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IS THIS A BETTER METHODOLOGY TO CALCULATE HUMAN DEVELOPMENT INDEX?

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Abstract

The Human Development Index (HDI) has become one of the most widely used measures of comparative human development; however, its conventional specification has been subject to continuing debate regarding indicator selection, weighting, aggregation and the extent to which a limited number of dimensions can adequately represent human well-being. This study revisits an alternative methodology for constructing the HDI based on second-order stochastic dominance. Building on the framework proposed by Ciupac-Ulici et al., the study considers 17 indicators covering three broad dimensions: a long and healthy life, a decent standard of living, and access to education. The original 90-country framework is conceptually extended from 1995–2013 to 1995–2023 in order to examine how a longer observation period may affect the distributional properties of the indicators and the resulting selection of dominant variables. Natural-log transformations and empirical distribution functions are employed, followed by pairwise second-order stochastic-dominance comparisons using the Meyer procedure. For the extended period, the results presented in this study demonstrate the potential implications of applying the methodology to the 1995–2023 period. The results identify four comparatively dominant indicators: population growth rate, GNI per capita, health expenditure as a percentage of GDP, and pupils in gymnasium and high school education. These indicators are subsequently incorporated into a three-dimensional Modified Human Development Index using normalized component indices and a geometric-mean aggregation procedure. The exercise

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demonstrates that the choice of indicators and the method used to select and aggregate them can substantially influence the measurement and distribution of human development across countries. The study therefore contributes to the continuing methodological debate on whether stochastic dominance can provide a more systematic basis for selecting indicators in composite measures of human development.The financial intermediaries play a pivotal role in the transmission mechanism of both fiscal and monetary policy for determining the rate of inflation. Moreover, in developing economies like Pakistan, fiscal dominance is a norm and tax exemption for certain sectors is a pattern. This study explicitly model to gauge the response of inflation for such situations, incorporating the acknowledged role of intermediaries in the frame of policy coordination by taking into account the risk taking behavior of deposit holders and loan advancing strategies of banking industry.

Keywords: Human Development Index (HDI); Modified Human Development Index; Stochastic Dominance; Second-Order Stochastic Dominance; Human Development Measurement; Composite Indicators; Indicator Selection; International Comparison; 1995–2023.

Introduction

The concept of Human Development Index (HDI) was introduced in 1990. It marked an important change the way development was interpreted across both developing and developed countries . the development indicators, previously, were measures mainly on the basis of income and economic growth. HDI shifted attention towards people and their well-being. The idea behind HDI was simple. It is not only income which account for development, rather is has to be a detailed index reflecting what people are able to achieve in their lives and "the process of enlarging people's choices and enhancing their capabilities". This idea is closely linked with Amartya Sen's capability approach. The approach views development as a process of expanding people's choices and capabilities. HDI was also strongly influenced by Mahbub ul Haq. He argued for a shift from income-based measures towards people-centred development. The index was therefore designed to combine important economic and social aspects of human well-being.

The basic strength of HDI is its simplicity. It brings different aspects of development into one composite measure. It also makes comparisons across countries easier. At the same time, this simplicity creates an important limitation. Human development is a much broader concept. The traditional HDI focuses mainly on health, education, and income. Although these dimensions are important, but they failed to capture every aspect of human well-being. To mention the most important issues such as poverty ND inequality, unemployment and quality of education. Another concern is related to the choice and weighting of indicators. Different dimensions of development may not contribute equally to human well-being. The selection of indicators can therefore influence the final value of the index. Adding too many indicators, however, can make the index difficult to interpret. The challenge, therefore, is to achieve a balance, between comprehensiveness and simplicity. These concerns provide the basis to look for ways to improve the measurement of human development. Previous studies have questioned the selection of variables, the weighting procedure, and the limited

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coverage of some dimensions. Other researchers have suggested incorporating inequality, environmental sustainability, freedom, and other aspects of human well-being. Against this background, the present study explores whether the existing HDI can be made more comprehensive. It does not simply focus on changing the ranking of countries. Instead, it focuses on the indicators used to represent the three main dimensions of human development. The study proposes additional indicators, in order to provide a broader picture of the health, education, and living standards sein human development index.

The study uses 17 indicators across the three dimensions. The health dimension is represented through indicators related to a long and healthy life. The education dimension includes indicators related to access to and provision of education. The living-standard dimension includes indicators related to income, employment, consumption, and population. The study further applies stochastic dominance to examine these indicators. The analysis covers 90 countries over the period 1995–2023. The objective is to identify a more representative set of indicators for constructing a modified measure of human development. In this way, the study contributes to the continuing debate on how human development should be measured. The central question is not whether HDI is useful. It clearly provides a simple and widely understood measure. The question is whether its underlying dimensions can be represented more fully without losing the simplicity that makes the index useful.

Literature Review

Measuring human development is not a simple task. Human well-being has many dimensions. Therefore, choosing the right indicators is an important challenge. The literature on human development has gradually moved beyond income and economic growth. There is abundance os research substantioally increasingly focused on poverty, inequality, health and education, and other aspects related to development. In literature, the earlier approaches are more often related to national income and per capita income as the main indicators of development. While, the economic growth was seen as a major sign of progress. However, this approach did not fully explain differences in living standards. A country could experience strong economic growth, while still large sections of its population may remained poor.

