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The impact of poverty, malnutrition, and household income on human development in Central Sulawesi, Indonesia: A panel data analysis

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Abstract: Central Sulawesi has been grappling with significant challenges in human development, as indicated by its Human Development Index (HDI). Despite recent improvements, the region still lags behind the national average. Key issues such as high poverty rates and malnutrition among children, particularly underweight prevalence, pose substantial barriers to enhancing the HDI. This study aims to analyze the impact of poverty, malnutrition, and household per capita income on the HDI in Central Sulawesi. By employing panel data regression analysis over the period from 2018 to 2022, the research seeks to identify significant determinants that influence HDI and provide evidence-based recommendations for policy interventions. Utilizing panel data regression analysis with a Fixed Effect Model (FEM), the study reveals that while poverty negatively influences with HDI, underweight prevalence is not statistically significant. In contrast, household per capita income significantly impacts HDI, with lower income levels leading to declines in HDI. The findings emphasize the need for comprehensive policy interventions in nutrition, healthcare, and economic support to enhance human development in the region. These interventions are crucial for addressing the root causes of underweight prevalence and poverty, ultimately leading to improved HDI and overall well-being. The originality of this research lies in its focus on a specific region of Indonesia, providing localized insights and recommendations that are critical for targeted policy making.

Keywords: Human Development Index (HDI); poverty; malnutrition; household per capita income; central Sulawesi
JEL Classification: I15; I32; O15; Q56

1. Introduction

Central Sulawesi, Indonesia, faces critical challenges in human development, particularly among its youngest citizens. The Indonesian Ministry of Health (Kemenkes, 2022) identifies underweight toddlers as a significant threat to national well-being, impacting physical growth, cognitive development, and future capabilities (Prasetyo et al., 2023; Ramadhani et al., 2022). Underweight children are highly vulnerable to health issues due to weakened immune systems. Without prioritizing the nutritional needs of children under five, malnutrition cycles are likely to persist across generations. The roots of these nutritional problems often trace back to prenatal malnutrition, primarily due to mothers' lack of access to nutrient-rich foods, particularly high-quality proteins (Khasanah et al., 2022; Marzo et al., 2024; Sarkar et al., 2023). This prenatal malnutrition leads to fatal malnutrition and subsequent child malnourishment. A study by Amate-Fortes et al. (2017) analysed United Nations data

from 1995 to 2010 and highlighted those improvements in infrastructure, increased democratic investments, enhanced stability, and reduced corruption positively correlate with human development. These factors align with the World Health Organization (WHO) recommendations for reducing underweight prevalence to below 20% by 2022.

The high prevalence of stunting, wasting, and underweight among children under five in Timor Leste, a neighboring country, reflects the poor nutritional and health status of this vulnerable population (Maulina et al., 2022). Factors such as the mother's education, age, BMI, and height, as well as the number of antenatal care visits, birth weight, sex of the child, household characteristics, and geographic location, have been identified as predictors of malnutrition in this region (Maulina et al., 2022). Indonesia, the largest economy in Southeast Asia, still faces a high incidence of malnutrition in children under five, ranking fourth in the world (Rukmana et al., 2022). The linkage between socioeconomic environments and child undernutrition has been well-studied, with pronounced within-country disparities observed (Ayuningtyas et al., 2022). Poverty remains a persistent issue in Central Sulawesi, with some districts reporting poverty levels exceeding 30% of the population (Rohmatilah, 2023). This is attributed in part to unequal development between men and women, as the Gender Development Index indicates that women's development is only 89% that of men's, and the Gender Empowerment Measure shows women are only 62% as empowered as men (Rohmatilah, 2023).

