**STUDYING THE ASSOCIATION OF HUMAN DEVELOPMENT INDEX AND SUSTAINABLE DEVELOPMENT GOALS WITH MULTIPLE CORRESPONDENCE ANALYSIS**

# ABSTRACT

*Since 1990’s, multiple different measurements were created to calculate and compare development levels of different countries. Human Development Index (HDI) by United Nations Development Programme is one of the most important measures of development economics despite numerous legitimate criticism. Sustainable Development Goals (SDG) were introduced as common goals to achieve by 2030 in United Nations Conference on Sustainable Development and they consist of multiple indicators to measure the progress on each of 17 goals within SDG. The indicators consist of measures from a large array of economic, social and environmental issues. There is some research on the relation of these indicators to income levels or development measured by GDP or other means. But this study aims to focus on the association of the levels of HDI and SDG indicators to each other, using multiple correspondence analysis as a statistical tool.*

*Multiple correspondence analysis is statistical method that can be used to visualize association between levels of categorical data. It is also useful for this research since a large number of variables can be used in the analysis and a value of inertia can be calculated for each variable that shows the contribution of that variable to overall variance within the data. To conduct the research, the HDI values for 189 countries and its indicators were collected from UNDP website from the most recent Human Development Report. SDG indicators for the same countries were collected from United Nations website. Most data that is used in this study was collected in 2019 with exception to variables that are observed over multiple years. Since multiple correspondence analysis uses categorical data, all the data in the study was reduced to categories based on percentiles from numeric measures.*

*The analysis shows that HDI levels, life expectancy and education related variables tend explain a large variance in the data. Results indicate that, for countries, having a lower value of the indicators tend to be more critical for their placement than having middle or higher value.*

**Key words:** *Human Development Index, SDG, Multiple Correspondence Analysis, Sustainable Development, Homogeneity Analysis*

**1. INTRODUCTION**

**1.1 Human Development Index and Sustainable Development Goals**

Since 1990’s, Human Development Index (HDI), reported annually in Human Development Reports (HDR) by United Nations Development Programme (UNDP), became a critical measure of comparing development of nations globally. Developed by economist Mahbub ul Haq, it was one of the attempts to create an index as an improvement from one dimensional measures of development such as GDP growth, and reflects the “capabilities approach” of the renowned development economist Amartya Sen (Stanton, 2007: 15). Sen (1999) introduced an understanding of development as “building blocks” and argued that the focus should be on expanding the “capabilities” of individuals. Human Development Index, in this context, marks a progress since it also includes healthy life, standard of living and education dimensions in calculation. HDI is computed as geometric average from indicators for three dimensions. These indicators are life expectancy at birth, mean of years of schooling for adults aged 25 and more, expected years of schooling for children of school entering age and gross national income per capita. The index faced some criticisms such as inability to capture complexities of human development, data problems, arbitrary calculation or poor choice of indicators (Kovacevic, 2010, Stanton, 2007: 18). Over the years, UNDP reacted to some of these criticism by changing the calculation of HDI or introducing several different indices such as Gender Development Index, Multidimensional Poverty Index and, recently in the most recent HDR in 2020, Planetary pressures-adjusted Human Development Index. Despite the criticisms, HDI is still one of the most commonly used measures of national development and is one of the most important statistic published periodically regarding development economics.

As “sustainability” became one of the most commonly referred topics in development economics in last decade, United Nations General Assembly introduced “Sustainable Development Goals” in 2015, as common goals to achieve by 2030 as well as a measure of sustainability. Sustainable Development Goals (SDGs) framework builds upon the Millenium Development Goals, 8 goals that were aimed to be achieved by 2015. SDGs consist of 17 main goals. Each of the 17 goals has multiple targets and each target has multiple indicators to monitor progress on that target, accumulating to 169 targets and 232 indicators in total. A list of 17 goals are presented in the Table 1 below. The SDGs aim to create progress on different fronts from poverty and socioeconomic well-being to gender equality to environment and sustainability. Although the usefulness of SDG targets, especially for underdeveloped countries, is debated, it is still one of the most comprehensive list of measures for development and became an important reference point for corporate social responsibility worldwide (Sridhar, 2016).

|  |  |
| --- | --- |
| **Table 1. Sustainable Development Goals** | |
| *Goal 1* | End poverty in all its forms everywhere |
| *Goal 2* | End hunger, achieve food security and improved nutrition and promote sustainable agriculture |
| *Goal 3* | Ensure healthy lives and promote well-being for all at all ages |
| *Goal 4* | Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all |
| *Goal 5* | Achieve gender equality and empower all women and girls |
| *Goal 6* | Ensure availability and sustainable management of water and sanitation for all |
| *Goal 7* | Ensure access to affordable, reliable, sustainable and modern energy for all |
| *Goal 8* | Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all |
| *Goal 9* | Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation |
| *Goal 10* | Reduce inequality within and among countries |
| *Goal 11* | Make cities and human settlements inclusive, safe, resilient and sustainable |
| *Goal 12* | Ensure sustainable consumption and production patterns |
| *Goal 13* | Take urgent action to combat climate change and its impacts |
| *Goal 14* | Conserve and sustainably use the oceans, seas and marine resources for sustainable development |
| *Goal 15* | Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss |
| *Goal 16* | Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels |
| *Goal 17* | Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development |

*Source:* [*https://sdgs.un.org/goals*](https://sdgs.un.org/goals)

This study aims to illustrate the associations between the levels of HDI and SDG indicators using multiple correspondence analysis.