This led the researchers to pay greater attention to another important aspect of distribution of income. Studies by Alesina and Rodrik (1994), Persson and Tabellini (1994), and Barro (2000) examined the relationship between inequality and economic growth. Their work helped strengthen the argument that growth and its distribution cannot be considered separately. The focus on growth alone was therefore gradually questioned. International organizations also recognized that economic growth was too narrow a measure of human well-being. The work of Amartya Sen on inequality and social justice further influenced this shift. His capability approach contributed to the development of the HDI in 1990.

The HDI itself has also been widely discussed in the literature. McGillivray (1991) questioned this structure of HDI, and its ability to measure development (human) across countries. Other studies raised concerns about this specific selection of indicators, questioning whether the same indicators are equally suitable for developed and developing countries. Hicks (1997) highlighted the absence of income distribution in the HDI, suggesting measures such as the Gini coefficient, which could provide additional information to add to a more sophisticated and correct reflection of human development. Streeten (2000) questioned the

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weighting of the main indicators and the exclusion of other important aspects of development.

Other researchers focused on dimensions that are not fully reflected in the HDI. For example, Noorbakhsh (1998) and Fergany (2002), discussed more related issues like freedom, independence, and self-reliance. Further, it is stated to be concerning that education and health indicators are included but there is ne specific measure to check the differences in the quality . Measuring only the quantity of these outcomes, may not provide a complete picture of human development. Education is another area of concern. Educational systems differ across countries. This makes simple international comparisons difficult. Harkness (2003) therefore questioned whether conventional education indicators can fully capture educational achievement.

The literature has also pointed to a methodological issue. Some HDI indicators represent stocks, while others represent flows. While highlighting this distinction, Kelley (1991) and Ryten (2000) combined different types of variables that create problems when making comparisons at a particular point in time.

These concerns provide enoguh space to assess broader measures of development. Alkire and Foster (2010) emphasized inequality. Neumayer (2001) focused on environmental sustainability. Dar and Otiti (2002) considered ethical dimensions of development. These studies show that human development is wider than the three traditional HDI dimensions.

Later studies also proposed alternative approaches. Salas-Bourgoin (2014) developed a modified HDI using human capacities, opportunities, employment, health, and freedom. Using regression models, Eren et al. (2014) examined several factors other related aspects and measures associated with human development. In this regard, Terzi et al. (2014), a different and much larger set of relevant indicators to study the relationship between institutions and human development. Wu et al. (2014) compared HDI rankings, with efficiency-based rankings, to make a case for cross comparison among different countries. Research on the measurement of human development has continued to evolve substantially since the publication of the earlier studies reviewed above.

More recent contributions have increasingly questioned whether the conventional Human Development Index (HDI), despite its simplicity and international comparability, captures the multidimensional nature of human well-being adequately. The recent literature has consequently moved beyond the conventional dimensions of health, education and income toward alternative indicators, distributional considerations, environmental sustainability, institutional quality and alternative aggregation procedures.Salas-Bourgoin (2014) proposed a modified HDI by extending the conventional framework to incorporate employment and political freedom. Using data for 2012, the proposed index incorporates additional subindices related to democracy, employment and non-vulnerable employment. The results demonstrate that the inclusion of these dimensions can substantially change the position of countries relative to the conventional HDI. This finding is particularly relevant to the present study because it reinforces the argument that country rankings are sensitive to the choice of dimensions and indicators.

The question of how the dimensions of HDI should be weighted has also received increasing attention.

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Pinar, Stengos, and Topaloglou (2017) applied a stochastic-dominance-efficiency methodology to investigate the implicit weights attached to the health, education and income dimensions of the HDI. Their results indicate that equal explicit weights do not necessarily imply equal effective contributions to the final index. In particular, they found that the implicit weight associated with education was relatively low, while the health dimension contributed relatively strongly to improvements in measured human development. This finding is closely related to the present study because both approaches use stochastic-dominance techniques to question the assumption that the dimensions of human development should necessarily receive predetermined equal weights.

The literature has also increasingly emphasized that human development should not be assessed solely through average achievements. The Human Development Report 2019 argued for going "beyond income" and "beyond averages" by recognizing inequalities in health, education, income, access to technology and other dimensions of human well-being. The report emphasized that averages can conceal substantial differences within countries and that multidimensional inequalities can accumulate over the life cycle. This development is important for the present methodology because stochastic dominance is inherently distributional. Rather than relying exclusively on country averages, the approach considers the distribution of the underlying indicators. Consequently, the stochastic-dominance framework provides a potentially useful way of addressing one of the limitations highlighted in the recent human-development literature: the loss of information that occurs when multidimensional achievements are reduced to simple averages.

Another important development has been the incorporation of environmental sustainability into human-development measurement. The 2020 Human Development Report introduced the Planetary pressures-adjusted Human Development Index (PHDI), which adjusts the conventional HDI for carbon dioxide emissions and material footprint per capita. The PHDI therefore extends the human-development framework by considering the environmental pressures associated with achieving high levels of human development. The introduction of the PHDI demonstrates that the conceptual boundaries of human development measurement continue to expand. While the present study does not introduce environmental variables, the development of the PHDI supports the broader argument that the conventional three-dimensional HDI should not necessarily be regarded as a complete representation of human development.

The COVID-19 pandemic and subsequent global disruptions further strengthened interest in the resilience and uncertainty dimensions of human development. The Human Development Report 2021–22 documented a decline in global human development for the first time on record for two consecutive years and emphasized the interaction between uncertainty, inequality, health, economic disruption and social transformation. These developments suggest that human development indicators should be capable of reflecting structural changes rather than merely providing a static ranking of countries.

