applied to income and health outcomes.
• Aggregate poverty indices are measured across states.
• These indices are meaningful indicators for analysing the link between the distribution of health and the distribution of income in a society.

A R T I C L E I N F O
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Introduction

Health and income outcomes as aspects of welfare have remained a concern to both national and international policymakers. In the context of developing countries such as those in Sub-Saharan Africa (SSA), Nwude et al. [2] show that income per capita is the most important determinant that significantly improves health outcomes out of a set of determinants comprising official development assistance that does not improve health outcomes. Previously, Pritchett and Summers [3] have highlighted that 'wealthier nations are healthier nations' and added that 'gains from rapid economic growth flow into health gains'. The axiom 'a wealthier nation is a healthier nation' has given rise to significant body of current research focused on the relationship between income per capita and health outcomes. From this perspective, several studies have highlighted that income remains one of the major determinants of health outcomes [4–8]. Furthermore, analyses based on the aforementioned axiom have focused on one of the two following hypotheses. The first is the absolute income hypothesis, which states that other factors being constant, the higher an individual's income, the better their health [9,10,3,11]. The second is the relative income hypothesis, which states that individual health is affected by the distribution of income within a society [12–18].

Controversies exist between analyses focused on the absolute and relative income hypotheses. A consensus was eventually proposed by Clarke and Erreygers [19] for future research on the relationship between health and income. Applying poverty concepts to the domain of health, the authors suggested the use of bivariate indicators to analyse the extent to which health poverty is correlated to income poverty for future research. Some criticisms of the absolute or the relative income hypothesis concern the occurrence of statistical artefacts [20]. Overall, Boef and Keele [21] highlight that statistical artefacts generally occur when analysts select and estimate a model, limit inferences to short-run effects, and do not compute and interpret quantities such as long-run impacts of the exogenous variables, the mean, and the median lag lengths of effects. In this case, the dynamic simulation approach developed by Jordan and Philips [22] offers an alternative to the hypothesis testing of model coefficients by conveying the substantive significance of the results through meaningful counterfactual scenarios.

In the context of this background on the relationship between health outcomes and income outcomes, this paper makes two main contributions. First, it proposes the income-health relative hypothesis stating that the distribution of health is correlated to the distribution of income in a society. Second, the paper proposes a rigorous step-by-step method to test this income-health relative hypothesis.

The author describes sequential method testing for the correlation between indices of both health outcomes and income outcomes that are calculated using the Foster–Greer–Thorbecke poverty index approach. The use of a dynamic simulation technique [22] allows a view of the correlation between health and income across time, compared to the more conventional static correlation approach. Formulating the income-health relative hypothesis and testing it using the dynamic simulation approach provides more comprehensive and useful information about temporal causality between health outcomes and income outcomes across countries. The proposed income-health relative hypothesis is validated using the described method, and the results show that the intensity and inequality of income poverty in a region dynamically affect respectively the intensity and inequality of health poverty in the region. These results light the way for policies aiming to reduce regional health inequalities.

Method details

In the sections and subsections below, we detail the steps and tools for conceptualising and testing the income-health relative hypothesis stating that the distribution of health in a society is correlated to the distribution of income in that society.

The FGT poverty measurement

The focus of our methods is the Foster–Greer–Thorbecke (FGT) poverty index [1]. Indeed, the FGT measures of poverty provide a unifying structure linking poverty, inequality and well-being, leading to these measures becoming the standard for international evaluations of poverty and inequality. The measures are applicable to monetary outcomes as well as non-monetary outcomes such as education and health [23].

- *Step 1:* Determination of health poverty and income poverty thresholds

The study is built on a cross-sectional framework using population data for different countries within a region. Typically, h_i and r_i are assumed to be the respective national health attainments, namely life expectancy at birth and the country's gross domestic product per capita expressed as purchasing power parity (PPP). Following Clarke and Erreygers [19], we assume that the definition of a country's minimal acceptable health and income levels will depend on the average health and income attainment in the region. Therefore, we assume the health and income thresholds z to be a fraction λ ($\lambda = 5\%$) below the region's annual average life expectancy at birth and gross domestic product per capita.

$$z_h = (1-\lambda)\bar{h}, \text{ with } \bar{h} = \frac{\sum_{i=1}^{N} h_i}{N} \tag{1a}$$

and

$$z_r = (1-\lambda)\bar{r}, \text{ where } \bar{r} = \frac{\sum_{i=1}^{N} gdp_i}{N} \tag{1b}$$

where $i = 1\ldots N$ represents the number of countries in the region.