**1.2. Multiple Correspondence Analysis**

Multiple correspondence analysis is a statistical method that is used to visualise the association between levels of categorical data. It can be thought as application of principal component analysis to categorical variables. So it is a multidimensional scaling method suitable for categorical data reported in contingency tables or frequency matrices. One of the main advantages of multiple correspondence analysis is that it does not assume any type of distribution for the variables which makes it very convenient for many different data sources. Multiple correspondence analysis is known under many different names such as optimal scaling, optimal scoring, dual scaling and homogeneity analysis (Kamalja and Kangar, 2017; Abdi and Valentin, 2007; Hoffman and Leeuw, 1992).

The existence of relation or dependence between two categorical variables is normally studied with use of chi-square independence test. But chi-square independence test cannot give an idea about what type of relationship exist, or if it exist at all, between the levels of these categorical variables. Correspondence analysis can be used in this case. (Bulut, 2018).

Correspondence analysis utilizes chi-square distances between observations, shown in the Equation 1.1.

(1.1)

The value of inertia is calculated using these chi-square distances between observations, as shown in Equation 1.2.

(1.2)

wi : The weight of observation i across all levels

mi: The chi-square distance of observation i to the center

Mathematically, inertia can be considered as a weighted average of chi-square distances or the normalized chi-square value, as it is closely related to chi-square statistics. Chi-square statistic can be calculated from total inertia value by multiplying inertia with the number of observations. The concept of inertia in multiple correspondence analysis can be considered as equivalent of the concept of variance in statistics. Correspondence analysis, essentially, tries to reduce the data matrix while explaining the most inertia (Bulut, 2018; Kamalja and Kangar, 2017; Beh and Lombardo, 2014).

Multiple correspondence analysis offers limited causal and inferential insight and has no significance test. But there are several advantages to using multiple correspondence analysis. The most important advantage is that multiple correspondence analysis technique does not assume a specific type of distribution for data set which is very useful in case of working with large sets of variables. Second advantage over commonly used techniques like OLS regression is getting rid of concerns over collinearity. Multiple correspondence analysis generally has few limitations on the data. Although categorical data is generally thought as less strong than numeric, it is more suitable in case of HDI levels (from Very High to Low). But numerically observed variables of SDG indicators had to be reduced to categorical data in order to conduct the analysis. Although there are important limitations of this technique, it can be very useful as mainly a visualisation method. It is able to reduce highly complex data that is made of tens of variables to simplified and insightful graphics.

**2. LITERATURE REVIEW**

Reaching Sustainable Development Goals require a complicated and dedicated effort to address targets on multiple fronts. Also, limited resources and timeframe means policy-makers have to prioritize certain goals over others and try to find an optimal policy. Hence, identifying the relationships between different goals and finding pathways to address multiple goals at once is critical for policy-makers. Although Sustainable Development Goals can be considered a relatively recent phenomenon, there is some research on the relationship among different goals. Many of the 17 goals are considered closely related. Le Blanc (2015) argues that SDGs can be considered as a network connected through targets that refer to more than one goal. Using network analysis, Le Blanc shows that while most targets are interconnected, some targets such as reducing inequality, poverty and improving education are core links in the network that connect to most other goals. Lusseau and Mancini (2019) also used network approach to estimate interactions among SDGs across different income levels which is particularly relevant for this study since HDI also takes national income into account. Their research contributed to the framework by showing that the SDG interactions differ by the country income level according to the income categories by World Bank.

Nerini et al. (2018) studied the relationship of 169 targets with the SDG7, “Ensuring access to affordable, reliable, sustainable and modern energy for all”. They found that at least 143 targets in SDGs have synergetic or trade-off relationship with efforts to achieve SDG7, more than twice synergies than trade-offs. Similarly, Fonseca et al. (2020) found that between most SDGs, there is strong positive interactions. But some SDGs like responsible consumption and production show requirement for trade-offs and moderate negative correlation with other SDGs (Fonseca et al., 2020: 11). Pradhan et al. (2017) also found the SDG12, responsible consumption and production, to be the goal that showed prominent trade-offs with other SDGs. A report published by United Nations (2019) identifies co-benefit and trade-off type of interactions among the SDGs at the target level based on over 100 articles written on the subject. It shows some trade-offs, but also the dominance of positive relationships over negatives.

Schmidt-Traub et al. (2017) compared several indices including HDI to an SDG index, a composite number created from over 60 SDG indicators. They found that SDG index is correlated with HDI, as well as with GDP, but there were substantial differences across regions and income groups. Perdomo et al. (2017) used Nussbaum’s theory of capabilities to define capabilities associated with health, survival and mental well-being as “Sustainable Well-being Dimensions” and analysed these through multiple correspondence analysis. They found that first dimension is mainly consisted of high and low categories, and first three dimensions accounted for about 41% of variation in data (Perdomo et al., 2017).

While methods like network analysis or other statistical methods were used to analyse SDGs or HDI, a significant amount of the research using multiple correspondence analysis is focused on analysing and assigning weights to Multidimensional Poverty Index. Asselin and Ahn (2008) proposed using multiple correspondence analysis for measuring multidimensional poverty because it has little restriction on the data types of indicators. Pasha (2017) proposed to use multiple correspondence analysis to get over the problem of collinearity in data when analysing the weights of the indicators of multidimensional poverty index. They found that standard of living indicators explain nearly 86% of variation in data. They also compared principal component analysis to multiple correspondence analysis and found similar results, but suggested PCA for more intuitive understanding (Pasha, 2017). Similarly, Ferrant (2010) used multiple correspondence analysis to determine weights to Gender Inequality Index. Ambapour (2020) analysed multidimensional poverty in Congo with multiple correspondence analysis and identified three types of non-monetary poverty: infrastructure poverty, vulnerability of human existence and poverty of comfort.

