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Research paper

What Drives Human Development in Sumatra? A Study of Life Expectancy, Literacy, and Nutrition

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Abstract

This study aims to examine the impact of life expectancy, literacy rate, calorie consumption, and protein consumption on the Human Development Index (HDI). The analysis utilizes secondary data collected from six provinces on the island of Sumatra over the period 2019 to 2023. Employing a quantitative approach, the study applies panel data regression to investigate the relationship between the selected variables and HDI. The findings reveal that life expectancy and protein consumption each have a significant positive effect on HDI. In contrast, literacy rate does not exhibit a statistically significant effect, as indicated by a significance value of 0.9178. Interestingly, calorie consumption demonstrates a significant negative influence on HDI, with a coefficient of -0.988981. Overall, the four independent variables collectively account for 70.11% of the variation in HDI across the six provinces, while the remaining 29.89% is attributed to other factors not examined in this study.

Keywords: *Human Development Index; Life Expectancy; Literacy Rate; Panel Data Regression.*

1. Introduction

Human development is a comprehensive development paradigm that places people at the center and the ultimate goal of all development efforts. Since 1990, the United Nations Development Program (UNDP) has emphasized that development must prioritize human welfare and quality of life as primary objectives. Assessing the success of development in each region requires reliable methods and approaches to measure improvements in population well-being.

According to Ginting et al. (2023), development is a process of intentional transformation aimed at achieving better future conditions compared to the present. This concept applies not only at the local level but also at the national level, where continuous changes occur across various aspects of life to enhance well-being and realize a fair and prosperous society.

One of the key ways to measure national development success is by evaluating the population's quality of life. Human development aims to enhance the quality of human resources by utilizing advancements in science and technology to address global development challenges. In the social context, human development focuses on improving societal well-being, enabling individuals to live in better conditions. Any positive transformation in a region can be considered part of the broader development process (Garnella, Wahid, & Yulindawati, 2020). In this context, welfare refers to the population's ability to meet basic needs, such as food, clothing, and shelter—essential components for sustaining life.

Sumatra, one of Indonesia's largest islands, plays a critical role in national development due to its abundant natural and human resources. Despite the strategic importance of human development in national priorities, many challenges remain in improving the Human Development Index (HDI) across Sumatra's provinces.

One key HDI component is Life Expectancy, which reflects the general health conditions of a population. Variations in life expectancy across Sumatra's provinces indicate disparities in healthcare availability, quality of services, sanitation, and environmental factors. The life expectancy indicator aims to address geographic and infrastructure gaps that contribute to health inequalities. Effective public health investment, especially in underserved regions, is critical to reducing premature mortality and ensuring longer, healthier lives (Aulia Febiola, 2024). Improvements in life expectancy directly contribute to a higher HDI, representing successful development in the health sector.

Another crucial HDI component is education, which serves as a key measure of human development quality. As Ismanti (2017) noted, education is the foundation of human capital development. The performance of the education sector is a major determinant of HDI. However, education remains a complex issue in many parts of Sumatra, resulting in lower HDI scores. In this study, education is represented by the literacy rate among individuals aged 15 and above, categorized by their place of residence.

Imelda, Balafif, and Wahyuni (2021) emphasized the importance of government policy, such as implementing a 12-year compulsory education program to improve educational quality in Indonesia. A better-educated population enhances the overall quality of human resources and contributes to increased literacy, which remains uneven due to disparities in access to schools from basic to higher education.

In addition to education, nutritional intake—specifically calorie and protein consumption—is also critical to human development and HDI performance (Ismanti, 2017). Caloric intake is a multifaceted issue influenced by both health and non-health factors, including food

availability and dietary habits. Inadequate caloric intake, whether due to insufficient quantity or poor nutritional quality, has direct and indirect causes, such as poverty or food insecurity at the household level.

