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A review of predominance of gross national income in human development index during COVID-19 crisis

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Abstract
The study explores the role of gross national income (GNI) in the Human Development Index (HDI), a key measure of social progress tied to the Sustainable Development Goals. Using 2021 macroeconomic data from 170 countries, the analysis applies principal component analysis (PCA) and logistic regression to evaluate the relative contribution of HDI predictors: GNI, life expectancy (LE), and mean years of schooling (ME). Data underwent transformation and normalization to ensure accuracy. PCA results indicate that the first principal component (PC1), largely representing income, explains 41.8% of the total variance, with GNI having the strongest positive loading (0.660), while LE and ME load modestly and inversely. Logistic regression shows GNI declined 5.3 times, but ME and LE increased the likelihood of GNI growth by 2.2 and 4.7 times respectively, while population reduced it by 61%. The findings underscore GNI's dominant role in HDI, urging global emphasis on income improvement to drive social progress.

Key Words: Gross national income, HDI, COVID-19

Introduction

Gross national income (GNI) is defined as the total monetary value added claimed by all resident units in a country through primary distribution of income (Shujian, 2025) [23]. It may have overarching influence on human development index (HDI), which provides unbiased estimation of citizens outcomes (Koohi, 2007) [13]. Studies reveal that GDP is largely incongruent if used to estimate social progress (Wang, 2022) [29]. Increase or decline in GDP is not instrumental in painting a clear comprehensive picture of people's social progress (Greve, 2017) [9]. A merited explanation is the likelihood of few private companies contributing disproportionately to GDP without benefiting residents commensurately. Studies show that many aspects of daily life cannot be meaningfully measured by GDP (Siglizt, 2010) [24]. In light of this, reliance on HDI which considers mean and expected years of education (education), life expectancy at birth (health), and GNI (Kovacevic, 2010) [14], provides a near complete picture. Pragmatically, life expectancy at birth and attainment of education in most low- and medium-income countries (LMICs), with little or no social safety nets, are dependent on disposable household income (Sede, 2015) [22]. As such, GNI might be a composite determinant of HDI and larger statistical and socioeconomic impact, given its manifest relations with education and health.

An exercise to identify which variable between education and health impacts people's income most ends in foreseeable trade-offs. On one hand, healthy people show up for work without absenteeism or sick leave (Pauly, 2002) [20]; on the other hand, the educated are more skilled, specialized, innovative, adaptive, and contribute more to both economy (Marrocu, 2012) [17] and household income.

When modelling determinants of GNI, it would be both misspecification and omitted variable bias if a country's population is not considered (Atanda, 2012; Wahyuningrum, 2021; Kerner, 2017) [5, 28, 10]. Some studies show that less populated countries that do not experience strife tend to possess favourable HDI (Gatt, 2004) [8] and associated indicators.

To demonstrate significance of GNI in HDI, principal component analysis is instrumental; to estimate determinants of GNI, the model specification (in proposition) considers mean years of schooling, life expectancy at birth (health), and population.

Literature Review

Human development index (HDI) is a statistical method used by United Nations Development Program (UNDP) to rank countries on human development since 1990 (Lind, 2019; Sagar, 1998) [16, 21]. It evaluates a countries milestone on health, life expectancy at birth; education, mean years of schooling and expected years of schooling; and standard of living, gross national income per capita (Ibid,1). It is noted that mean years of schooling as a variable is more relevant than expected years of schooling (Krueger, 2001) [15] because the former is lived education. Also, life expectancy at birth provides rational insights in status of health of individuals in a country (Aksan, 2003) [3]. Obviously, countries where citizens are afflicted by: disease, preventable and curable but neglected; strife, civil strife and or other forms of political violence; and economic hardship, are characterized by low life expectancy at birth (Tulchinsky, 2014) [26]. In another perspective, life expectancy at birth also points remotely to the impact of governments' investments in people's health and wellbeing, otherwise known as quality of life (Usher, 1973) [27].