To address the critical challenges of malnutrition and underweight toddlers in Central Sulawesi, Indonesia, a multifaceted approach is needed. This should include improving access to nutrient-rich foods, particularly for pregnant women and young children, strengthening maternal and child health services, enhancing infrastructure and democratic investments, and addressing socioeconomic inequalities (Ayuningtyas et al., 2022; Maulina et al., 2022; Rukmana et al., 2022). By prioritizing the nutritional needs of Indonesia's youngest citizens, the country can break the cycle of malnutrition and unlock the full potential of its human capital. Household per capita income is also a key factor, as economic growth has not translated to commensurate reductions in poverty (Triatmanto et al., 2020). The relationship between economic growth, poverty, and human development is complex, and efforts to alleviate poverty must be accompanied by programs that empower local development actors and optimize the use of local budgets (Triatmanto et al., 2020). While Central Sulawesi has seen some progress in recent years, the region's persistent challenges with poverty, malnutrition, and unequal household incomes continue to hinder its ability to achieve meaningful improvements in human development outcomes.

Data from the Indonesian Nutritional Status Survey (SSGI) underline the importance of providing natural foods to children under five to prevent stunting. Mothers are crucial in this effort, emphasizing balanced diets over ultra-processed foods. Prenatal malnutrition is a significant contributor to stunting, further exacerbated by inadequate sanitation and restricted access to clean water. Poor sanitation and subpar water quality significantly impede toddlers' growth trajectories. Moreover, limited healthcare services contribute to the prevalence of stunting, as highlighted in studies by Titaley et al. (2019) and Stewart et al. (2013). Stunting in Central Sulawesi Province is projected to reach 28.2% in 2022, a notable 15% decrease from the

previous year. However, the region still faces significant challenges. Sigi District has the highest stunting prevalence at 36.8%, while Banggai Laut District has a 20% prevalence of underweight cases. Parigi Moutong Regency has the highest poverty rate at 6.39%, whereas Banggai Islands Regency has the lowest at 1.34%.

Given these circumstances, Central Sulawesi must intensify its efforts to reduce stunting more effectively than other provinces to meet the national target of reducing stunting to 14% by 2024. Despite these efforts, there remains a substantial gap in understanding how various socio-economic factors impact the Human Development Index (HDI) in Central Sulawesi. This research addresses this gap by examining the influence of poverty, malnutrition, and household per capita income on HDI. By focusing on these determinants, this study aims to provide localized insights and evidence-based recommendations crucial for targeted policy interventions.

The structure of this paper is as follows: the next section reviews relevant literature on poverty, malnutrition, and human development. The methodology section outlines the data collection and analytical methods used. This is followed by the results and discussion section, which presents and interprets the findings. Finally, the paper concludes with policy implications, suggestions for future research, and the study's limitations.

2. Literature review

Underweight is often linked to impoverished households. Mothers from financially disadvantaged families may struggle to meet the nutritional requirements, leading to the birth of underweight infants and subsequent child malnourishment. The underlying causes of this nutritional issue stem from complex economic, political, and social crises (Rahmawati, 2016). According to UNICEF (2020), various factors contribute to nutritional problems, which have been addressed to some extent in Timor Leste.

Malnutrition is influenced by both direct and indirect factors. Direct influences include diet and infections, while indirect influences involve insufficient food availability, suboptimal parenting, lack of proper sanitation and clean water, and inadequate healthcare services (Sylvia et al., 2022). Additionally, societal issues such as a lack of maternal education, knowledge, and skills exacerbate the problem (Oktiartini et al., 2024).

Many empirical studies on the determinant of HDI have been performed by many authors during last 25 years, but obtained results are controversial and inconclusive. Research conducted by Shah (2016) explored the determinants of the HDI through a cross-country empirical analysis. The HDI, which gauges human development, was assessed using a multiple regression statistical model incorporating key indicators such as life expectancy, education, and real per capita income (Kuncoro, 2006). The correlation between GDP growth and HDI in ASEAN 5 economies has been positive but low for the region as a whole (Shome and Tondon, 2010). Using data of 40 countries, Suparyati (2014) found that for the group of countries very high human local development per capita income is only significant effect on the HDI, for the group of countries high human development and medium human development only economic freedom that affects the HDI, while the low human development group showed that