**3. METHODOLOGY AND DATA**

The data of Human Development Index values for 189 countries and its indicators were collected from UNDP website. The HDI values used for this study is from 2019 collections which were used for the most recent Human Development Report (2020). SDG indicators for the same countries were collected from United Nations website (<https://unstats.un.org/>). Most data observations that is used in this study belong to the year 2019 with following exceptions: Female or total population with at least some secondary education (2015-2019), government expenditure on education as percentage of GDP (2013-2018), prison population per 100.000 people (2013-2018), homicide rate per 100.000 people (2013-2018), fossil fuel energy consumption as percentage of total energy consumption (2013-2015) and carbon dioxide emissions (2017). The number of variables were chosen from SDG indicators according to availability of data for the countries in data set. A list of all variables used in this study can be seen in the Table 2 below.

**Table 2. Variables that are used in the study**

|  |  |
| --- | --- |
| Variable | Data Observation Period |
|  |
| *HDI* | 2019 |  |
| *Expected Years Of Schooling* | 2019 |  |
| *Mean Years Of Schooling* | 2019 |  |
| *GNI per capita* | 2019 |  |
| *Maternal mortality ratio* | 2017 |  |
| *Adolescent Birth Rate* | 2015-2020 |  |
| *Women's share of seats at parliament* | 2019 |  |
| *Female Population with at least some secondary education* | 2015-2019 |  |
| *Male population with at least some secondary education* | 2015-2019 |  |
| *Female - Labor force participation rate* | 2019 |  |
| *Male - Labor force participation rate* | 2019 |  |
| *Infant Mortality Rate* | 2018 |  |
| *Healthy life expectancy at birth (years)* | 2019 |  |
| *Current health expenditure (% of GDP)* | 2017 |  |
| *Government expenditure on education (% of GDP)* | 2013-2018 |  |
| *Employment in agriculture* | 2019 |  |
| *Employment in services* | 2019 |  |
| *Unemployment (% of labor force)* | 2019 |  |
| *Youth unemployment (% of ages 15-24)* | 2019 |  |
| *Youth not in school or employment* | 2019 |  |
| *High-skill to low-skill employment ratio* | 2009-2019 |  |
| *Old-age pension recipients (% of statutory pension age population)* | 2014-2019 |  |
| *Prison population (per 100,000 people)* | 2013-2018 |  |
| *Homicide rate (per 100,000 people)* | 2013-2018 |  |
| *Average dietary energy supply adequacy (percentage)* | 2017/2019 |  |
| *Fossil fuel energy consumption (% of total energy consumption)* | 2013-2015 |  |
| *Carbon dioxide emissions (kg per 2010 US$ of GDP)* | 2017 |  |
| *Forest area (% of total land area)* | 2016 |  |

Since multiple correspondence analysis uses categorical data, all the data in the study was reduced to categories based on percentiles from numeric measures. For HDI measures, officially reported four categories for countries were used: Very High Human Development, High Human Development, Medium Human Development and Low Human Development. For all other variables, the observations were reduced to three categories as High, Medium and Low. The final data is analysed with the help of statistical package program Stata. Multiple correspondence analysis is first conducted with HDI levels and SDG indicators and secondly with HDI indicators and SDG indicators to see the effect of income level separately.

**4. RESULTS**

For the first analysis with HDI levels, the contribution of each dimension to total inertia, calculated by multiple correspondence analysis is shown in the Table 3 below. The first dimension accounts for 54,15 percent of all inertia. The second dimension accounts for 24,35 percent of all inertia, while the rest of dimensions explain below 5 percent of total inertia. Only the first two dimensions will be used in this study as they explain significant part of all variance in data.

**Table 3. Inertia values for dimensions from multiple correspondence analysis results**

|  |  |  |
| --- | --- | --- |
| Dimension | Percent | Cumulative Percent |
|  |
| *dim1* | 54.15 | 54.15 |  |
| *dim2* | 24.35 | 78.5 |  |
| *dim3* | 4.46 | 82.96 |  |
| *dim4* | 2.03 | 84.99 |  |
| *dim5* | 1.05 | 86.04 |  |
| *dim6* | 0.73 | 86.77 |  |
| *dim7* | 0.44 | 87.21 |  |
| *dim8* | 0.23 | 87.45 |  |
| *dim9* | 0.18 | 87.63 |  |
| *dim10* | 0.11 | 87.74 |  |
| *dim11* | 0.08 | 87.82 |  |
| *dim12* | 0.03 | 87.85 |  |
| *dim13* | 0.01 | 87.86 |  |
| *dim14* | 0.01 | 87.86 |  |
| *dim15* | 0 | 87.86 |  |

The coordinates and the contribution to total inertia is given below in Table 4.