- *Step 2:* Determination of the poverty gap

Empirically, a country's outcome poverty gap is the distance between its outcome attainment and the relevant outcome poverty threshold (z). The gap is normalised as a fraction of the threshold. Thus, the normalised poverty gap for health (g_i^h) and for income (g_i^r) are, respectively:

$$g_i^h = \begin{cases} \frac{z_h - h_i}{z_h} \text{ if } h_i < z_h \\ 0 \text{ if } h_i \geq z_h \end{cases} \tag{2a}$$

and

$$g_i^r = \begin{cases} \frac{z_r - r_i}{z_r} \text{ if } r_i < z_r \\ 0 \text{ if } r_i \geq z_r \end{cases} \tag{2b}$$

where $i = 1\ldots N$ represents the number of countries in the region. Fig. 1 highlights the SSA countries' profile plots in terms of both income poverty gap and health poverty gap for the period 1990–2017.

- *Step 3:* Aggregate measures of health poverty and income poverty

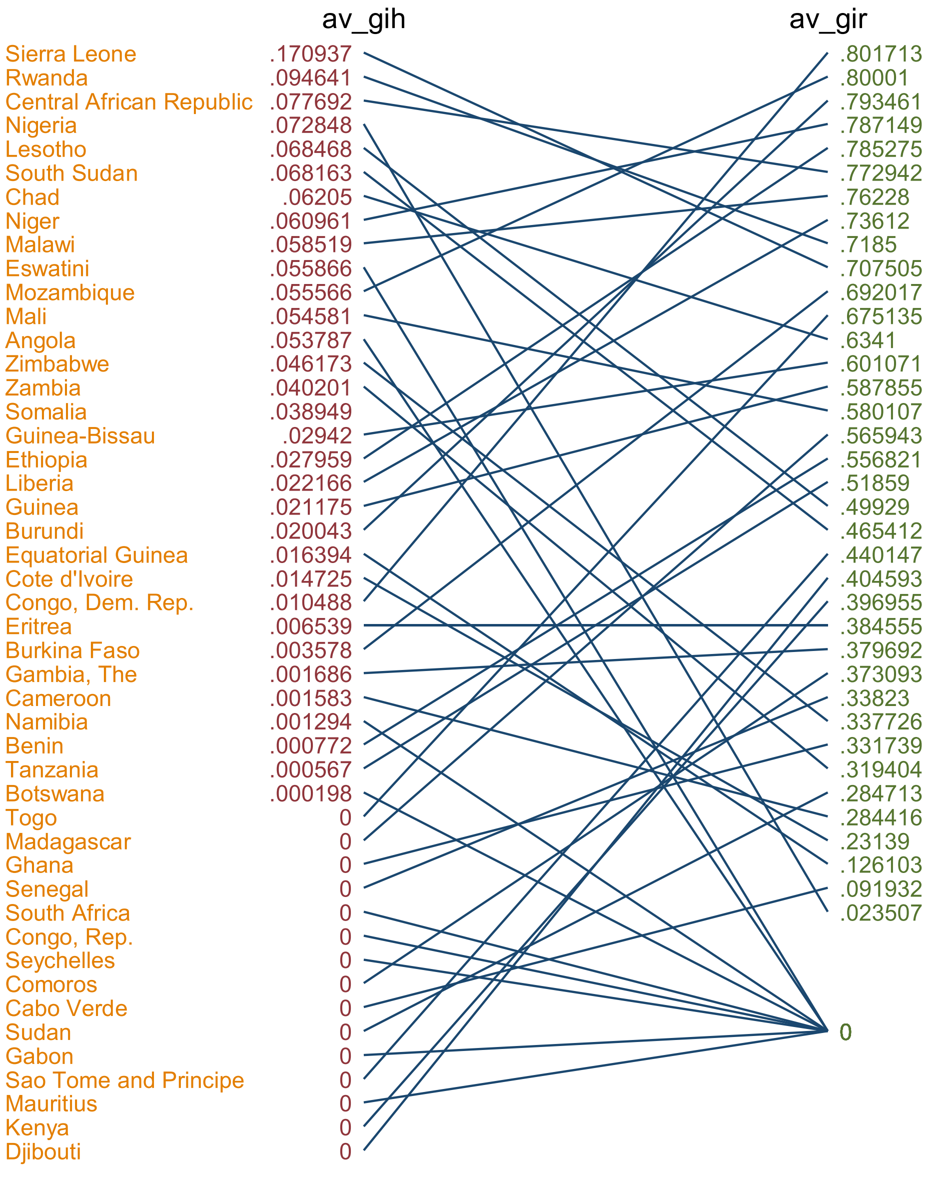

Fig. 1. Paired display ranking countries in terms of health poverty and income poverty.
Notes: av_gih: average health poverty gap; av_gir: average income poverty gap.

Table 1
Descriptive statistics of income poverty and health poverty indices.

Variable	Obs	Mean	Std. Dev.	Min	Max
Income poverty indices					
P0r	28	0.741	0.018	0.721	0.786
P1r	28	0.404	0.024	0.369	0.441
P2r	28	0.252	0.023	0.219	0.287
Health poverty indices					
P0h	38	0.367	0.062	0.255	0.447
P1h	38	0.027	0.007	0.014	0.036
P2h	38	0.003	0.002	0.001	0.007

Notes: P0r, P1r and P2r indicate the income poverty incidence, intensity, and inequality, respectively. P0h, P1h and P2h indicate the health poverty incidence, intensity, and inequality, respectively.

Using the poverty gaps defined in Step 2, aggregate poverty measures (unifying measures of health poverty and income poverty) for all countries in the region are calculated. To this end, the FGT index measures of health poverty and income poverty are as follows:

$$P_\alpha^h = \frac{1}{N}\sum_{i=1}^{N}\left(g_i^h\right)^\alpha \tag{3a}$$

and

$$P_\alpha^r = \frac{1}{N}\sum_{i=1}^{N}\left(g_i^r\right)^\alpha \tag{3b}$$

where α is a non-negative parameter that reflects poverty aversion. As Foster et al. [24] highlight, with the values taken by $\alpha(\alpha = 0, 1, 2)$, the health poverty indices P_0^h, P_1^h and P_2^h that respectively capture the incidence, intensity and inequality of health poverty in the whole region are consecutively obtained. Similarly, P_0^r, P_1^r and P_2^r capture the incidence, intensity and inequality of income poverty in the region, respectively. The indices of poverty P_0^h and P_0^r indicate the proportion of countries whose life expectancy at birth and GDP per capita are below their corresponding regional thresholds, respectively. The intensity of poverty $P_1^h$and P_1^r indicate how far below the health poverty and income poverty thresholds poor countries are, respectively. The inequality of poverty P_2^h and P_2^rrespectively measure the gap sizes of health-poor countries and income-poor countries from the corresponding thresholds as well as the inequalities between these countries. Table 1 summarises the statistics of income poverty and health poverty indices.

Analysis of health and income distributions

After the application of the FGT poverty index to population data related to health and income in a region, an econometric approach to analyse the correlation between the distribution of health and the distribution of income generated by the FGT measures may be performed.

- *Step 4:* Cointregation testing

A vector-error-correction cointegration testing [25] is formalised as follows:

$$\Delta P_t = \lambda\beta' P_{t-1} + \sum_{t=1}^{p-1}\eta_i \Delta P_{t-i} + e_t \tag{4}$$