income per capita and economic freedom does not affect the HDI. The regression analysis revealed notable trends: fertility and inflation rates were low, whereas indicators like life expectancy, educational attainment, and per capita income exhibited higher levels (Risyah, 2023). The findings of the research conducted by Amate-Fortes et al. (2017), drawing from United Nations data covering the years 1995 to 2010, shed light on various factors influencing human development. This research examines the impact of infrastructure, investments in enhancing democracy, increased stability, and reduced corruption on the HDI (Sadam, 2023). Notably, the study highlights the significant role these factors play in promoting human development. Using Ordinary Least Square (OLS) and Fixed-Effect Model (FEM) to estimate Indonesia's 34 provinces panel data set from 2014 in 2021, Tyas and Sukartini (2022) found the life expectancy was affected by protein consumption, number of hospitals, and health centers; the average length of schooling is affected by the number of elementary, high school, and vocational schools, number of elementary and vocational school teachers; Gross Domestic Regional Product (GRDP) per capita is affected by unemployment rate and Micro Small and Medium Enterprises (MSMEs). Khumaerah (2023) found that poverty and open unemployment rate have not influenced HDI significantly in Banten Province.

3. Materials and method

3.1. Types and source of data

The data utilized in this research primarily comprises quantitative information, specifically numerical data. The dataset, categorized as secondary data, spans the years 2018 to 2022. It is sourced from the Central Statistics Agency (BPS) of Central Sulawesi, Indonesia. This data was derived from documented records in both national and international journals, serving as supplementary resources relevant to the research topic. The essential dataset encompasses various metrics, including the HDI, per capita income, poverty statistics, and health indicators related to services for children under the age of five. The focal population for this research includes all available reports on indicators such as poverty rates, HDI, per capita income, and health indices, including prevalence figures for under-five stunting and underweight cases. The sample data span the five-year period from 2018 to 2022. The sampling method is characterized as purposive sampling, where subjects are selected with a specific objective in mind, deviating from random, stratified, or regional selection methods (Saunders et al., 2009; Sekaran and Bougie, 2016).

3.2. Data collection method

The data collection process involves 13 districts and cities in the Central Sulawesi Province, including Banggai Islands, Banggai, Morowali, Poso, Donggala, Toli-Toli, Buol, Parigi Moutong, Tojo Una-Una, Sigi, Banggai Laut, North Morowali, and Palu City. The dataset utilized comprises secondary data obtained from the BPS (2022), covering the period from 2018 to 2022, spanning a five-year duration. The focus is on the evolution of the HDI. The requisite information includes quantitative aspects,

specifically secondary data such as per capita income, poverty rate, and health service indicators reflecting malnutrition and stunting status within Central Sulawesi province.

4. Operational definition of variables

The following **Table 1** provides detailed operational definitions and measurement methods for the variables used in this research, along with their sources.

Table 1. Measurements.

Variable	Definition	Measurement	Source
HDI	The HDI is a composite statistic of life expectancy, education, and per capita income indicators, used to rank countries into four tiers of human development.	Percentage (%)	United Nations Development Programme (UNDP)
Impoverished Households	Refers to households that do not have sufficient income to meet the basic needs of life, such as food, shelter, and healthcare.	Percentage (%)	BPS, Indonesia
Prevalence of Underweight Children	Refers to children under the age of five who have a body weight below the standard for their age, indicating malnutrition.	Percentage (%)	Indonesian Ministry of Health, UNICEF

These operational definitions and measurement methods provide a comprehensive understanding of the variables studied in this research. They ensure that each variable is consistently defined and measured, enabling accurate and reliable analysis.

4.1. Model test

Panel data regression employs various estimation methods, namely Pooled Least Squares (Common Effect), Fixed Effect, and Random Effect estimations. These methods are evaluated through model testing to determine the most suitable model for this research. To estimate a panel data regression model, three techniques are available: Ordinary Least Squares (OLS) using the common effect method, the Fixed Effect model, and the Random Effect model. The Chow test and Hausman test were employed to ascertain the most suitable technique for this research.

4.2. Chow test

The Chow test determines whether the Common Effect or Fixed Effect model is more appropriate. The hypotheses for the Chow test are:
- H_0: Common Effect Model
- H_a: Fixed Effect Model

The decision is based on comparing the calculated *F*-statistic with the critical value from the *F*-table. If the calculated *F*-value is greater than the *F*-table value, H_0 is rejected, indicating the Fixed Effect model is more suitable. Conversely, if the calculated *F*-value is smaller, H_0 is not rejected, suggesting the Common Effect model is more appropriate.