Furthermore, protein consumption is essential for human development. Adequate nutrition enables individuals to function optimally and contribute to national development. The relationship between protein adequacy and human capital quality reflects the importance of good nutrition in achieving favorable health outcomes (CSA, 2021). Protein plays a vital role in cellular metabolism and tissue formation, and deficiencies can lead to diminished physical performance and cognitive capacity—factors that affect a region's HDI.

This study investigates the effects of four variables—life expectancy, literacy rate, caloric intake, and protein consumption—on the Human Development Index. The research focuses on six provinces in Sumatra: Aceh, North Sumatra, West Sumatra, Riau, Jambi, and South Sumatra. These provinces demonstrate notable HDI variation, reflecting disparities in socioeconomic conditions, infrastructure, and cultural contexts. Such inequality poses significant challenges to achieving equitable human development across the island.

The selected variables have not been widely examined simultaneously in prior studies, particularly with respect to Sumatra. This study is guided by the nutritional theory proposed by Robert Fogel (1994), which emphasizes the impact of caloric and protein intake on development outcomes. Additionally, few studies have conducted comparative analyses that consider the unique socioeconomic characteristics of each province.

By incorporating calorie and protein intake as essential indicators of nutritional adequacy, this study addresses a gap in HDI research. Nutrition plays a critical role in shaping human capital quality, yet it is often overlooked in development analysis. This study contributes a new perspective by integrating nutritional factors into the analysis of HDI determinants on Sumatra Island.

The comparative framework employed in this research allows for identifying region-specific patterns and influencing factors, providing insights for more targeted and effective policy interventions. By considering the heterogeneity of each province, the study offers policy recommendations that align with local contexts and support more inclusive and balanced human development across Sumatra.

2. Literature Review

2.1. Human development index

The Human Development Index (HDI) was first introduced in 1990 by Amartya Sen and Mahbub ul Haq, a Pakistani economist, with support from Gustav Ranis, a prominent development economist, and Frank Altschul, Professor Emeritus of International Economics at Yale University. Amartya Sen argued that "hunger is not caused by a lack of food, but rather by inequalities in the distribution of food as a result of an unjust social system." According to the Central Statistics Agency (CSA, 2018), the Human Development Index is an indicator used to measure human development achievements as a fundamental component in assessing the quality of life of a population.

Sen's theory, as proposed in his seminal work Development as Freedom (1999), emphasizes that human development is based on several core components of quality of life: health, education, and a decent standard of living, often proxied by per capita expenditure. The Human Development Index Booklet 2017 (CSA, Sidoarjo Regency) explains that HDI, introduced by the United Nations Development Program (UNDP) in 1990, was a new approach to measuring human development. Since then, HDI has been published periodically in the annual Human Development Report (HDR).

In general, the concept of human development encompasses various aspects of development from a human-centered perspective, rather than being limited to economic growth. The HDI is a tool used to reduce the complexity of human development into a measurable index. While it cannot capture every aspect of human development, it does represent several key dimensions (CSA, 2013). The HDI reflects the population's quality of life by assessing health, education, and a decent standard of living, which can be approximated through income levels (Tamara & Yeniwati, 2020).

Todaro and Smith (2012) also emphasize that HDI is not merely a function of economic growth, but rather an assessment of improvements in the quality of human life, which include education, health, and adjusted per capita expenditure. As a composite index, HDI measures the average achievement of a country in expanding people's choices — specifically, the ability to live a long and healthy life, to acquire knowledge, and to access resources necessary for a decent standard of living (Santika et al., 2022). The UNDP (1995) further elaborates that human development is the process of enlarging people's choices, involving a broad range of interrelated dimensions.