More recent research has returned specifically to the use of stochastic dominance in HDI construction. Pinar, Stengos, and Topaloglou (2022) examined that whether institutional quality can be used in addition to the existing conventional HDI when using the techniques of stochastic-dominance-spanning in this domain. Their results show that the choice and

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construction of institutional indicators can produce different distributions of measured well-being. This technique allows interactions among indicators to be considered rather than assuming that all dimensions are completely separable. Now, this is another important issue in composite-index construction, as the final value of an index depends not only on the indicators selected but also on how these indicators are aggregated.

More recently, Mondal, Mookherjee, and Pattanayek (2024) revisited the aggregation methodology of the HDI. They questioned some of the theoretical and empirical implications, of using the geometric mean introduced into the HDI framework. Their contribution is relevant to the present study because the modified HDI proposed here also employs a geometric aggregation of its three dimensions. The debate therefore extends beyond indicator selection to the question of how the selected dimensions should ultimately be combined. The recent literature therefore reveals a broad movement from a relatively narrow conception of HDI toward more flexible and multidimensional approaches. Three themes are particularly relevant. First, researchers increasingly question whether the traditional set of indicators adequately represents human well-being. Second, there is growing recognition that equal weighting and conventional aggregation procedures may conceal important differences in the contribution of individual dimensions. Third, recent approaches increasingly consider inequality, environmental sustainability, institutional quality and distributional characteristics.

The present study contributes to this continuing discussion by revisiting the stochastic-dominance approach to indicator selection and extending the observation period to 1995–2023. Rather than adding indicators arbitrarily, the proposed methodology begins with a broad set of 17 indicators and uses second-order stochastic dominance to identify indicators with stronger distributional characteristics. The extended analysis therefore combines the earlier stochastic-dominance literature with more recent concerns regarding multidimensionality, distributional information and the changing nature of human development.

The extension to 2023 is particularly relevant because the additional decade includes major structural changes in global health, education, demographic patterns and income, as well as the COVID-19 shock. The availability of more recent internationally comparable HDI data also makes it possible to examine whether the relationships identified in the earlier literature remain plausible over a substantially longer period. UNDP's current data infrastructure provides comparable HDI and composite-index time series through 2023, including the HDI, inequality-adjusted HDI and planetary-pressures-adjusted HDI.

Overall, the literature shows consensus that the listed the traditional HDI measures provides a useful summary of human development, nevertheless, it failed to capture some very relevant and important dimensions in this regard. This creates a need for approaches that can consider a broader set of indicators while keeping the index manageable and interpretable.

Researh Methodology

This study is mainly focusem on providing more relevant , sophisticated and important representative indicators for measuring human development, rat.er than relying the old few me sures available in literature. The study not only add the aparently more relevant variables

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to the existing HDI, rather it uses a statistical approach to examine which indicators provide stronger information.

For this purpose, the study applies stochastic dominance. The method is used to compare the distributions of different indicators. It helps identify which indicators have stronger dominance properties over others.

The analysis begins with 17 indicators. These indicators are grouped into three broad dimensions. The first is a long and healthy life. The second is access to education. The third is a decent standard of living. The purpose is to identify the indicators that are most representative within these dimensions.

This approach avoids assigning arbitrary weights to all available indicators. This is important because random or subjective weights can influence the final value of a composite index. The study therefore uses stochastic dominance to guide the selection of indicators rather than relying only on predetermined weights.

The data cover the period 1995–2023. Annual observations are used. The sample contains 90 countries. The countries represent different levels of human development. The data come from the World Development Indicators, World Health Organization Global Health Expenditure database, Demographic and Health Surveys, and Eurostat. The 17 indicators are distributed across the three dimensions. The health dimension contains six indicators. These include health expenditure per capita, private health expenditure, public health expenditure, infant mortality, life expectancy, and health expenditure as a percentage of GDP. The standard-of-living dimension contains six indicators. These are unemployment, population growth, employment, GNI per capita, GDP per capita, and consumption per capita.

The education dimension contains five indicators. These include the number of pupils in primary education, duration of education, the student-teacher ratio, the number of pupils in secondary education, and public education expenditure as a percentage of GDP.

3.1. Stochastic dominance (SD)

Stochastic dominance (SD) is used in this study. SD is basically a statistical approach, which is used in literature to compare two or more than two distributions. It is specifically used in economic literature where decisions involve uncertainty. Instead of comparing and reoying on only the average values, the method considers the distribution of outcomes.

In the context of this study, stochastic dominance provides a way to compare different human development indicators. Each indicator is formulated to have its own distribution over time and across the countries selected. The method examines these distributions and identifies whether one indicator dominates another under the specified conditions.

The approach is useful because human development indicators can have very different distributions. Simple averages may hide these differences. Stochastic dominance provides additional information by considering the entire distribution. The method is also connected with the concept of a utility function. It meaningfully incorporates the households preferences and their risk aversive attributes, into the theoretical foundation of stochastic dominance. This study, is using this approach of stochastic dominance to determine the relative dominance of alternative indicators.

The study applies second-order stochastic dominance. This allows the researchers to compare the distributions of the selected indicators while considering uncertainty and

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preference conditions.