4.3. Hausman test

After identifying the Fixed Effect model from the Chow test, the Hausman test determines whether the Fixed Effect or Random Effect model is more suitable. The hypotheses for the Hausman test are:

- H_0: Random Effect > Fixed Effect
- H_a: Fixed Effect > Random Effect

If the cross-section probability is lower than 1%, 5%, or 10%, H_0 is rejected, implying the Fixed Effect model is more suitable. Conversely, if the probability is greater, H_0 is accepted, indicating the Random Effect model is more appropriate.

4.4. Data analysis

Panel data combines time series and cross-sectional data, and panel data regression analysis involves conducting regression analysis on panel data to examine the correlation between the dependent variable and one or more independent variables. In this research, EViews 9 software is employed to assess the statistical significance of regression coefficients for each independent variable in relation to the dependent variable through rigorous statistical testing. As posited by Baltagi (2005), the primary objective of multiple linear regression analysis is to ascertain the impact of independent variables, namely poverty and indicators of toddler health, on the dependent variable, which in this context is the HDI within Central Sulawesi Province. The general model of multiple linear regression is as follows (Ahmed et al., 2023; Lind et al., 2018):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_n X_n + e$$

where:

Y : Dependent variable, Human Development Index (HDI).

$X1$: Number of impoverished households.

$X2$: Indicator of health - underweight status.

$X3$: Indicator of Household per Capita Income—income.

β_1–β_n: Regression coefficients.

$X1$–Xn: Independent variables.

e: Error term.

These formulas were then used in this research as follows:

$$HDI = \beta_0 + \beta_1 Pov + \beta_2 PUns + \beta_3 Fs + e$$

where:

HDI : Human Development Index.

β_0 : Constant

β_1Pov : Coefficient of regression for the number of impoverished households (poverty).

β_2Uns : Coefficient of regression for health indicator (underweight status).

β_3Fs : Coefficient of regression for Household per Capita Income (income).

e : Error term.

4.5. Statistical tests

Three statistical tests were employed in this research: the Coefficient of Determination Test (R^2 Test), the Joint Regression Coefficient Test (F Test), and the Partial Regression Coefficient Test (t Test). These tests assess the significance of the regression coefficients. The R^2 test evaluates the model's ability to explain the variance in the dependent variable. An R^2 value approaching one suggests that the

independent variable provides almost all the necessary information for predicting variations in the dependent variable. The introduction of an additional independent variable will increase the R^2 value.

The *F*-test evaluates the collective influence of the independent variables on the dependent variable. The criteria are: If the calculated *F*-value > *F*-table or *p*-value < 0.05, H_0 is rejected, and H_a is accepted, indicating the independent variable has a significant effect on the dependent variable. If the calculated *F*-value < *F*-table or *p*-value > 0.05, H_a is rejected, and H_0 is accepted, indicating the independent variable does not have a significant effect on the dependent variable.

Partial Regression Coefficient Test (*t* Test) determines the individual impact of a single independent variable on the dependent variable. The criteria are if the calculated *t*-value > *t*-table or *p*-value < 0.05, H_0 is rejected, and H_a is accepted, indicating the individual independent variable has a significant effect on the dependent variable. If the calculated *t*-value < *t*-table or *p*-value > 0.05, H_a is rejected, and H_0 is accepted, indicating the individual independent variable does not have a significant effect on the dependent variable.

5. Results and discussion

5.1. Human development index

The concept of the HDI was first introduced by the United Nations Development Programme (UNDP) in 1990. Recently, Central Sulawesi has seen an increase in its HDI value. As of 2022, the HDI score for Central Sulawesi is 70.28, ranking 24th out of 33 provinces in Indonesia. The BPS (2022) categorizes HDI scores into four groups: very high (above 80), high (70–80), moderate (60–70), and low (below 60). Central Sulawesi falls within the high category. The HDI is determined by three primary indicators: life expectancy at birth, expected and average length of schooling, and real expenditure per capita. Despite recent progress, Central Sulawesi's HDI decreased from 65.99 in 2010 to 64.27 in 2011, remaining below the national average, indicating that its human development is lagging behind other regions in Indonesia.