**Table 4. Contribution and coordinates of categories**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Overall | | | Dimension 1 | | | Dimension 2 | | |
| Categories | mass | quality | %inert | coord | sqcorr | contrib | coord | sqcorr | contrib |
| hdi1 |  |  |  |  |  |  |  |  |  |
| HIGH | 0.013 | 0.118 | 0.007 | 0.258 | 0.068 | 0.001 | 0.329 | 0.05 | 0.001 |
| LOW | 0.008 | 0.654 | 0.023 | 1.825 | 0.622 | 0.026 | 0.617 | 0.032 | 0.003 |
| MID | 0.009 | 0.741 | 0.014 | 1.335 | 0.593 | 0.016 | 0.992 | 0.147 | 0.009 |
| VERY HIGH | 0.016 | 0.893 | 0.039 | -1.868 | 0.767 | 0.055 | -1.128 | 0.126 | 0.02 |
| mmr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.9 | 0.02 | 0.925 | 0.672 | 0.025 | 0.805 | 0.228 | 0.019 |
| LOW | 0.006 | 0.862 | 0.016 | -1.127 | 0.263 | 0.008 | -2.533 | 0.599 | 0.04 |
| MID | 0.01 | 0.897 | 0.025 | -1.968 | 0.842 | 0.039 | -0.75 | 0.055 | 0.006 |
| adolescent~h |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.88 | 0.016 | 0.739 | 0.54 | 0.016 | 0.875 | 0.34 | 0.022 |
| LOW | 0.004 | 0.84 | 0.022 | -0.728 | 0.058 | 0.002 | -3.998 | 0.783 | 0.069 |
| MID | 0.012 | 0.86 | 0.02 | -1.574 | 0.788 | 0.029 | -0.709 | 0.072 | 0.006 |
| womeninpar~t |  |  |  |  |  |  |  |  |  |
| HIGH | 0.03 | 0.834 | 0.003 | -0.405 | 0.828 | 0.005 | 0.05 | 0.006 | 0 |
| LOW | 0.003 | 0.26 | 0.004 | 0.709 | 0.26 | 0.002 | 0.027 | 0 | 0 |
| MID | 0.012 | 0.815 | 0.005 | 0.814 | 0.805 | 0.008 | -0.133 | 0.01 | 0 |
| female\_lfpr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.195 | 0.005 | -0.23 | 0.168 | 0.002 | 0.137 | 0.027 | 0.001 |
| LOW | 0.005 | 0.77 | 0.023 | 1.728 | 0.365 | 0.016 | -2.715 | 0.405 | 0.039 |
| MID | 0.012 | 0.368 | 0.007 | -0.223 | 0.044 | 0.001 | 0.904 | 0.324 | 0.009 |
| male\_lfpr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.731 | 0.005 | 0.225 | 0.156 | 0.001 | 0.645 | 0.575 | 0.012 |
| LOW | 0.005 | 0.836 | 0.024 | 1.718 | 0.348 | 0.016 | -3.034 | 0.488 | 0.049 |
| MID | 0.012 | 0.864 | 0.013 | -1.345 | 0.854 | 0.021 | -0.21 | 0.009 | 0.001 |
| imr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.03 | 0.901 | 0.019 | 0.959 | 0.769 | 0.028 | 0.593 | 0.132 | 0.011 |
| LOW | 0.003 | 0.734 | 0.017 | -1.996 | 0.43 | 0.013 | -2.502 | 0.304 | 0.021 |
| MID | 0.012 | 0.885 | 0.027 | -1.838 | 0.818 | 0.041 | -0.782 | 0.067 | 0.007 |
| healthexp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.865 | 0.006 | -0.543 | 0.827 | 0.009 | -0.174 | 0.038 | 0.001 |
| LOW | 0.004 | 0.164 | 0.006 | 0.629 | 0.164 | 0.002 | 0.01 | 0 | 0 |
| MID | 0.012 | 0.872 | 0.01 | 1.12 | 0.817 | 0.015 | 0.43 | 0.054 | 0.002 |
| eduexp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.633 | 0.007 | -0.583 | 0.622 | 0.008 | 0.115 | 0.011 | 0 |
| LOW | 0.012 | 0.392 | 0.005 | 0.519 | 0.392 | 0.003 | 0.028 | 0 | 0 |
| MID | 0.01 | 0.667 | 0.005 | 0.766 | 0.62 | 0.006 | -0.316 | 0.047 | 0.001 |
| agri\_emp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.9 | 0.017 | 0.709 | 0.463 | 0.014 | 1.028 | 0.437 | 0.03 |
| LOW | 0.005 | 0.858 | 0.029 | 0.502 | 0.025 | 0.001 | -4.36 | 0.833 | 0.101 |
| MID | 0.012 | 0.916 | 0.028 | -1.989 | 0.886 | 0.046 | -0.55 | 0.03 | 0.003 |
| serv\_emp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.898 | 0.016 | -0.951 | 0.871 | 0.026 | 0.248 | 0.027 | 0.002 |
| LOW | 0.005 | 0.89 | 0.039 | 2.491 | 0.46 | 0.033 | -3.595 | 0.43 | 0.068 |
| MID | 0.012 | 0.834 | 0.015 | 1.216 | 0.63 | 0.017 | 1.032 | 0.204 | 0.012 |
| unemployment |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.613 | 0.008 | -0.337 | 0.214 | 0.003 | 0.685 | 0.399 | 0.013 |
| LOW | 0.005 | 0.851 | 0.039 | 2.092 | 0.325 | 0.023 | -3.974 | 0.526 | 0.084 |
| MID | 0.012 | 0.021 | 0.007 | -0.124 | 0.014 | 0 | 0.122 | 0.006 | 0 |
| youth\_unemp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.699 | 0.011 | -0.594 | 0.504 | 0.01 | 0.553 | 0.196 | 0.009 |
| LOW | 0.005 | 0.859 | 0.043 | 2.414 | 0.391 | 0.031 | -3.936 | 0.468 | 0.082 |
| MID | 0.012 | 0.174 | 0.008 | 0.366 | 0.107 | 0.002 | 0.434 | 0.067 | 0.002 |
| youth\_noti~l |  |  |  |  |  |  |  |  |  |
| HIGH | 0.029 | 0.794 | 0.013 | 0.404 | 0.193 | 0.005 | 1.065 | 0.601 | 0.032 |
| LOW | 0.005 | 0.881 | 0.034 | 1.195 | 0.12 | 0.008 | -4.494 | 0.761 | 0.107 |
| MID | 0.012 | 0.783 | 0.02 | -1.55 | 0.736 | 0.028 | -0.58 | 0.046 | 0.004 |
| skill\_worker |  |  |  |  |  |  |  |  |  |
| HIGH | 0.025 | 0.93 | 0.011 | -0.834 | 0.88 | 0.018 | -0.298 | 0.051 | 0.002 |
| LOW | 0.01 | 0.816 | 0.014 | 1.402 | 0.768 | 0.019 | -0.52 | 0.048 | 0.003 |
| MID | 0.01 | 0.736 | 0.009 | 0.736 | 0.318 | 0.005 | 1.26 | 0.419 | 0.016 |
| pension |  |  |  |  |  |  |  |  |  |
| HIGH | 0.022 | 0.9 | 0.019 | -1.19 | 0.872 | 0.031 | -0.322 | 0.029 | 0.002 |
| LOW | 0.015 | 0.74 | 0.012 | 1.03 | 0.74 | 0.016 | -0.002 | 0 | 0 |
| MID | 0.009 | 0.692 | 0.011 | 1.173 | 0.57 | 0.012 | 0.807 | 0.121 | 0.006 |
| prison |  |  |  |  |  |  |  |  |  |
| HIGH | 0.03 | 0.324 | 0.005 | -0.302 | 0.323 | 0.003 | -0.014 | 0 | 0 |
| LOW | 0.004 | 0.634 | 0.01 | 1.547 | 0.515 | 0.009 | 1.109 | 0.119 | 0.005 |
| MID | 0.012 | 0.116 | 0.006 | 0.247 | 0.066 | 0.001 | -0.32 | 0.05 | 0.001 |
| homicide |  |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.255 | 0.005 | -0.005 | 0 | 0 | 0.465 | 0.255 | 0.005 |
| LOW | 0.013 | 0.8 | 0.015 | 1.302 | 0.783 | 0.022 | -0.288 | 0.017 | 0.001 |
| MID | 0.009 | 0.886 | 0.02 | -1.791 | 0.822 | 0.03 | -0.747 | 0.064 | 0.005 |
| diet |  |  |  |  |  |  |  |  |  |
| HIGH | 0.027 | 0.935 | 0.011 | -0.817 | 0.901 | 0.018 | 0.235 | 0.033 | 0.002 |
| LOW | 0.007 | 0.861 | 0.011 | 1.248 | 0.56 | 0.011 | -1.364 | 0.301 | 0.013 |
| MID | 0.011 | 0.838 | 0.011 | 1.237 | 0.814 | 0.017 | 0.315 | 0.024 | 0.001 |
| fossilfuel |  |  |  |  |  |  |  |  |  |
| HIGH | 0.022 | 0.793 | 0.019 | -1.127 | 0.782 | 0.028 | 0.2 | 0.011 | 0.001 |
| LOW | 0.015 | 0.851 | 0.03 | 1.689 | 0.765 | 0.042 | -0.846 | 0.086 | 0.01 |
| MID | 0.009 | 0.308 | 0.006 | 0.017 | 0 | 0 | 0.923 | 0.308 | 0.007 |
| co\_emission |  |  |  |  |  |  |  |  |  |
| HIGH | 0.022 | 0.804 | 0.013 | -0.923 | 0.76 | 0.019 | 0.331 | 0.044 | 0.002 |
| LOW | 0.014 | 0.849 | 0.028 | 1.649 | 0.761 | 0.039 | -0.837 | 0.088 | 0.01 |
| MID | 0.009 | 0.276 | 0.005 | -0.379 | 0.146 | 0.001 | 0.534 | 0.13 | 0.003 |
| forest |  |  |  |  |  |  |  |  |  |
| HIGH | 0.03 | 0.182 | 0.002 | -0.039 | 0.015 | 0 | -0.194 | 0.167 | 0.001 |
| LOW | 0.004 | 0.007 | 0.006 | -0.051 | 0.001 | 0 | -0.198 | 0.006 | 0 |
| MID | 0.012 | 0.314 | 0.003 | 0.112 | 0.027 | 0 | 0.541 | 0.287 | 0.004 |