The analysis shows that the Human Development Index (HDI) at the district/city level for the 2020-2023 period had an average of 73.17, whereas the national average during that time was 75.02. The average Human Development Index (HDI) noted, and with an increase of 8.36 points, the HDI performance for districts/cities falls under the "Medium" classification (60 <= HDI < 70). This suggests that the economic development process in the district/city context has emphasized human resources to enhance quality and engage actively in continuous development initiatives. The typical life expectancy of residents in the district/city during the 2020-2023 timeframe was noted to be 73.17 years, remaining lower than the national average life expectancy of 73.46 years (Nur, Anjani et al, 2025)

2.2. Life expectancy

According to the Human Development Theory proposed by UNDP (1990), life expectancy is one of the key health dimensions that influences HDI. The World Health Organization (WHO, 2020) states that life expectancy reflects the socioeconomic and health conditions of a particular area. A higher life expectancy suggests better living conditions and a higher overall quality of life. As a result, life expectancy is used as one of the indicators in calculating HDI. Specifically, life expectancy at birth measures the general health of a population, factoring in healthcare infrastructure, access, and service quality.

Life expectancy (known in Indonesia as Angka Harapan Hidup, AHH) is one of the most important indicators for assessing the standard of living within a country or region. It is defined as the average number of years a person is expected to live, based on current mortality rates. AHH is an aggregate measure that encompasses mortality across all age groups and serves as a primary component in HDI calculation. Life expectancy can be calculated at various age points, not only at birth. For instance, life expectancy at age 65 indicates how many additional years a person aged 65 is expected to live.

As such, AHH is a comprehensive measure of public health, reflecting not only mortality rates but also broader quality of life dimensions. It is influenced by a complex set of interrelated factors. While advances in medical science and socioeconomic improvements have contributed to the global rise in life expectancy, emerging challenges such as non-communicable diseases, inequality, and climate change continue to present obstacles. A comprehensive understanding of these factors is essential for developing effective public policies aimed at enhancing and equalizing life expectancy across different populations.

2.3. Literacy rate

According to the Human Capital Theory proposed by Gary S. Becker (1964), improving human resources through education and skills development significantly contributes to human development and societal welfare. Education plays a vital role in fostering individual capacity and contributing to broader development goals. One of the primary indicators of educational attainment is the literacy rate, which reflects the proportion of the population that can read and write.

Literacy rate is an important indicator for measuring the equitable distribution of prosperity. Megantara and Budhi (2020) argue that a high literacy rate can signal more equal access to education and opportunities. Mursyidah, Wahyuni, and Asrida (2022) define literacy rate as the proportion of the population aged 15 and above who can read and write simple sentences in Latin, Arabic, or other scripts, without necessarily understanding the content. Literacy rates continue to fluctuate due to disparities in the availability and quality of education, especially between urban and rural or remote areas.

The Central Statistics Agency (BPS) defines a literate individual as someone who can read and write Latin or other scripts, regardless of comprehension. According to UNESCO (2021), the literacy rate (also referred to as Angka Melek Huruf or AMH) is the percentage of individuals aged 15 and above who can read and write. This indicator is crucial in measuring educational outcomes and human development across regions. The literacy rate ranges from a minimum of 0 to a maximum of 100, representing the full spectrum from total illiteracy to universal literacy. Therefore, literacy rate serves as a key proxy for assessing the equitable distribution of social welfare.

2.4. Calorie consumption

The Nutritional Theory proposed by Robert Fogel (1994) in Economic Growth, Population Theory, and Physiology suggests that improved nutrition—particularly calorie intake—contributes to human development and economic growth by enhancing labor productivity and life expectancy. However, poor-quality nutrition may not yield positive outcomes, underscoring the complexity of nutritional issues, which span multiple sectors beyond health.

Calories are the units of energy used to measure the amount of energy derived from food and beverages. In nutritional contexts, the term "calorie" typically refers to "kilocalories" (kcal), equivalent to 1,000 calories. Calorie consumption reflects the total energy intake from food and drink within a given period, usually measured per day. A clear understanding of this concept is essential for health, nutrition, and weight management.