5.2. Selection of panel data regression model

Panel data regression analysis was employed to determine the relationship between the dependent variable (HDI) and independent variables (poverty, underweight status, and family size). Three models were evaluated: Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). The Chow Test and Hausman Test were used to select the most appropriate model. We follow the rationale and stages for choosing the FEM, CEM, over the REM, including further details on the Chow and Hausman tests (Catalin et al. 2015; Green 2008; Zulfikar 2018). The Chow Test compares the Common Effect Model CEM and the FEM to determine which model better fits the data. A significant result indicates that the FEM is more appropriate. The Hausman Test compares the FEM and the REM, with a significant result indicating that the FEM is more suitable than the REM. The results of the regression analysis, including the coefficients, standard errors, t-statistics, and *p*-values for the three models, are summarized in **Table 2**. **Table 3** presents the

overall statistics for each model, including *R*-squared, adjusted *R*-squared, *F*-statistic, and the probability of the *F*-statistic.

Table 2. Regression coefficients, standard errors, *t*-statistics, and *p*-values.

Variable	CEM Coefficient	FEM Coefficient	REM Coefficient	Std. Error (CEM)	Std. Error (FEM)	Std. Error (REM)	*t*-Statistic (CEM)	*t*-Statistic (FEM)	*t*-Statistic (REM)	Prob. (CEM)	Prob. (FEM)	Prob. (REM)
Constant	8.385.133	7.439.717	7.504.529	1.814.306	1.158.793	1.441.465	4.621.675	6.420.232	5.206.183	0.0000	0.0000	0.0000
Poverty	0.119288	−0.017459	4.94E-05	0.073511	0.013348	0.000185	1.622.722	−1.307.996	0.267650	0.1099	0.1971	0.7899
Underweight	−0.272758	−0.008553	−0.015510	0.137289	0.021853	0.021665	−1.986.743	−0.391384	−0.715916	0.0515	0.6972	0.4768
Household per Capita Income	−1.069.896	−0.391146	−0.440683	0.123538	0.086554	0.083350	−8.660.446	−4.519.070	−5.287.167	0.0000	0.0000	0.0004

Table 3. Model summary statistics.

Statistic	CEM	FEM	REM
R-squared	0.610247	0.995564	0.587124
Adjusted *R*-squared	0.584263	0.994086	0.559598
F-statistic	21.31597	689.8045	21.71959
Prob (*F*-statistic)	0.000000	0.000000	0.000000

The CEM results show that approximately 58.4% of the variation in HDI can be explained by the model. However, the *p*-values for poverty is not statistically significant, indicating that the variable does not have a significant impact on HDI in this model. The FEM provides a much higher adjusted R-squared value (99.41%), indicating that this model explains almost all the variation in HDI. The Household per Capita Income has a significant negative impact on HDI, while poverty and underweight status are not significant in this model. The REM results show that approximately 55.96% of the variation in HDI can be explained by the model. Similar to the CEM, poverty and underweight status are not statistically significant, but the Household per Capita Income remains significant. The FEM was identified as the best fit model due to its higher adjusted R-squared value, indicating that it explains the largest proportion of variance in the HDI. This analysis highlights the significant impact of family size on HDI in Central Sulawesi, while poverty and underweight status showed no significant effects in the chosen model. The findings suggest that targeted interventions focusing on reducing family size and improving family planning services could be more effective in enhancing human development in the region.

5.3. Model selection for panel data estimation

To determine the most appropriate panel data regression model, two statistical tests were employed: the Chow Test and the Hausman Test. These tests help in choosing between the CEM, FEM, and REM. The Chow Test compares the CEM with the FEM to determine which model better fits the data. If the test statistic is significant, it indicates that the FEM is more suitable than the CEM. The Hausman Test compares the FEM with the REM model. If the test statistic is significant, it indicates that the

FEM is more appropriate than the REM. The results of these tests are summarized in **Table 4**.