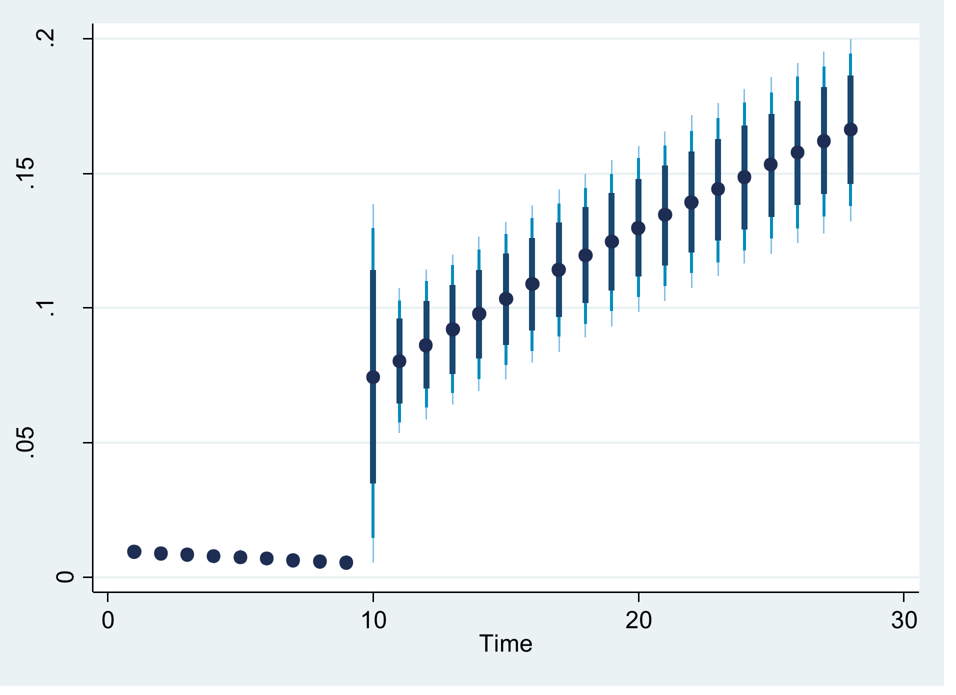

Fig. 2. Dynamic simulation of the effects of income poverty intensity on health poverty intensity
Notes: Dots show the average predicted value. Shaded lines show (from darkest to lightest) the 75%, 90% and 95% confidence intervals.

with

$$P_t = \begin{pmatrix} P^h_{0,t} \\ P^r_{0,t} \\ P^h_{1,t} \\ P^r_{1,t} \\ P^h_{2,t} \\ P^r_{2,t} \end{pmatrix}$$

where λ and $\beta$are $(6xr)$ parameter matrices with rank $r < 6$. r represents the rank of the cointegrated equation between health poverty indices and income poverty indices. Existence of cointegration highlights long-term relationships between indices of health poverty and indices of income poverty.

- *Step 5:* Causality testing

If cointegration is found, exploring senses of causality between health and income may be of interest. Following Hansen's [26] approach, the autoregressive distributed lag relationship (ARDL) between identical pairwise health poverty and income poverty indices is tested as follows:

$$P^h_{\alpha,t} = a_0 + \sum_{i=1}^{K} \lambda_i P^h_{\alpha,t-i} + \sum_{i=1}^{K} \beta_i P^r_{\alpha,t-i} + e_t;\ \alpha = 0, 1, 2. \quad (5)$$