Different categories of HDI contribute to more than 8 percent of all inertia by themselves. Apart from the HDI levels, Maternal Mortality Ratio, Adolescent Birth Rate, Infant Mortality Rate, employment in agriculture, employment in services, youth unemployment, youth not in school or employment and fossil fuel energy consumption as percentage of total energy consumption are also very prominent in terms of their contribution.

**Figure 1. Graphical illustration of categories**

Graphical user interface, application

Description automatically generated

The graphical interpretation of the multiple correspondence analysis plot is made by the proximity of levels of different categories. The Figure 1 above shows that medium and high values of most categories are clustered around each other. High and medium values of variables are generally clustered around the centre while low values are far from centre which indicates, relatively, being on the low level of categories has more distinct effect for a country than being on medium or high level. This is especially more relevant for the categories of youth not in school or employment, employment in agriculture, unemployment, Infant Mortality Rate and employment in services. However some low categories such as female labor force participation rate or high-skill to low-skill employment ratio are closer to the big cluster around the centre. While some of these categories are much less distinct and have little contribution to overall inertia, it is notable that low HDI is also around this cluster. While this does not mean low HDI is necessarily belong to this cluster of medium and high values, it can be argued that having low HDI has relatively less distinct effect than having lower values on some employment statistics.

For the second analysis, HDI indicators are separately used instead of a composite index. The first dimension accounts for 64,64 percent of all inertia. The second dimension accounts for 17,88 percent of all inertia, while the rest of dimensions explain below 5 percent of total inertia. The results show that the first two dimensions, as well as the whole set, explain more variance in data when HDI indicators are used separately without being reduced to a single index.

Table 5. Inertia values for dimensions from multiple correspondence analysis results

|  |  |  |
| --- | --- | --- |
| Dimension | Percent | Cumulative Percent |
|  |
| *dim1* | 64.64 | 64.64 |  |
| *dim2* | 17.88 | 82.52 |  |
| *dim3* | 3.69 | 86.21 |  |
| *dim4* | 1.46 | 87.67 |  |
| *dim5* | 1.17 | 88.84 |  |
| *dim6* | 0.59 | 89.42 |  |
| *dim7* | 0.34 | 89.76 |  |
| *dim8* | 0.26 | 90.02 |  |
| *dim9* | 0.2 | 90.22 |  |
| *dim10* | 0.11 | 90.33 |  |
| *dim11* | 0.08 | 90.41 |  |
| *dim12* | 0.05 | 90.46 |  |
| *dim13* | 0.03 | 90.49 |  |
| *dim14* | 0.02 | 90.51 |  |
| *dim15* | 0.01 | 90.53 |  |
| *dim16* | 0 | 90.53 |  |
| *dim17* | 0 | 90.53 |  |
|  |  |  |  |