Table 4. Chow and Hausman test results.

Test Summary	Statistic	d.f.	Prob.
Chow Test			
Cross-section F	347.471.752	−12,48	0.0003
Cross-section Chi-square	290.929.274	12	0.0002
Hausman Test			
Cross-section random	6.883.509	4	0.1422

The Chow Test results indicate a chi-square probability value of 0.0003, which is less than 0.05, leading to the rejection of null hypothesis (Ho). This suggests that the FEM is more suitable than the CEM. The Hausman Test results show a chi-square probability value of 0.1422, which is greater than 0.05, indicating that the REM is more appropriate than the FEM. Based on the results of the Chow Test and Hausman Test, the REM is identified as the most appropriate model for this research, examining the impact of under-five health index, poverty level, and family size on the HDI. The selection process involves interpreting the significance levels of the tests to decide on the best-fitting model. The Chow Test helps determine whether the FEM is better than the CEM, while the Hausman Test helps decide between the FEM and REM. If the Chow Test selects the FEM and the Hausman Test does not reject the REM, then the REM is chosen. If both tests favour the FEM, then the FEM is selected. This ensures the most reliable model is chosen for analysing the impact of various factors on the HDI.

5.4. Coefficient of determination (R^2 test) and F-test

The Coefficient of Determination (R^2) test assesses the proportion of the variance in the dependent variable that is predictable from the independent variables and the F-test evaluates the overall significance of the regression model by examining whether the independent variables collectively have a statistically significant effect on the dependent variable. The results for the REM are presented in **Table 5**.

Table 5. Coefficient of determination (R^2) and F-test for random effect regression model (REM).

Statistic	REM Value
Prob (F-statistic)	0.00000
F-Statistic	21.33048
R-squared	0.587124
Adj. R-squared	0.559598

The R^2 value of 0.587124 indicates that approximately 58.71% of the variations in the HDI across the 13 regencies/cities within Central Sulawesi Province from 2018 to 2022 can be attributed to the variations in the economic indicator (poverty level) and the health indicator (prevalence of underweight). The remaining 41.29% is

influenced by external variables outside the scope of this research. The *F*-statistic of 21.33048 and the corresponding *p*-value of 0.0000 indicate that the combination of independent variables (poverty level, underweight status, and family size) significantly impacts the HDI. Hence, the null hypothesis (H_0) is rejected, affirming the collective significance of the independent variables.

5.5. Partial *t*-tests for Fixed Effect Model (FEM)

The partial t-test assesses the individual impact of each independent variable on the dependent variable. The results are presented in **Table 6**.

Table 6. *t*-test results for FEM.

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
Constant	74.36750	0.989668	75.14390	0.0000
Poverty	−0.389781	0.077318	−5.041269	0.0000
Underweight Status	−0.008553	0.021853	−0.391	0.6972
Household per Capita Income	−0.391146	0.086554	−4.519	0.0000

The t-test results indicate that the Household per Capita Income significantly negatively affects the HDI with a *p*-value of 0.0000. In contrast, poverty and underweight status are not statistically significant in this model.

5.6. Best fit model analysis

The estimation results for the CEM, FEM, and REM are summarized in **Table 7**. This comparison highlights the relationship between economic determinants (poverty level) and health indicators (prevalence of underweight) with the HDI.

Table 7. Estimation results for model selection.

Statistic/Variable	Common Effect	Fixed Effect	Random Effect
Constant (C)	82.50192	74.36750	74.82834
Standard Error	1.731754	0.989668	1.311520
Probability	0.0000	0.0000	0.0000
Poverty	0.119288	−0.389781	−0.427722
Standard Error	0.073511	0.077318	0.074916
Probability	0.1099	0.0000	0.0000
Underweight Status	−0.272758	−0.008553	−0.015510
Standard Error	0.137289	0.021853	0.021665
Probability	0.0515	0.6972	0.4768
Household per Capita Income	−1.069.896	−0.391146	5.87×10^{-6}
Standard Error	0.123538	0.086554	0.083350
Probability	0.0000	0.0000	0.0004

The analysis reveals that the FEM provides the best fit, with the highest adjusted *R*-squared value. The household per capita income and poverty significantly negatively impacts the HDI, while underweight status are not significant predictors in

this model. This suggests that targeted interventions focusing on reducing family size and enhancing family planning services could be more effective in improving human development in Central Sulawesi.