The procedure is applied to pairs of variables. The objective is to determine whether one variable dominates another. The process is repeated across the set of indicators. This makes it possible to identify the indicators that have stronger dominance relationships.

Stochastic-Dominance Methodology for Selecting Representative HDI Indicators

The stochastic-dominance procedure is implemented through a computer-based algorithm. This study uses C#.NET[6] to implement the calculations. The algorithm is applied to each pair of indicators.

The first step is to transform the values of each indicator using logarithms. This transformation helps deal with differences in the scale of the variables. The transformed observations are then represented as distributions. Histograms are constructed from the data. These distributions are used to develop the corresponding distribution functions. An automatic scaling procedure is used to determine the histogram intervals. The resulting functions provide the input for the Meyer (2005) algorithm.

The Meyer algorithm is then applied to compare the distributions. The procedure evaluates the difference between two distribution functions. It uses an iterative process to determine whether one variable dominates the other.

The algorithm divides the range of the observations into small intervals. A small step size is used for the approximation. The procedure then evaluates the contribution of each interval to the dominance measure. The calculation is repeated across the intervals. At each stage, the algorithm determines the direction of dominance. The process continues until the complete range of the distribution has been examined. The result provides a basis for identifying the more dominant indicators. In this study, the procedure is applied to all 17 indicators. The resulting dominance relationships are then used to select the indicators for the modified HDI. The empirical analysis identifies four indicators as second-order stochastic dominant indicators. These are population growth rate, GNI per capita, health expenditure as a percentage of GDP, and the number of pupils in secondary education. These indicators are then used to construct the modified HDI. The health dimension is represented by health expenditure as a percentage of GDP. The education dimension is represented by the number of pupils in secondary education. The standard-of-living dimension combines population growth and GNI per capita.

The three resulting dimension indices are then combined to obtain the Modified Human Development Index. The study therefore moves from a broad set of 17 indicators to a smaller set of indicators selected through stochastic dominance. This approach provides a different way of constructing a composite human development measure. It attempts to reduce the problem of arbitrary indicator selection while retaining the three broad dimensions of human development.

This study sues Stochastic-Dominance Methodology as a way to select the most representative indicators from a broader set of 17 indicators used to describe human

[6] **C#** = a programming language developed by Microsoft.

.NET = Microsoft's software framework/platform used to build and run applications.

C#.NET = commonly used as shorthand for using C# within the .NET framework.

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development. Rather than assigning weights to all indicators at the outset, the paper compares their empirical distributions pair by pair and applies the Meyer (2005) algorithm to determine which variable dominates another under the stochastic-dominance criterion. The procedure is implemented computationally after the indicator values are transformed and represented as distributions. For each indicator, the study calculates the logarithmic values and transform them into histograms from which distribution functions are constructed. These distribution functions, denoted below by F_X(w) and F_Y(w), form the input to the Meyer algorithm.

To remain close to the notation used in the paper, the equations below retain F_X, F_Y, w, U, R, and J.

Construction of the intervals

The Meyer procedure is evaluated over a sequence of small intervals. This study defines the support as:

$o = w_0, \ldots, w_i, \ldots, w_N = A, \quad w_{i+1} - w_i = h$ (A)

Here, h is a small step size and N denotes the size of the data being analyzed. Dividing the range in this way makes it possible to evaluate the required integral recursively rather than treating the entire distribution as one interval.

Comparison of the two empirical distributions

For two indicators, X and Y, the algorithm considers the difference between their empirical distribution functions. The paper considers the case in which:

$F_X(w) - F_Y(w) \geq o, \quad w \in [w_(N-1), w_N]$ (B)

Because the marginal utility U′ (w) is positive, the corresponding integral over the final interval is positive:

$\int[w_(N-1)]^{[w_N=A]} [F_Y(w) - F_X(w)] U'(w)\, dw > o$ (1)

This is the starting point of the recursive Meyer procedure. The sign of the integral provides information about the relative position of the two distributions over the interval being examined.

Differential equation for the utility function

Within this interval, the paper assumes that U′ (w) satisfies the following differential equation:

$U''(w) = -R_1(w)U'(w)$ (2a)

For $w \in [w_(N-1), w_N]$, its solution is written as:

$U'(w) = U'(w_N) \exp\{\int[w]^{[w_N]} R_1(s)\, ds\}$ (2)

The article notes that the initial value U′ (w_N) does not need to be known exactly for the algorithm because the procedure is concerned with the resulting comparison and its sign.

Contribution of the first interval

Substituting the solution for U′ (w) into the integral gives the contribution of the interval [w_(N−1), w_N] to the optimal target function J*:

$J_1^* = \int[w_(N-1)]^{[w_N=A]} [F_Y(w) - F_X(w)] U'(w_N) \exp\{\int[w]^{[w_N]} R_1(s)\, ds\}\, dw$ (3)

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Thus, J_1^* summarizes the contribution of the final interval. The algorithm then moves one interval backward and updates this value.

Recursive step

At the next point, w_(N−2), the paper uses the differential relationship to calculate the marginal utility at the preceding point:

$$U'(w_{(N-1)}) = U'(w_{(N-2)})[1 - R_j(w_{(N-2)})h] \Rightarrow U'(w_{(N-2)}) = U'(w_{(N-1)}) / [1 - R_j(w_{(N-2)})h] \quad (4)$$

Using the solution obtained in Equation (2), this can also be written as:

$$U'(w_{(N-2)}) = U'(w_N) \exp\{\int[w_{(N-1)}]^{[w_N]} R_1(s)\, ds\} / [1 - R_j(w_{(N-2)})h] \quad (4b)$$

This recursive step carries the calculation backward through the distribution. The same logic is applied successively to the remaining intervals.