Noticeably, acquisition of education and enjoyment of sound health do not exist outside availability of disposable income (Dalstra, 2006) [7], demonstrating predominance of GNI. Quality of life and income are concomitant such that, acquisition of education, and attainment of good health are associated with disposable income (Pappa, 2009) [19]. It is also discernible that countries with smaller populations, and not experiencing strife tend to have high national income and life expectancy. On the other hand, countries with larger populations tend to have both low GNI and life expectancy, and are predisposed to various forms of strife (King, 2001) [10]. In a way, population and GNI in most circumstances tend to have unique relationship. In this way, failing to include population in any GNI estimating model may result on omitted variable bias.

From this theoretical analysis, it is clear that mean years of schooling, attainment of good health, and population have a bearing on gross national income. In this case, population is a confounding variable whose absence in HDI related model exhibits misspecification. With the idea that GNI may disproportionately influences other variables in estimating HDI, we seek to empirically investigate the composite nature of GNI, and estimate its determinants.

Methods

The paper considers macroeconomic data for the year 2021 of 170 countries mined from World Bank portal (Bank, 2021). All countries considered in the analysis were chosen in no particular order. To limit impact of outlier data impact we normalize and perform logarithmic transformation on the dataset. And to determine the proportion of GNI in the total variance among the variables, principal component analysis is performed, dominant dimensions isolated and results interpreted. To estimate the determinants of GNI, multiple logistic regression model is employed to approximate relative contribution of mean years of school (ME), life expectancy at birth (LE), and POP. In the specification we included population (POP) to avoid omitted variable bias. The results were interpreted including test statistics. The validity of the model estimated is evaluated. The analysis is done using R 4.3.2 version statistical software. Results are obtained, interpreted and explained. Finally, conclusions are drawn.

Results

Table 1: Principal Component Analysis results

Variable	PC1	PC2	PC3
LE	-0.48847	-0.7975	0.354102
ME	-0.57043	0.598935	0.562041
GNI	0.660315	-0.07255	0.747477

Interpretation

- **PC1:** GNI (0.660) loads strongly positively. PC1 is mostly income dimension. Both LE (life expectancy -0.488) and ME (mean years of education -0.570) load modestly and negatively.
- **PC2:** LE (-0.797) loads strongly by negatively; ME (0.599) load averagely and positively; and GNI (-0.0725) loads modestly and inversely. PC2 is mostly life expectancy dimension but inversely; as the PC2 increases life expectancy declines.
- **PC3:** GNI (0.747) loads very strongly; ME (0.562) load averagely but positively; LE (0.354) loads modestly and positively. PC3 is also income dimension.

Summary

PC1 $\approx$ is mostly GNI (income)

PC2 $\approx$ is averagely ME (education)

PC3 $\approx$ is mostly GNI (income)

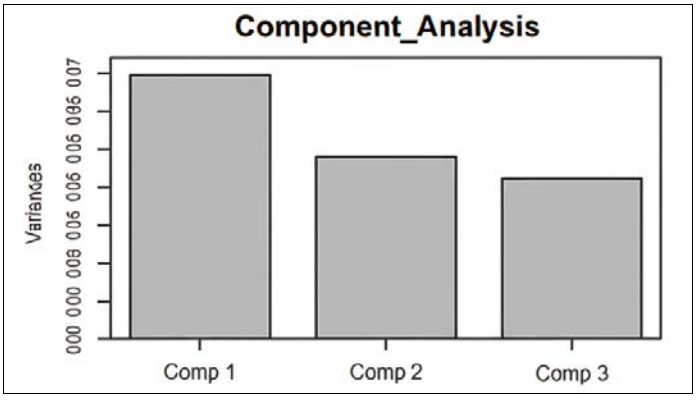

Fig1: variance proportion of PC1, PC2, and PC3

Table 2: PC1, PC2, and PC3 test statistics.

	PC1	PC2	PC3
Standard Deviation	0.279	0.238	0.213
Proportion of Variance	0.4177	0.323	0.2591
Cumulative Proportion	0.4177	0.741	1.00

Interpretation

1. PC1 explains 41.8% of the total variance — income dimension is the most informative component
2. The first two components explain 74.1% of the total variance, which is quite good. You could reduce your data from 3 variables to 2 principal components without losing much information.
3. If needed for visualization a 2D PCA plot using PC1 and PC2 would retain most of the structure.
4. If precision is critical, include PC3 to retain 100% of the variance, but for most purposes, PC1 + PC2 suffice.