**Table 6. Multiple Correspondence Analysis Results**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Overall | | | Dimension 1 | | | Dimension 2 | | |
| mass | quality | %inert | coord | sqcorr | contrib | coord | sqcorr | contrib | coord |
| gnipercap |  |  |  |  |  |  |  |  |  |
| HIGH | 0.025 | 0.924 | 0.015 | 0.922 | 0.904 | 0.021 | 0.262 | 0.02 | 0.002 |
| LOW | 0.002 | 0.691 | 0.013 | -2.403 | 0.69 | 0.014 | 0.131 | 0.001 | 0 |
| MID | 0.01 | 0.909 | 0.022 | -1.713 | 0.872 | 0.029 | -0.678 | 0.038 | 0.005 |
| lifeexp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.013 | 0.885 | 0.023 | 1.507 | 0.81 | 0.028 | 0.871 | 0.075 | 0.01 |
| LOW | 0.012 | 0.918 | 0.03 | -1.827 | 0.886 | 0.041 | -0.66 | 0.032 | 0.005 |
| MID | 0.012 | 0.155 | 0.005 | 0.301 | 0.134 | 0.001 | -0.228 | 0.021 | 0.001 |
| expecyears~l | |  |  |  |  |  |  |  |  |
| HIGH | 0.025 | 0.929 | 0.014 | 0.897 | 0.906 | 0.02 | 0.268 | 0.022 | 0.002 |
| LOW | 0.002 | 0.709 | 0.012 | -2.379 | 0.69 | 0.013 | -0.738 | 0.018 | 0.001 |
| MID | 0.01 | 0.925 | 0.02 | -1.655 | 0.903 | 0.027 | -0.489 | 0.022 | 0.002 |
| meanyearso~l | |  |  |  |  |  |  |  |  |
| HIGH | 0.025 | 0.904 | 0.017 | 0.948 | 0.844 | 0.022 | 0.477 | 0.059 | 0.006 |
| LOW | 0.002 | 0.684 | 0.013 | -2.432 | 0.681 | 0.014 | 0.295 | 0.003 | 0 |
| MID | 0.01 | 0.879 | 0.026 | -1.77 | 0.773 | 0.031 | -1.248 | 0.106 | 0.016 |
| femaleedu | |  |  |  |  |  |  |  |  |
| HIGH | 0.022 | 0.925 | 0.022 | 1.187 | 0.925 | 0.031 | 0.029 | 0 | 0 |
| LOW | 0.006 | 0.853 | 0.028 | -2.174 | 0.676 | 0.03 | 2.116 | 0.177 | 0.028 |
| MID | 0.009 | 0.791 | 0.019 | -1.409 | 0.588 | 0.018 | -1.577 | 0.203 | 0.022 |
| secondaryedu | |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.925 | 0.02 | 1.112 | 0.925 | 0.028 | -0.011 | 0 | 0 |
| LOW | 0.005 | 0.86 | 0.024 | -2.089 | 0.57 | 0.021 | 2.836 | 0.29 | 0.039 |
| MID | 0.009 | 0.84 | 0.024 | -1.657 | 0.688 | 0.025 | -1.481 | 0.152 | 0.02 |
| mmr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.909 | 0.014 | -0.863 | 0.79 | 0.018 | -0.637 | 0.119 | 0.01 |
| LOW | 0.005 | 0.872 | 0.011 | 1.234 | 0.447 | 0.008 | 2.286 | 0.425 | 0.027 |
| MID | 0.008 | 0.901 | 0.018 | 1.723 | 0.887 | 0.024 | 0.42 | 0.015 | 0.001 |
| adolescent~h | |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.869 | 0.012 | -0.706 | 0.67 | 0.012 | -0.733 | 0.2 | 0.013 |
| LOW | 0.004 | 0.808 | 0.014 | 1.016 | 0.172 | 0.004 | 3.72 | 0.637 | 0.049 |
| MID | 0.01 | 0.86 | 0.014 | 1.385 | 0.834 | 0.018 | 0.459 | 0.025 | 0.002 |
| womeninpar~t | |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.832 | 0.002 | 0.354 | 0.81 | 0.003 | -0.112 | 0.022 | 0 |
| LOW | 0.003 | 0.331 | 0.003 | -0.707 | 0.322 | 0.001 | 0.231 | 0.01 | 0 |
| MID | 0.01 | 0.791 | 0.004 | -0.688 | 0.77 | 0.005 | 0.215 | 0.021 | 0 |
| female\_lfpr | |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.115 | 0.003 | 0.074 | 0.032 | 0 | -0.228 | 0.083 | 0.001 |
| LOW | 0.004 | 0.745 | 0.014 | -1.079 | 0.234 | 0.005 | 3.034 | 0.511 | 0.04 |
| MID | 0.009 | 0.394 | 0.004 | 0.311 | 0.134 | 0.001 | -0.825 | 0.26 | 0.006 |
| male\_lfpr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.748 | 0.003 | -0.236 | 0.257 | 0.001 | -0.619 | 0.49 | 0.009 |
| LOW | 0.004 | 0.848 | 0.016 | -1.132 | 0.229 | 0.006 | 3.535 | 0.618 | 0.054 |
| MID | 0.009 | 0.831 | 0.009 | 1.103 | 0.829 | 0.011 | -0.087 | 0.001 | 0 |
| imr |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.887 | 0.014 | -0.867 | 0.832 | 0.018 | -0.421 | 0.054 | 0.004 |
| LOW | 0.003 | 0.689 | 0.011 | 1.783 | 0.511 | 0.009 | 1.996 | 0.177 | 0.011 |
| MID | 0.01 | 0.895 | 0.02 | 1.668 | 0.874 | 0.027 | 0.495 | 0.021 | 0.002 |
| healthexp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.886 | 0.004 | 0.495 | 0.883 | 0.006 | 0.057 | 0.003 | 0 |
| LOW | 0.004 | 0.2 | 0.003 | -0.549 | 0.2 | 0.001 | -0.068 | 0.001 | 0 |
| MID | 0.01 | 0.871 | 0.008 | -1.032 | 0.868 | 0.01 | -0.118 | 0.003 | 0 |