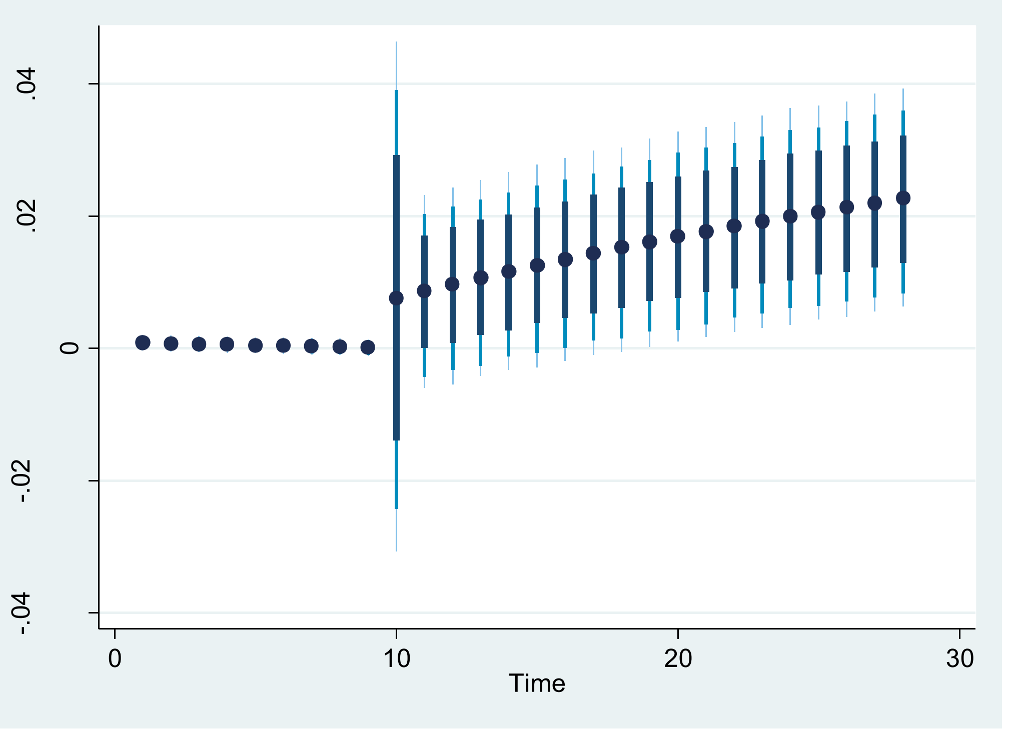

Fig. 3. Dynamic simulation of the effects of income poverty inequality on health poverty inequality
Notes: Dots show the average predicted value. Shaded lines show (from darkest to lightest) the 75%, 90% and 95% confidence intervals.

The test hypotheses are formalised as follows:

$$\begin{cases} H_0 : \beta_i = 0 \text{ for all } i = 1, \ldots, K \\ H_1 : \beta_i \neq 0 \text{ for all } i \end{cases}$$

- *Step 6:* Performing cointegration over the ARDL bounds test

In order to avoid statistical artefacts [20,21] in the stationarity of the indices and the correlation between the distribution of health and the distribution of income, strong checks for cointegration between the health poverty indices and the income poverty indices must be conducted. Therefore, cointegration testing using the ARDL bounds test developed by Philips [27] is adopted across the following levels: (i) Phillips-Perron and Dickey-Fuller GLS unit root tests are applied; (ii) Depending on the sense of causality in Step 5 and the results of the Dickey-Fuller GLS unit root test (maximum lags of each indices), the ARDL bounds model in error-correction form is formulated as follows:

$$\Delta P^r_{0,t} = \alpha_0 + \theta_0 P^r_{0,t-1} + \beta_1 \Delta P^h_{0,t} + \theta_1 P^h_{0,t-1} \quad (6a)$$

$$\Delta P^h_{1,t} = \lambda_0 + \gamma_0 P^h_{1,t-1} + \gamma_1 P^h_{1,t-2} + \phi_1 \Delta P^r_{1,t} + \gamma_2 P^r_{1,t-1} \quad (6b)$$

$$\Delta P^h_{2,t} = \mu_0 + \eta_0 P^h_{2,t-1} + \eta_1 P^h_{2,t-2} + \phi_1 \Delta P^r_{2,t} + \eta_2 P^r_{2,t-1} \quad (6c)$$

Note that each index in models (3a)–(3c) must be consecutively lagged to its maximum lags obtained from the Phillips-Perron and Dickey-Fuller GLS unit root tests. (iii) The ARDL models described above are estimated and checks for no serial correlation are conducted using the Breusch-Godfrey, Durbin, and Cumby-Huizinga tests. Additionally, a test for the normality of the residuals is conducted using the Shapiro-Wilk test. The bounds cointegration test results aim to retain the stronger long-term relationships between models (3a)–(3c).

- *Step 7:* Simulation of ARDL relationships

The Jordan and Philips [22] dynamic simulation of ARDL error-correction models obtained at the end of substep (iii) is run, and the extent to which the indices of health poverty are linked to the indices of income poverty is obtained. Views of the simulation approach are represented in Figs. 2 and 3.

Conclusion

In the context of controversial analyses of the relationship between health and income, this paper proposes an income-health relative hypothesis and provides a detailed description of how to test this hypothesis. The proposed method is applied to a dataset of life expectancy at birth and income per capita expressed as PPP spanning the period 1990–2017. The method accounts for both static and dynamic correlation analysis. The results show that the distribution of income (poverty incidence and inequality) dynamically affects the distribution of health (poverty incidence and inequality) in a region. This finding strongly supports the relative income-health hypothesis, which states that the distribution of income in a society is correlated with the distribution of health. This means that addressing societal income disparities is an important strategy by which to decrease health disparities. Our method makes a conceptual contribution to the literature on the relationship between health and income. The use of the poverty index leads to the exclusion of the sub-sample of both income- and health-non-poor individuals. Future research may generate the same indicators over the subgroup of non-poor individuals or use other inequality indicators covering the entire sample, i.e. the entire distribution of health outcomes and income outcomes across the population under consideration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this paper.

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