Table 3: Estimated coefficients of the model fitted.

Variable	Estimate	Std. Error	T-Value	P-value	Significance	OR (Odds Ratio)	2.5% (OR)	97.5% (OR)
Intercept	-5.3338	0.2562	-20.823	0.000002	***	0.00482	0.00288	0.00787
ME	2.20636	0.36092	6.113	0.00213	***	5.40831	1.8838	15.7173
POP	-0.387	0.5618	-0.689	0.4919		0.67909	0.1995	1.88348
LE	4.7126	0.4902	9.614	0.0000022	***	58.30080	48.109	94.711

Dispersion parameter = 0.0784, Null Deviance=49.100 on 170 DF, Residual Deviance=11.16 on 167 DF, from the analysis, the estimated equation is;

$$GNI = -5.334_{(0.2562)} + 2.206ME_{(0.36092)} - 0.387POP_{0.5618} + 4.713LE_{(0.4902)}$$

Results

Holding mean years of education, life expectancy, and population constant there is likelihood of 5.3 times decline in GNI for the year 2021. In the same period, accounting for influence of POP, and LE, the analysis pointed that unit increase in ME was 2.2 times more likely to increase GNI. Likewise, unit increase LE is 4.7 times more likely to increase GNI. However, unit increase in POP is 61.3% less likely to increase population.

The estimated model is accurate evidenced by small residual deviance (11.16) on 167 degrees of freedom against null deviance of 49.1 on 170 degrees of freedom. It implies that the sum of squares of the difference between the predicted and actual values is 11.16. We find that the amount of variability not explained by the model is 11.16, i.e., there is no omitted variable bias in the model. The dispersion parameter (0.0784) attests to infinitesimal variation.

Coefficients

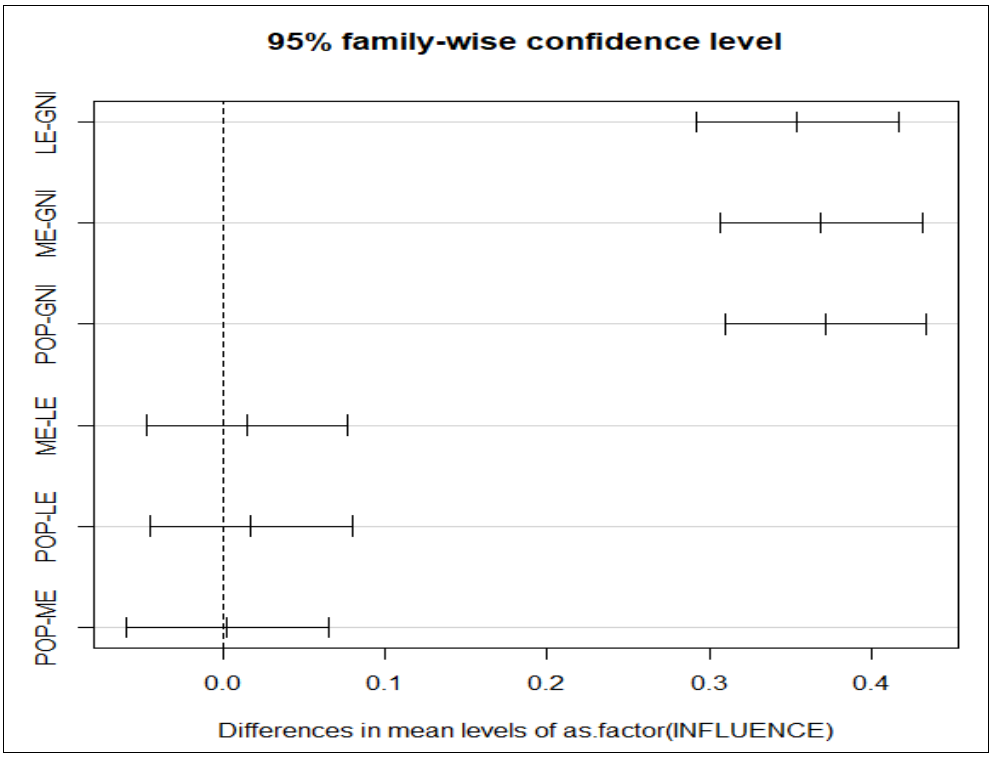

Fig 2: pair wise comparison of residual means.