| eduexp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.019 | 0.582 | 0.004 | 0.427 | 0.537 | 0.004 | -0.233 | 0.044 | 0.001 |
| LOW | 0.01 | 0.36 | 0.003 | -0.376 | 0.34 | 0.001 | 0.172 | 0.02 | 0 |
| MID | 0.008 | 0.572 | 0.003 | -0.567 | 0.517 | 0.003 | 0.351 | 0.055 | 0.001 |
| agri\_emp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.917 | 0.012 | -0.71 | 0.632 | 0.012 | -0.908 | 0.286 | 0.019 |
| LOW | 0.004 | 0.864 | 0.018 | 0.117 | 0.002 | 0 | 4.534 | 0.862 | 0.089 |
| MID | 0.009 | 0.912 | 0.019 | 1.707 | 0.909 | 0.027 | 0.173 | 0.003 | 0 |
| serv\_emp |  |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.943 | 0.014 | 0.902 | 0.902 | 0.019 | -0.363 | 0.04 | 0.003 |
| LOW | 0.004 | 0.887 | 0.026 | -1.917 | 0.391 | 0.016 | 4.104 | 0.496 | 0.073 |
| MID | 0.009 | 0.912 | 0.014 | -1.356 | 0.797 | 0.017 | -0.981 | 0.115 | 0.009 |
| unemployment | |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.622 | 0.005 | 0.246 | 0.184 | 0.001 | -0.724 | 0.439 | 0.012 |
| LOW | 0.004 | 0.851 | 0.024 | -1.382 | 0.223 | 0.008 | 4.407 | 0.628 | 0.084 |
| MID | 0.009 | 0.022 | 0.004 | 0.023 | 0.001 | 0 | -0.225 | 0.021 | 0 |
| youth\_unemp | |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.764 | 0.008 | 0.533 | 0.547 | 0.007 | -0.639 | 0.217 | 0.01 |
| LOW | 0.004 | 0.863 | 0.027 | -1.784 | 0.324 | 0.014 | 4.371 | 0.539 | 0.082 |
| MID | 0.009 | 0.333 | 0.006 | -0.503 | 0.279 | 0.002 | -0.419 | 0.054 | 0.002 |
| youth\_noti~l | |  |  |  |  |  |  |  |  |
| HIGH | 0.023 | 0.718 | 0.008 | -0.366 | 0.256 | 0.003 | -0.936 | 0.462 | 0.02 |
| LOW | 0.004 | 0.881 | 0.022 | -0.602 | 0.047 | 0.002 | 4.843 | 0.834 | 0.101 |
| MID | 0.009 | 0.682 | 0.013 | 1.184 | 0.681 | 0.013 | 0.101 | 0.001 | 0 |
| skill\_worker | |  |  |  |  |  |  |  |  |
| HIGH | 0.021 | 0.93 | 0.008 | 0.754 | 0.915 | 0.012 | 0.18 | 0.014 | 0.001 |
| LOW | 0.008 | 0.881 | 0.011 | -1.284 | 0.789 | 0.013 | 0.837 | 0.093 | 0.006 |
| MID | 0.008 | 0.722 | 0.006 | -0.65 | 0.351 | 0.003 | -1.27 | 0.371 | 0.013 |
| pension |  |  |  |  |  |  |  |  |  |
| HIGH | 0.018 | 0.944 | 0.016 | 1.147 | 0.94 | 0.023 | 0.143 | 0.004 | 0 |
| LOW | 0.012 | 0.772 | 0.009 | -0.923 | 0.752 | 0.011 | 0.284 | 0.02 | 0.001 |
| MID | 0.007 | 0.809 | 0.01 | -1.253 | 0.717 | 0.011 | -0.855 | 0.092 | 0.005 |
| prison |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.608 | 0.005 | 0.427 | 0.606 | 0.004 | 0.051 | 0.002 | 0 |
| LOW | 0.003 | 0.715 | 0.008 | -1.628 | 0.674 | 0.008 | -0.762 | 0.041 | 0.002 |
| MID | 0.01 | 0.333 | 0.005 | -0.529 | 0.329 | 0.003 | 0.119 | 0.005 | 0 |
| homicide |  |  |  |  |  |  |  |  |  |
| HIGH | 0.019 | 0.225 | 0.003 | 0.12 | 0.052 | 0 | -0.418 | 0.174 | 0.003 |
| LOW | 0.011 | 0.877 | 0.013 | -1.263 | 0.844 | 0.017 | 0.474 | 0.033 | 0.002 |
| MID | 0.008 | 0.8 | 0.013 | 1.453 | 0.785 | 0.016 | 0.374 | 0.014 | 0.001 |
| diet |  |  |  |  |  |  |  |  |  |
| HIGH | 0.022 | 0.952 | 0.009 | 0.761 | 0.916 | 0.013 | -0.286 | 0.036 | 0.002 |
| LOW | 0.006 | 0.818 | 0.007 | -0.942 | 0.489 | 0.005 | 1.467 | 0.329 | 0.013 |
| MID | 0.009 | 0.908 | 0.011 | -1.299 | 0.898 | 0.015 | -0.253 | 0.009 | 0.001 |
| fossilfuel |  |  |  |  |  |  |  |  |  |
| HIGH | 0.018 | 0.885 | 0.017 | 1.114 | 0.865 | 0.022 | -0.328 | 0.021 | 0.002 |
| LOW | 0.012 | 0.903 | 0.023 | -1.53 | 0.781 | 0.028 | 1.148 | 0.122 | 0.016 |
| MID | 0.007 | 0.449 | 0.004 | -0.253 | 0.071 | 0 | -1.108 | 0.378 | 0.009 |
| co\_emission | |  |  |  |  |  |  |  |  |
| HIGH | 0.018 | 0.874 | 0.011 | 0.861 | 0.806 | 0.013 | -0.474 | 0.067 | 0.004 |
| LOW | 0.012 | 0.901 | 0.022 | -1.485 | 0.767 | 0.026 | 1.179 | 0.134 | 0.016 |
| MID | 0.007 | 0.333 | 0.003 | 0.267 | 0.107 | 0.001 | -0.735 | 0.225 | 0.004 |
| forest |  |  |  |  |  |  |  |  |  |
| HIGH | 0.024 | 0.258 | 0.001 | 0.086 | 0.1 | 0 | 0.206 | 0.159 | 0.001 |
| LOW | 0.003 | 0.002 | 0.004 | -0.033 | 0.001 | 0 | 0.119 | 0.002 | 0 |
| MID | 0.01 | 0.367 | 0.002 | -0.203 | 0.122 | 0 | -0.546 | 0.245 | 0.003 |