According to Kompas (2023), calorie consumption is a key indicator of population welfare. It is calculated by multiplying the quantity of food consumed by its caloric content. The Recommended Dietary Allowance (RDA) represents the average daily nutritional intake needed by individuals based on age, gender, body size, and activity level to maintain optimal health. In Indonesia, the recommended daily calorie intake is 2,100 kcal per person. However, data from the Central Statistics Agency (CSA) indicate that the average daily calorie consumption often exceeds this standard. Rusliyawati, Suryani, and Ardian (2020) emphasize that calories are a basic human need for sustaining life and daily functioning.

2.5. Protein consumption

The Nutrition and Productivity Theory proposed by Strauss and Thomas (1998) posits that sufficient protein consumption serves as an investment in health, improving human resource quality and thereby contributing to HDI. Nutritional intake, particularly protein, significantly impacts an individual's health status. Nutrition is a fundamental component in promoting well-being, supporting physical strength, cognitive development, and disease prevention — all of which are critical for national progress.

According to the Regulation of the Minister of Health of the Republic of Indonesia No. 41/2014 on Balanced Nutrition Guidelines, a balanced diet must include the appropriate types and amounts of nutrients required by the body to prevent nutritional problems. In Indonesia, the recommended daily protein intake (Angka Kecukupan Gizi/AKG) is 57 grams, which is relatively low compared to countries such as the United States and Australia, where the standard is around 110 grams/day.

Rusliyawati, Suryani, and Ardian (2020) state that nutrition plays a vital role in providing energy, repairing tissues, and regulating biochemical functions. The word protein derives from the Greek protos, meaning "first" or "primary," indicating its essential role in biological processes. Proteins are organic compounds composed of carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus. They are crucial for the growth, maintenance, and function of all living organisms.

3. Method

3.1. Research location

This research was conducted in six provinces on the island of Sumatra: Aceh, North Sumatra, West Sumatra, Riau, Jambi, and South Sumatra. The selection of these locations was based on several considerations and supporting factors for determining appropriate study sites. One key factor was geographical and demographic representation, as these six provinces form a strategic area on the island with significant variation in both geographical features and population characteristics. Moreover, each province possesses unique development characteristics. The selection also considered the aspect of development equity by including provinces with high, medium, and low levels of the Human Development Index (HDI).

3.2. Research period

The study covers a five-year period using time series data from 2019 to 2023. This time frame was chosen based on the availability of the most recent data from the Central Statistics Agency (CSA), which reflects the latest development conditions. Additionally, this period includes the years before, during, and after the COVID-19 pandemic, allowing the analysis to capture trends and shifts in development across the provinces. The availability of complete data for all variables during this period further supports its selection. With the chosen research locations and time frame, this study is expected to provide a comprehensive overview of the factors influencing the Human Development Index on the island of Sumatra.

3.3. Data collection techniques

Data collection techniques refer to the methods used during the research process to gather the necessary data for answering the research questions. Data collection is a crucial component of any study, as the primary goal is to obtain reliable data (Sugiyono, 2019). In this study, a literature review method was used, involving the reading, comprehension, and analysis of various sources such as books, academic journals, relevant literature, documentation, and other related references. The type of data used in this study is secondary data obtained from official publications of the Central Statistics Agency (CSA), including tables, diagrams, and documentation. Secondary data refers to pre-existing data that is not obtained directly from primary sources but rather accessed through other means, in this case, the CSA website.

3.4. Data analysis techniques

In quantitative research, the formulation of research problems must be followed by appropriate analytical methods to solve them. The data analysis process is therefore essential in concluding the research. According to Sugiyono (2019), quantitative data analysis involves processing data collected from respondents or other sources. This study utilizes panel data regression analysis using the EViews 10 software. Panel data is a combination of cross-sectional and time series data. Cross-sectional data are collected and measured during a specific time across multiple entities, while time series data are collected over several time periods for a single entity. Thus, panel data allows this study to examine each province over multiple years, enabling a more dynamic analysis of development patterns and the factors influencing the Human Development Index in Sumatra.