Table 4: Estimated confidence intervals of coefficients.

Pairing	Lower	Upper	p-value
LE-GNI	0.292116	0.416857	0
ME-GNI	0.306909	0.43165	0
POP-GNI	0.309526	0.434267	0
ME-LE	-0.04758	0.077163	0.928645
POP-LE	-0.04496	0.07978	0.889589
POP-ME	-0.05975	0.064987	0.999548

According to Tukey post-hoc the comparison of residual means of population, mean years of education, and life expectancy as factors of GNI exhibits no significance statistical different. Expressed individually among themselves, the means of independent variables used significantly differ.

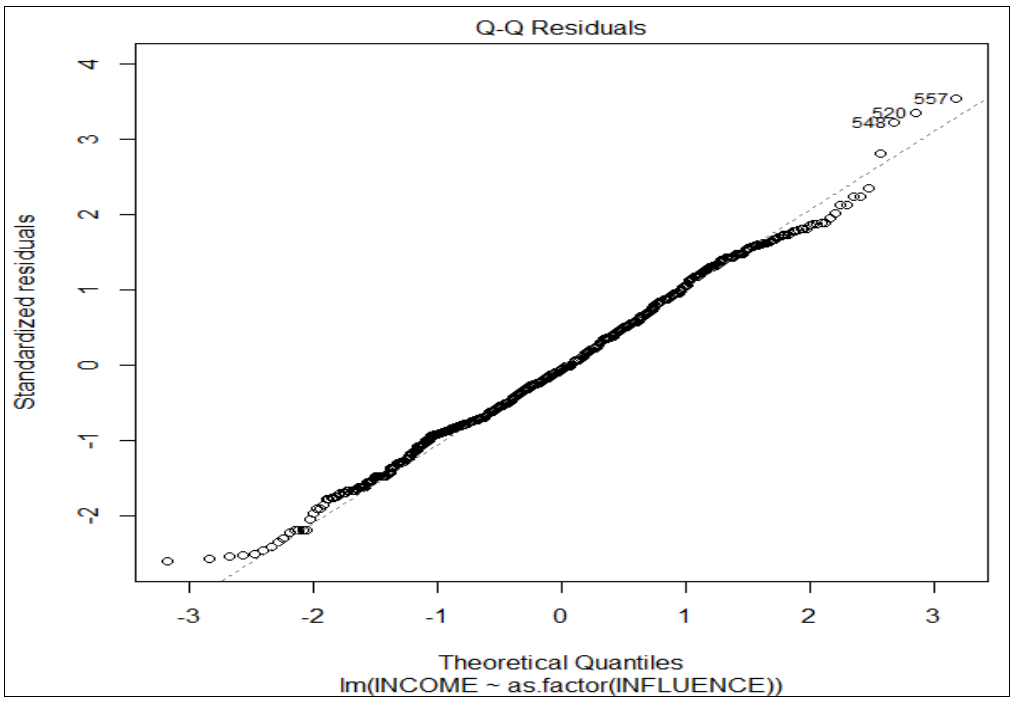

Fig 3: Normality of residuals of the models.