The Table 6 above shows that Gross National Income per capita explains about 5% of inertia by itself and belongs to dimension 1. Other prominent variables in terms of explaining most variance in data are mean years of schooling, healthy life expectancy at birth, female population with at least some secondary education, male population with at least some secondary education, employment in services. The variables of forest area, average dietary energy supply adequacy, homicide rate, prison population, high-skill to low-skill employment ratio, current health expenditure’s share in GDP, government expenditure on education (as a share of GDP), women's share of seats at parliament explain relatively lower share of total inertia for both of the analyses. It’s notable that employment, education and health related variables tend to explain more of the variance in data and have more of a discriminating effect, health and education expenditure’s share in GDP are less prominent in terms of their relative effect. Also comparing the results of first and second analyses, it can be observed that including life expectancy variable separately in the analysis reduced the effect of mortality rates as they explain less than 5% of the inertia now.

Figure 2. Graphical illustration of categories

Chart, scatter chart

Description automatically generated

The general pattern in Figure 2 is similar to Figure 1, while high and medium levels are closer to each other than low values are, they are also closer to origin. While low values in most categories are scattered in the plot and less strongly associated with each other for some of the categories, they seem to be more discriminating on the results than high and medium values. GNI per capita’s placement in the graphs is also consistent with the literature that interactions among SDGs differ according to income level (Lusseau and Mancini, 2019). On the low level of GNI per capita, the other variables on the same level are scattered and less strongly associated with each other while countries with high income are consistently associated with high level on other variables.

**5. CONCLUSION**

Human Development Index and Sustainable Development Goals and their indicators are critical measures of development economics. Multiple correspondence analysis was conducted to understand the relation between different indicators. Some of the indicators explain the variance (calculated by inertia in multiple correspondence analysis) more than others. The analysis shows that HDI and its components and other education and employment related variables such as youth not in school or employment, employment in agriculture, unemployment, employment in services explain most variance in the data. Results indicate that being on the lower end of these indicators for countries are more influential in their place than being on middle or higher end. The relative place of different levels can give an idea about which indicators should be more focused on in terms of policy making. Although multiple correspondence analysis is useful for limited assumptions on data distribution or cases like collinearity, and provides simplified visualisations, it has limitations in terms of causal and inferential explanations of data. The relationships found in this research should be considered more in terms of relative placement and proximity than cause and effect. But identifying these relations and proximity is critical for policy makers to plan and prioritize an optimal action towards 2030 agenda.

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