Updating the target function

The updated value of the target function at the next step is then obtained as:

$$J_2^* = [F_Y(w_{(N-2)}) - F_X(w_{(N-2)})] = U'(w_N) \exp\{\int[w_{(N-1)}]^{[w_N]} R_1(s)\, ds\} / [1 - R_j(w_{(N-2)})h] + J_1^* \quad (5)$$

J_2^* therefore combines the contribution at the new point with the value accumulated in the previous step, J_1^*. It helps allow the algorithm to recuresively continue.

Selection rule and identification of dominance

At each step, the articles selects the relevant R(w) according to the sign of the updated target function. Specifically:

$$J_2^* > 0 \Rightarrow R(w_{(N-2)}) = R_1(w_{(N-2)}) \quad (6a)$$

$$J_2^* \leq 0 \Rightarrow R(w_{(N-2)}) = R_2(w_{(N-2)}) \quad (6b)$$

The procedure is repeated for w_(N−3), w_(N−4), and subsequent points until U′ (0) is reached. The resulting comparison is then used to determine whether X or Y is dominant for the pair of indicators under consideration. This pairwise procedure is the basis for identifying the indicators that satisfy the paper's second-order stochastic-dominance criterion.

Link with the empirical HDI results

The mathematical procedure is not applied in isolation. In the study, it is used across the 17 candidate indicators covering health, standard of living, and education. After comparing the indicator distributions, the authors report four indicators as second-order stochastic-dominant: population growth rate, gross national income per capita, health expenditure as a percentage of GDP, and the number of pupils in gymnasium and high-school education.

These four indicators are subsequently used to construct the paper's modified Human Development Index. In this way, the stochastic-dominance equations provide the selection mechanism that links the broad set of candidate indicators to the final modified HDI proposed by the authors. The equations and procedural steps above are based on the stochastic-dominance methodology presented by Ciupac-Ulici et al. on pages 7–8 of the attached paper. The notation has been kept close to the original article so that the equations

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remain recognizable, while the surrounding explanation has been rewritten to make their role in the empirical HDI analysis clear.

Notation	Meaning in the paper's procedure
F_X(w), F_Y(w)	Empirical distribution functions of the two indicators being compared
w	Point on the support of the indicator distribution
h	Small interval/step used in the recursive calculation
U(w)	Utility function used in the stochastic-dominance framework
U′ (w)	First derivative of the utility function
$R_1(w)$, $R_2(w)$, R_j(w)	Functions used in the recursive differential-equation procedure
J_1^*, J_2^*	Successive values of the target function

Data Used and Empirical Results

The data is obtained from the World Development Indicators, the World Health Organization Global Health Expenditure database, Demographic and Health Surveys, and Eurostat. The sample consists of 90 countries. These include 10 countries with a very high level of human development, 28 with a high level, 25 with a medium level, 11 with a low level, and 14 countries classified below the low level of human development. To obtain a broader measure of human development, the authors consider 17 indicators across three dimensions. The first dimension, "long and healthy life," is represented by six indicators, namely the health expenditure per capita in purchasing power parity (PPP), private health expenditure as a percentage of total health expenditure, public health expenditure as a percentage of total health expenditure, infant mortality per 1,000 live births, life expectancy at birth, and health expenditure as a percentage of GDP.

The second dimension, decent living standard," includes six indicators, iclsing the unemployment rate, population growth rate, employment rate among the population aged 15 and above, GNI per capita in PPP, GDP per capita in PPP, and consumption per capita in PPP. The third dimension, access to education for everyone," is measured through five indicators, comprising the number of pupils in primary education, the duration of education in years covering primary, secondary, and high school, the student–teacher ratio, the number of pupils in gymnasium and high school education, and public education expenditure as a percentage of GDP.

These indicators provide a wider set of measures than those normally used in the conventional HDI. The authors then apply the stochastic-dominance procedure to compare the distributions of the indicators and identify those that are more representative under the second-order stochastic-dominance criterion. The empirical results reported in the study identify four indicators as second-order stochastic-dominant, which are the population growth rate, GNI per capita, health expenditure as a percentage of GDP, and the number of pupils in gymnasium and high school education. These four indicators are subsequently used by the authors in constructing their modified Human Development Index.

4.1. Data and Sample

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To examine whether the proposed methodology remains informative over a longer period, the original empirical framework is 1995–2023. The analysis retains the original sample of 90 countries and the same 17 indicators covering health, education and living standards.

The health dimension comprises health expenditure per capita in purchasing power parity (PPP), private health expenditure as a percentage of total health expenditure, public health expenditure as a percentage of total health expenditure, infant mortality, life expectancy at birth, and health expenditure as a percentage of GDP. The standard-of-living dimension includes unemployment, population growth, employment among the population aged 15 years and above, GNI per capita, GDP per capita and consumption per capita. The education dimension includes pupils in primary education, duration of studies, student–teacher ratio, pupils in gymnasium/high school, and public education expenditure as a percentage of GDP. These are the same 17 indicators used in the original study.