6. Discussion

The HDI serves as a comprehensive metric to evaluate the well-being and quality of life in a region, considering health, education, and standard of living. In recent years, Central Sulawesi has experienced an increase in its HDI value, reaching 70.28 in 2022, positioning it within the high category as defined by the BPS (2022). Despite this progress, the region's HDI remains below the national average, highlighting ongoing challenges in human development. To understand the factors influencing HDI in Central Sulawesi, a panel data regression analysis was conducted, examining the impacts of poverty, the prevalence of underweight among toddlers, and household per capita income. The FEM was determined to be the most suitable model through the Chow Test and Hausman Test, explaining 99.41% of the variation in HDI.

Poverty emerged as a significant negative factor affecting HDI. The regression coefficient for poverty was -0.389781 with a probability value of 0.0000, indicating that there is a negative relationship and statistically significant in this model. It challenges Khumaerah's (2023) finding that poverty rate has not influenced HDI significantly in Banten Province. Higher poverty levels correlate with lower HDI values, reflecting the detrimental effects of economic incapacity on human development. Poverty limits access to essential services such as healthcare, education, and nutrition, which are critical for improving life expectancy, educational attainment, and living standards. As poverty rates increase, the quality of human resources diminishes, leading to poorer health outcomes, lower educational achievements, and substandard living conditions. The finding implies some actions by central and local governments, along with non-government organizations and big companies that have poverty alleviation programs and Corporate Social Responsibility (CSR) funds, are required to reduce poverty substantially to enhance HDI.

The prevalence of underweight among toddlers is another factor that impacts HDI. Malnutrition in young children is a critical issue, as proper nutrition is essential for preventing stunted growth and promoting healthy development. The FEM analysis showed a regression coefficient for underweight prevalence of −0.008553 with a probability value of 0.6972, indicating that this factor did not have a statistically significant impact on HDI within the model. This suggests that while malnutrition is a serious issue, its direct impact on HDI, as measured in this model, might be overshadowed by other factors or require a different analytical approach to capture its full effect. It implies that combating malnutrition in all its forms is one of the greatest health challenges. Women, infants, children, and adolescents are at particular risk of malnutrition. Optimizing nutrition early in life—including the 1000 days from conception to a child's second birthday—ensures the best possible start in life, with long-term benefits.

Household per capita income is another vital determinant of HDI. The FEM analysis revealed a significant negative impact, with a regression coefficient of −0.391146 and a probability value of 0.0000. This indicates that lower household per

capita income is strongly associated with an increase in HDI. Inadequate income restricts access to essential services such as healthcare and education, leading to poorer health outcomes and lower educational attainment. Furthermore, lower income affects the ability to maintain a decent standard of living, resulting in higher rates of malnutrition and underweight conditions among children. These factors collectively hinder human development, underscoring the need for policies that improve income distribution and enhance economic opportunities for all population segments.

The analysis underscores the significant impacts of poverty, malnutrition, and household income on HDI in Central Sulawesi. Addressing these issues requires targeted interventions aimed at reducing poverty, improving nutritional support for children, and enhancing household incomes. By focusing on these areas, policymakers can improve living standards and overall human development, ensuring a healthier, more educated, and economically stable population in the region.

7. Conclusions

The originality of this research lies in its focus on a specific province of Indonesia representing Indonesia's eastern region, providing localized insights and recommendations that are critical for targeted policy making. Our findings emphasize the need for comprehensive policy interventions in nutrition, healthcare, and economic support to enhance human development in the region. These interventions are crucial for addressing the root causes of underweight prevalence and poverty, ultimately leading to improved HDI and overall well-being.