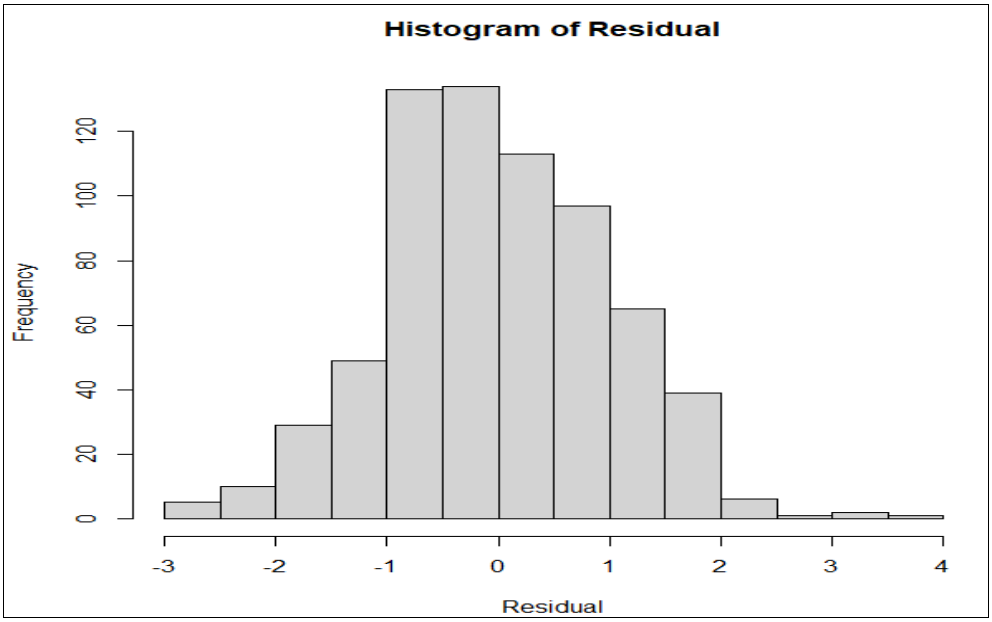

Fig 4: histogram of model residuals.

Discussion

Results of Principal Component Analysis (PCA) reveal that 2 out of 3 PCs are income dimensions: PC1, GNI (0.66); PC3, GNI (0.747). It is PC1 which is most informative as it explains 41.8% of the total variations. These demonstrate the composite variability of income in estimating human development indices. In 2021, human conditions plunged, and income is singled out in this paper as the key

determinant.

The 5.3 times likelihood of decline in gross national income without the influence of variables considered in the model points to socioeconomic interruption of COVID-19 in 2021. Most families relapsed to abject poverty in the absence of social safety nets. In most LMICs there was (little if any) social protection in spite of massive job losses, and demise of bread winners in some cases (Milovanska-Farrington, 2023) [18]. Household incomes drastically declined (Tafa, 2022) [25]. Although one unit increase in mean years of schooling (education) among nationals was 2.2 times likely to increase GNI, it did not compensate for job losses in 2021. However, households whose members had advance years of education improved family's ability to cope with socioeconomic disruptions (Wilder, 2023). Educated people were disposed to finding alternative ways of surviving, not thriving. These could include austerity measures, avoidance of duplicity of services, pooling of resources, and optimizing benefits of charity (Kitara, 2020).

From the analysis, unit increase in life expectancy is 4.7 times more likely to increase GNI when all other variables are held constant. Life expectancy is dependent on investments in health to determine long and healthy life for all. Notably, longevity in service benefits the economy and ensure availability of disposable income for families. Experience gained over time and work output outweighs the initial cost of training. Studies (Abushammala, 2022) [1] show that households with more than one breadwinner or those with vast experiences in both private sector and civil service were relatively more stable compared you younger families.

The likelihood of 61.3% decline in GNI due to population parameters accounts for governments' overstretched expenditure in provision of services when citizens were disrupted by no pharmaceutical interventions like lockdowns and other forms of cessation of movements (Aikins, 2021) [2]. Even non-responsive governments proved somewhat benevolent during the pandemic, however infective (Alexander, 2022) [4].

Validity of estimated model

The estimated logistic regression model is accurate, significant, and reliable as evidenced by small residual deviance (11.16) on 167 degrees of freedom against null deviance of 49.1 on 170 degrees of freedom. The sum of squares of the difference between the predicted and actual values is 11.16. And the amount of variability not explained by the model is 11.16, i.e., there is no omitted variable bias in the model. The dispersion parameter (0.0784) points that the variation is infinitesimal.

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