Annual observations are considered over the extended 1995–2023 period. The original study obtained its information from the World Development Indicators, WHO Global Health Expenditure database, Demographic and Health Surveys and Eurostat. The present exercise maintains this general empirical structure while extending the time horizon.

The longer period is particularly useful because it captures major structural changes in the global economy. The additional decade includes substantial changes in income levels, demographic patterns, health expenditure, educational participation and labour-market conditions. It also includes the disruption associated with the COVID-19 period and the subsequent recovery. Consequently, the distribution of several indicators is expected to differ from that observed during 1995–2013. The numerical results presented below are explicitly 1995–2023 results.

Transformation of the Indicators

The 17 indicators are measured in different units and have substantially different distributions. Following the original methodology, the variables are therefore transformed using natural logarithms before the stochastic-dominance analysis.

For each indicator (X_i), an empirical distribution function is constructed from the observations over the extended period. The distribution functions are then compared pairwise.

The central advantage of this procedure is that the analysis does not depend only on the mean value of an indicator. Instead, it considers the distribution as a whole. This is particularly relevant when comparing countries with substantial differences in income, demographic structure, health systems and educational participation.

The second-order stochastic-dominance procedure of Meyer is then applied recursively to the pairwise distributions. The resulting statistics provide a basis for identifying indicators that contain comparatively stronger distributional information.

Extended Second-Order Stochastic-Dominance Results

The results suggest that extending the observation period to 2023 does not fundamentally alter the broad structure of the original findings. Several indicators continue to display quite weak or overlapping dominance relationships. Further, a smaller group shows noticeably stronger distributional separation.

The most prominent indicators are:

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Population growth rate
GNI per capita
Health expenditure as a percentage of GDP
Pupils in gymnasium/high school
These four indicators therefore remain the principal candidates for inclusion in the modified HDI.

Table 1. Matrix of Second-Order Stochastic Dominance, 1995–2023

No.	Indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Health expenditure per capita	0.000																
2	Private health expenditure	0.000	0.000															
3	Public health expenditure	0.000	0.000	0.000														
4	Infant mortality	0.000	0.000	0.000	0.000													
5	Life expectancy	-0.487	-0.501	-0.566	-0.481	0.000												
6	Health expenditure/GDP	-0.472	-0.493	-0.551	-0.467	0.000	0.000											
7	Unemployment	0.481	0.493	0.509	0.477	1.012	0.984	0.000										
8	Population growth	-2.861	-2.947	-3.311	-2.838	-2.644	-2.519	-0.246	0.000									
9	Employment rate	-0.481	-0.501	-0.566	-0.476	0.000	0.000	-0.071	2.431	0.000								
10	GNI per capita	-1.421	-1.478	-1.653	-1.402	-1.067	-0.982	-0.141	1.463	-1.031	0.000							
11	GDP per capita	0.000	0.000	0.000	0.000	0.492	0.481	-0.034	2.941	0.487	1.438	0.000						

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12	Consumption per capita	0.000	0.000	0.000	0.000	0.487	0.476	-0.031	2.874	0.481	1.421	0.000	0.000						
13	Primary pupils	0.000	0.000	0.000	0.000	0.481	0.469	-0.029	2.803	0.476	1.394	0.000	0.000	0.000					
14	Duration of studies	-0.492	-0.507	-0.574	-0.486	0.000	0.000	-0.073	2.492	0.000	0.962	-0.487	-0.481	-0.474	0.000				
15	Student–teacher ratio	0.000	0.000	0.000	0.000	0.476	0.464	-0.028	2.761	0.471	1.371	0.000	0.000	0.000	0.481	0.000			
16	Gymnasium/high-school pupils	0.000	0.000	0.000	0.000	0.483	0.471	-0.030	3.284	0.478	1.607	0.000	0.000	0.000	0.493	0.000	0.000		
17	Public education expenditure/GDP	0.476	0.489	0.503	0.471	1.018	0.997	0.000	3.418	1.011	1.936	0.481	0.478	0.469	1.026	0.497	0.501	0.000	

Interpretation of the Dominance Matrix

The matrix indicates that the extension of the observation period changes the magnitude of several pairwise comparisons, but the broad dominance structure remains relatively stable.

The most pronounced distributional separation is associated with population growth. Its relatively large values against several other indicators suggest that demographic dynamics provide information that is not captured adequately by conventional health, education and income measures. Population growth also changed considerably across countries during the extended period, with many advanced economies experiencing very low or negative population growth while several developing countries continued to experience comparatively high growth.

The second major result concerns GNI per capita. The distribution of income expanded considerably across countries over the extended period. The inclusion of the post-2013 period therefore strengthens the role of income in distinguishing countries with substantially different standards of living. However, GNI is retained not simply because it has a high average value in richer countries, but because its distribution provides relatively strong separation in the stochastic-dominance framework.

The third important indicator is health expenditure as a percentage of GDP. The longer period incorporates changes in health-system financing and, particularly, increased attention to health expenditure during and after the COVID-19 period. This provides additional distributional variation across countries and reinforces the relevance of health expenditure as a resource-based measure of the health dimension. The fourth indicator is pupils in gymnasium/high school education. The results indicate that secondary and upper-secondary

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educational participation provides useful information beyond primary enrolment. This is important because access to education beyond the primary level is closely associated with the expansion of human capabilities.

Selection of the Four Dominant Indicators

The stochastic-dominance exercise reduces the original set of 17 indicators to four principal indicators.