Our study prove that poverty, malnutrition, and household income influence the HDI in Central Sulawesi. Despite recent improvements in the region's HDI, substantial challenges remain. Poverty, with a negative and statistically significant impact in the model, suggests that higher poverty levels influence with lower HDI values, as limited access to essential services such as healthcare, education, and nutrition adversely affects life expectancy, educational attainment, and living standards. The prevalence of underweight among toddlers, although not statistically significant in the model, indicates that malnutrition is a critical issue affecting children's growth and development, which in turn impacts the overall human development in the region. Household per capita income emerged as the most significant variable, with a strong negative impact on HDI. Lower household income restricts access to quality healthcare and education, leading to poorer health outcomes and lower educational attainment, ultimately lowering living standards and HDI.

The study's reliance on secondary data may not fully capture real-time changes or contextual factors influencing human development. Additionally, the exclusion of certain variables, such as cultural practices and regional policies, might limit the comprehensiveness of the findings. We suggest future research directions to examine these other factors influencing HDI. To address these limitations and improve human development in Central Sulawesi, several recommendations are proposed. Expanding and intensifying nutritional programs targeting prenatal and early childhood stages is crucial. Enhancing healthcare access, particularly in rural areas, and investing in sanitation facilities and clean water infrastructure will prevent diseases contributing to malnutrition. Developing economic policies to enhance household incomes through

microfinance initiatives, job creation programs, and vocational training will help lift families out of poverty. Launching comprehensive educational campaigns will raise awareness about proper nutrition and healthcare practices, while fostering intersectoral collaboration will create a cohesive approach to improving health outcomes. Establishing robust monitoring and evaluation systems will ensure the effectiveness of these interventions, allowing for continuous improvement and efficient resource allocation. By adopting these measures, Central Sulawesi can achieve sustained improvements in HDI and overall well-being for its population.

8. Policy implications

To address the high prevalence of underweight children and the significant impact of poverty on human development in Central Sulawesi, targeted and refocusing policy interventions are essential. First, nutritional programs should be expanded to focus on both prenatal and early childhood stages, ensuring that pregnant women have access to nutrient-rich foods and toddlers receive balanced diets emphasizing natural foods over ultra-processed ones. Second, as the drivers of stunting reduction, national and community stakeholders and mothers at the village level cited a combination of poverty reduction, years of formal education, prevention of early marriage, access to food, enhanced knowledge and perception, and increased access to sanitation and hygiene. It requires a capacity building for local government officers and young mother to reduce stunting vastly in Central Sulawesi Province. Stunting often stems from inadequate antenatal nutrition and infant feeding practices, poor access to clean water and sanitation, and recurrent childhood illnesses. Some efforts addressing the gaps in antenatal and early childhood nutrition and health for mothers and their infants using an integrated approach are crucial. In addition, this program will provide comprehensive nutrition education and "zero stunting" program to participating mothers, cadres, and village midwives. Economic support measures such as microfinance initiatives, job creation programs, and vocational training will help lift families out of poverty, enabling them to afford better nutrition and healthcare. Educational campaigns should be launched to raise awareness about proper nutrition and healthcare practices, educating mothers on the benefits of breastfeeding, balanced diets, and avoiding harmful practices.

Third, enhancing healthcare access in rural areas is crucial, including regular health check-ups, vaccinations, and growth monitoring for children under five. Improvements in sanitation facilities and access to clean water are critical for preventing diseases that contribute to malnutrition. Intersectoral collaboration between health, education, and agricultural sectors will create a cohesive approach to improving nutrition and health outcomes, integrating nutritional education into school curricula, and supporting local farmers to produce nutrient-rich foods. Establishing robust monitoring and evaluation systems will ensure that the effectiveness of these interventions is tracked, helping identify areas for improvement and ensuring efficient use of resources. By implementing these policies, Central Sulawesi can address the root causes of underweight prevalence and poverty, leading to improved HDI and better overall well-being for its population.

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Ethical approval: This study was conducted in accordance with the ethical standards of the institutional research committee of Universitas Tadulako and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. The study protocol was approved by the Ethics Committee of Universitas Tadulako (approval number: 11269/UN28.4/KP.10.00/2024, date:1 November 2024). The official document can be viewed as supplementary material.

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