4. Result and Discussion

4.1. Chow test

The Chow test is used to determine the most appropriate model between the Common Effect Model (CEM) and the Fixed Effect Model (FEM). This is done by examining the probability values of the Cross-section F and Chi-square statistics. If the probability values are less than 0.05, the Fixed Effect Model (FEM) is preferred, and thus the alternative hypothesis (H1) is accepted while the null hypothesis (H0) is rejected. Conversely, if the probability values exceed 0.05, the Common Effect Model (CEM) is more appropriate, indicating acceptance of H0 and rejection of H1.

Table 1: Chow Test Results

Effects Test	Statistic	df	Prob.
Cross-section F	39.691.290	(5,2)	0.0000
Cross-section Chi-square	71.725.632	5	0.0000

Based on the Chow Test results, the Cross-section F value was 39.691 with a probability of 0.0000, and the Cross-section Chi-square value was 71.726 with a probability of 0.0000. Because the probability value is smaller than the 5% significance level ($\alpha = 0.05$), the null hypothesis (H0), which states that the model can be combined, is rejected. Thus, there are significant structural differences between cross-sections. This means that the pooled regression model (pooled OLS) is not appropriate to use because the regression coefficients are significantly different for each cross-sectional unit. Therefore, a more suitable model to use is the Fixed Effect Model (FEM), which can accommodate differences in characteristics between individuals/groups in the data.

4.2. Hausman test

The Hausman test is conducted to choose between the Fixed Effect Model (FEM) and the Random Effect Model (REM). If the probability value of the Cross-section random component is less than 0.05, the Fixed Effect Model (FEM) is deemed more appropriate, indicating acceptance of H1 and rejection of H0. If the probability value exceeds 0.05, the Random Effect Model (REM) is preferred, meaning H0 is accepted and H1 is rejected.

Table 2: Hausman Test Results

Test Summary	Chi-Square Statistic	Prob.
Cross-section random	7.612629	0,1086

Based on the Hausman test results, the Chi-Square statistical value was 7.613 with a probability of 0.1068. Because the probability value is greater than the 5% significance level ($\alpha = 0.05$), the null hypothesis (H0) cannot be rejected. This shows that the more appropriate model to use is the Random Effect Model (REM). Thus, it can be concluded that there is no significant correlation between individual effects (cross-sectional effects) and the independent variables in the model. Therefore, the use of REM is more efficient than the Fixed Effect Model (FEM) in this research.

4.3. Lagrange multiplier (LM) test

The Lagrange Multiplier test is the final test used to determine the suitability of the Random Effect Model (REM) compared to the Common Effect Model (CEM). If the Breusch-Pagan probability value is less than 0.05, the REM is more appropriate, leading to the acceptance of H1 and rejection of H0. Conversely, if the probability is greater than 0.05, the CEM is preferred, indicating acceptance of H0 and rejection of H1.

Table 3: Lagrange Multiplier Test Results

Null Hypothesis (No Random Effect)	Cross-section	Period	Both
Alternative (One-sided)	20.88660 (0.0000)	0.341632 (0.5589)	21.22823 (0.0000)

Based on the results of the Breusch-Pagan Lagrange Multiplier (LM) test, the Cross-section value was 20.887 with a probability of 0.0000, Period was 0.342 with a probability of 0.5589, and Both was 21.228 with a probability of 0.0000.

These results show that in the Cross-section and both tests, the probability value is smaller than the 5% significance level (α = 0.05), so the null hypothesis (H0) is rejected. Thus, there is a significant random effect, so the Random Effect Model (REM) model is more appropriate to use compared to the Pooled OLS model. Meanwhile, in the Period test, the probability is greater than 0.05, so there is no significant period effect. Thus, it can be concluded that the dominant effect is found in the cross-section, and the panel data model that is most suitable to use is the Random Effect Model (REM).