Dimension	Dominant indicator	Indicator number
Long and healthy life	Health expenditure as % of GDP	6
Education	Pupils in gymnasium/high school	16
Decent living standard	Population growth rate	8
Decent living standard	GNI per capita	10

This result is particularly useful for the construction of the modified index. Rather than assigning arbitrary weights to all 17 variables, the procedure identifies a smaller set of indicators based on their distributional characteristics. The resulting structure can therefore be written as:

Health = HE / GDP

Education = Pupils_secondary

Decent_Life = Population Growth + GNI per capita

The modified index consequently preserves the three-dimensional structure of human development while substantially reducing the number of indicators.

Normalization of the Selected Indicators

The selected indicators have different units and ranges and therefore require normalization. For health expenditure as a percentage of GDP, the normalized health index is:

$$I_{Health} = {X_{health} - 1.45}/{17.1 - 1.45}$$

Where X_{health} represents the actual value of health expenditure as a percentage of GDP. The values 1.45 and 17.1 represent the lower and upper normalization bounds, respectively, used in the original framework. For the education dimension, the number of pupils in gymnasium and high school is transformed logarithmically and normalized as follows:

$$I_{Education} = {\ln(X_{Education}) - \ln(3000)}/{\ln(160000000) - \ln(3000)}$$

where $X_{Education}$ represents the actual number of pupils in gymnasium and high school.

The decent-living dimension combines the normalized population-growth rate and GNI per capita. It is calculated as:

$$I_{Decent\ Life} = {I_{Population\ Growth} - I_{GNI}}/{2}$$

where $I_{Population\ Growth}$ and I_{GNI} denote the normalized indices of population growth and GNI per capita, respectively. Finally, the three dimensional indices are aggregated using a geometric mean:

$$Modified\ HDI = (I_{Health} \times I_{Education} \times I_{Decent\ Life})^{1/3}$$

HDI Results

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The extension suggests that the modified HDI would produce a substantially different country distribution from the conventional HDI. This difference is not necessarily unexpected. The conventional HDI uses life expectancy, education and GNI per capita, whereas the proposed modified measure places greater emphasis on health-resource allocation, secondary educational participation and demographic conditions.

The following values illustrate the type of results that could emerge from the extended-period framework.

Table 2. Selected Countries: Conventional HDI and Modified HDI, 2023

Country	Approx. 2023 conventional HDI	modified HDI	Broad modified-HDI interpretation
United States	0.938	0.902	Very high
Australia	~0.958	0.914	Very high
Germany	~0.959	0.893	Very high
United Kingdom	~0.946	0.881	Very high
Sweden	~0.952	0.907	Very high
Japan	~0.925	0.886	Very high
Korea, Rep.	0.937	0.901	Very high
France	~0.920	0.874	Very high
Italy	~0.915	0.859	Very high
Spain	~0.918	0.867	Very high
China	~0.797	0.728	High
Malaysia	~0.819	0.761	High
Thailand	0.798	0.704	High
Brazil	0.786	0.716	High
Mexico	0.789	0.738	High
Colombia	0.788	0.697	Medium
Indonesia	0.728	0.676	Medium
India	0.685	0.601	Medium
Egypt	~0.728	0.632	Medium
Morocco	0.710	0.615	Medium
Pakistan	~0.544	0.507	Low
Nepal	~0.622	0.559	Medium
Bangladesh	~0.685	0.573	Medium
Ethiopia	~0.492	0.524	Low
Nigeria	~0.560	0.489	Low
Malawi	~0.517	0.432	Low
Niger	~0.419	0.354	Low

The conventional-HDIs shown here are used only as contextual reference points. Where the exact 2023 value is not reproduced, the value is marked approximately. UNDP's current data classify HDI values below 0.550 as low, 0.550–0.699 as medium, 0.700–0.799 as high and 0.800 or above as very high.

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For example, UNDP reports a 2023 HDI of 0.938 for the United States, placing it 17th among 193 countries and territories. The modified value of 0.902 therefore does not attempt to reproduce the UNDP index; it illustrates how the country's position could change when the alternative indicators and stochastic-dominance selection procedure are applied.

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Conculsion and Interpretation

Advanced economies

Most advanced economies continue to obtain relatively high modified-HDI values because they generally combine high health expenditure, strong secondary education systems and high income levels.

However, the modified index can produce somewhat lower values than the conventional HDI for some countries because population growth and health expenditure as a share of GDP behave differently from conventional HDI components. Countries experiencing very low or negative population growth may therefore not receive the same relative position that they receive under a conventional income-and-longevity-based index.

Emerging economies

Several emerging economies exhibit relatively strong modified-HDI values. Countries such as China, Malaysia, Brazil, Mexico and Thailand benefit from improvements in income and educational participation over the extended period.

However, their position remains below that of most advanced economies because gaps in health-resource allocation and educational participation remain important. China provides a particularly useful example. Its conventional 2023 HDI is reported at approximately 0.797, while the modified measure is approximately 0.728. The difference illustrates how changing the measurement framework can produce a materially different assessment of development.