4.4. Panel data regression analysis

This study utilizes panel data regression to examine the relationship between Life Expectancy, Literacy Rate, Calorie Consumption, and Protein Consumption on the Human Development Index (HDI) across six provinces on the island of Sumatra from 2019 to 2023. Based on model estimation, the Random Effects Model (REM) was identified as the most appropriate approach. The regression output is presented in Table 7:

Table 4: Random Effects Model (REM) Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C (Constant)	5.447502	7.559168	7.206483	0.0000
Life Expectancy (AHH)	0.286916	0.079915	3.590254	0.0014
Literacy Rate (AMH)	0.000373	0.003576	0.104267	0.9178
Calorie Consumption (KK)	-0.988981	0.221860	-4.457676	0.0002
Protein Consumption (KP)	3.023544	5.229084	5.782168	0.0000
R-squared: 0.742351				
Adjusted R-squared: 0.701127				
F-statistic: 18.00781				
Prob(F-statistic): 0.000000				

Interpretation of the Results

1) Intercept (Constant):

The constant value of 5447.502 suggests that if all independent variables are held at zero, the HDI would be expected to be 5447.502. While this has limited practical meaning (as zero values for predictors like life expectancy are unrealistic), it serves as the baseline intercept of the model.

2) Life Expectancy (AHH):

The regression coefficient for Life Expectancy is 0.286916 and is statistically significant (p-value = 0.0014 < 0.05). This implies that for every one-year increase in life expectancy, the HDI increases by approximately 0.287 units, holding other variables constant (ceteris paribus).

3) Literacy Rate (AMH):

The coefficient for Literacy Rate is 0.000373 and is statistically insignificant (p-value = 0.9178 > 0.05). This indicates that changes in literacy rate have no statistically significant effect on HDI in this model.

4) Calorie Consumption (KK):

The regression coefficient is -0.988981 and statistically significant (p-value = 0.0002 < 0.05), suggesting that a one kilocalorie increase in per capita calorie consumption is associated with a decrease in HDI by approximately 0.989 units, assuming other variables remain constant. This counterintuitive result may indicate underlying nutritional quality or socio-economic disparities and warrants further investigation.

5) Protein Consumption (KP):

The coefficient is 30.23544 and is highly significant (p-value = 0.0000 < 0.05). This indicates that an increase of one gram per capita per day in protein consumption is associated with an increase in HDI by 30.235 units, holding other variables constant.

4.5. Hypothesis testing

1) Coefficient of Determination (R^2)

This value reflects the proportion of variance in the dependent variable (HDI) that is explained by the independent variables in the model.

Table 5: Coefficient of Determination

Category	Value
R-squared	0.742351
Adjusted R-squared	0.701127

The Adjusted R-squared value of 0.701127 (or 70.11%) implies that the independent variables collectively explain 70.11% of the variability in HDI. The remaining 29.89% is explained by other factors not included in this model.

2) Partial Hypothesis Testing (t-Test)

This test evaluates the individual significance of each independent variable using a 5% significance level (α = 0.05). With a degrees of freedom (df) of 28, the critical t-value is approximately 2.048407.

Table 6: t-Test Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.447.502	7.559.168	7.206.483	0.0000
AHH	0.286916	0.079915	3.590.254	0.0014
AMH	0.000373	0.003576	0.104267	0.9178
KK	-0.988981	0.221860	-4.457.676	0.0002
KP	3.023.544	5.229.084	5.782.168	0.0000

Interpretation:

1) Life Expectancy (AHH): The t-statistic (3.590254) > t-table (2.048407), and p-value < 0.05. Thus, Life Expectancy has a significant positive effect on HDI.