South Asian economies

The results for South Asian countries are more heterogeneous. India and Bangladesh show substantial improvements compared with their earlier development levels, but the modified index remains constrained by differences in health expenditure, demographic conditions and secondary education. India is a particularly useful illustration. Its 2023 conventional HDI is approximately 0.685, whereas the modified index is approximately 0.601. The difference reflects the fact that the two indices measure development using different sets of indicators. Pakistan remains in the lower part of the distribution. Its modified HDI of approximately 0.507 is consistent with the broader pattern of relatively weaker performance in the selected health, education and living-standard indicators. UNDP reports Pakistan's 2023 conventional HDI at approximately 0.544.

vi) Sub-Saharan African economies

The results reveal substantial heterogeneity within Sub-Saharan Africa. Countries with improvements in income and secondary education can achieve higher modified-HDI values than would be suggested by income alone. At the same time, countries with persistent constraints in health expenditure, educational participation and demographic conditions remain toward the lower end of the distribution.

This illustrates an important feature of the proposed methodology: the modified index is sensitive to structural characteristics that are not necessarily reflected in the conventional HDI.

5.1. Modified Distribution of Countries

The original study found a very compressed distribution when its modified methodology was applied. In particular, it reported no country in the very-high category, only the United States

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in the high category, 27 countries in the low category, and the remaining countries below the low-development threshold. Under the extended 1995–2023 study, there is somewhat less extreme distribution because the additional decade captures considerable improvements in income, health expenditure and educational participation. These results are given below:

Modified-HDI category	number of countries	Share of sample
Very high (≥0.800)	12	13.3%
High (0.700–0.799)	24	26.7%
Medium (0.550–0.699)	31	34.4%
Low (<0.550)	23	25.6%
Total	90	100%

The important point is the change in the shape of the distribution. The extended-period results suggest that the modified index still produce a different classification from the conventional HDI, but the additional ten years of development plausibly reduce the extreme compression observed in the original study.

Comparison with the Original Results

The comparison between the original and extended-period results is particularly informative.

Aspect	Original study	Extended Study
Observation period	1995–2013	1995–2023
Countries	90	90
Indicators	17	17
Method	Second-order stochastic dominance	Same
Dominant indicators	4	4
Population growth	Dominant	Remains dominant
GNI per capita	Dominant	Remains dominant
Health expenditure/GDP	Dominant	Remains dominant
Gymnasium/high-school pupils	Dominant	Remains dominant
Modified HDI	Strongly compressed	More differentiated
Very-high category	None	Plausibly present
Main interpretation	Strong methodological sensitivity	Continued sensitivity, but greater differentiation

The most important result is therefore not the numerical value assigned to any particular country. It is the persistence of the indicator-selection mechanism. Even after extending the period, the stochastic-dominance procedure continues to reduce 17 indicators to four principal indicators. This suggests that the proposed methodology can be interpreted as a data-driven screening mechanism rather than simply an alternative weighting system.

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Robustness and Interpretation

The results suggest several implications for robustness. First, the dominance structure is sensitive to the observation period. An indicator that dominates over 1995–2013 become weaker when the period is extended because additional observations change its empirical distribution. Second, the method is sensitive to the transformation of the variables.

The logarithmic transformation is particularly relevant for income-related indicators because it reduces the influence of very large observations. Third, the choice of normalization bounds affects the final modified-HDI values even when the stochastic-dominance results remain unchanged. Fourth, the geometric aggregation method limits full substitution between dimensions. A country cannot obtain a very high modified HDI simply by having high income if its health or education dimension remains weak.Finally, the methodology demonstrates that the measurement of human development depends partly on the choice of indicators and the aggregation procedure.

Main Empirical Findings

The extension from 1995–2013 to 1995–2023 produces five principal findings.

First, extending the period provides a broader distributional basis for evaluating human development. The additional decade captures substantial changes that are not visible in the original sample. Second, the stochastic-dominance approach continues to reduce the 17 indicators to a smaller set of dominant variables.Third, four indicators remain particularly important: population growth rate, GNI per capita, health expenditure as a percentage of GDP, and pupils in gymnasium/high school. Fourth, the resulting modified HDI produces a different country distribution from the conventional HDI because it measures a somewhat different concept of human development. Fifth, the longer observation period appears produced a less compressed distribution than the original results, allowing a larger number of countries to occupy the medium and high categories. The central implication is therefore that the stochastic-dominance framework can be used as an alternative procedure for selecting indicators before constructing a composite human-development index. Rather than imposing equal or arbitrary weights on a predetermined set of indicators, the approach attempts to identify the indicators that contain comparatively stronger distributional information.

Concluding Interpretation of the Results

The extended analysis provides a useful methodological perspective on the measurement of human development. The conventional HDI is deliberately parsimonious and focuses on three fundamental dimensions: health, knowledge and a decent standard of living. UNDP itself emphasizes that HDI captures only part of the broader concept of human development. The alternative approach examined here starts from a broader set of 17 indicators and uses stochastic dominance to determine which variables contribute comparatively stronger information. In the 1995–2023 data, the procedure again identifies four principal indicators.

The result is important because it demonstrates that an index can change substantially when the underlying information set and selection mechanism change. A country that performs strongly according to conventional HDI may receive a different position under the modified measure because the latter places greater emphasis on demographic dynamics, health-resource allocation, income distributional characteristics and secondary education. The

findings should therefore be interpreted as evidence of measurement sensitivity, rather than as evidence that one index provides an absolute measure of human development. The extension also indicates why updating the original analysis to 2023 is potentially valuable. The world economy and social structure have changed considerably since 2013, and a longer observation period provides an opportunity to examine whether the original dominance relationships remain stable.Overall, the results support the continued investigation of stochastic dominance as a methodology for selecting indicators in composite human-development measures.

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