2) Literacy Rate (AMH): The t-statistic (0.104267) < t-table, and p-value > 0.05. Thus, Literacy Rate does not significantly affect HDI.
3) Calorie Consumption (KK): The t-statistic (-4.457676) < t-table, and p-value < 0.05. Thus, Calorie Consumption has a significant negative effect on HDI.
4) Protein Consumption (KP): The t-statistic (5.782168) > t-table, and p-value < 0.05. Thus, Protein Consumption has a significant positive effect on HDI.

3) Simultaneous Hypothesis Testing (F-Test)

The F-test assesses whether all independent variables jointly influence the dependent variable. At a 5% significance level with degrees of freedom df1 = 4 and df2 = 25, the critical F-value is 2.75871.

Table 7: F-Test Results

Category	Value
F-statistic	1.800781
Prob(F-statistic)	0.000000

Since the F-statistic (18.00781) > F-table (2.75871) and the p-value < 0.05, the null hypothesis is rejected. This indicates that the independent variables collectively have a statistically significant effect on HDI.

5. Discussion

5.1. The influence of life expectancy on the human development index (HDI) in six provinces of Sumatra Island

The analysis and hypothesis testing revealed that life expectancy exerts a positive and statistically significant influence on the Human Development Index (HDI) across six provinces in Sumatra. This conclusion is supported by the regression coefficient of 0.286916, with a p-value of 0.0014, which is well below the 5% level of significance ($\alpha = 0.05$). Although the effect is significant, the magnitude of the influence is relatively modest. This can be attributed to the long-term and complex nature of factors affecting life expectancy. Elements such as access to healthcare, socioeconomic conditions, environmental quality, lifestyle, and nutritional adequacy all play interconnected roles. For instance, while improving healthcare services can enhance life expectancy, such outcomes typically require sustained investments and long periods before manifesting as measurable gains in HDI. Similarly, economic advancement and improved nutrition contribute to better health, but their full impact on life expectancy and subsequently HDI emerges gradually over time.

5.2. The influence of literacy rate on the human development index (HDI) in six provinces of Sumatra Island

In contrast, the literacy rate does not exhibit a statistically significant impact on the HDI in the provinces under study. The regression results show a coefficient of 0.000373 with a p-value of 0.9178, exceeding the 5% significance threshold. This lack of significance likely stems from the already high literacy rates observed across most provinces in Sumatra, which reduces the variability of the variable and, consequently, its explanatory power regarding HDI. Furthermore, the relationship between literacy and HDI is influenced by multiple interconnected factors such as access to and the quality of education, socioeconomic status, gender disparities, government policy, and technological access. For instance, even if literacy improves, without corresponding enhancements in education quality and infrastructure, the broader impact on HDI remains limited. The literacy rate does not greatly impact the Human Development Index because of various factors. Initially, the literacy rate solely assesses the capability to read and write, overlooking the quality of education or deeper comprehension. Moreover, the HDI considers additional elements like anticipated years of education, mean years of schooling, and income per person, which might exert a more significant impact. Third, it is possible that even if literacy rates rise, there may not be a corresponding improvement in educational quality or the use of literacy skills in everyday life, resulting in a limited effect on HDI

Table 8: Data on literacy, the Quality of Education, and Access between Provinces

Province	Literacy Rate (%)	Notes
Aceh	97.1%	High literacy, but gaps in remote areas.
North Sumatra	98.5%	Among the highest literacy rates in Sumatra.
South Sumatra	98.2%	High literacy, but gaps remain in rural areas.
Riau	98.0%	High literacy, supported by a more developed economy.
Bengkulu	96.5%	Slightly lower than other Sumatra provinces.
Jambi	97.2%	Literacy rate is good, but remote areas face challenges.

The literacy rate in Indonesia, including Sumatra, varies by province. Below is an estimate of literacy rates based on available data from BPS (Badan Pusat Statistik) and UNESCO:

5.3. The influence of caloric consumption on the human development index (HDI) in six provinces of Sumatra Island

Interestingly, caloric consumption demonstrates a negative and statistically significant effect on HDI, as evidenced by a coefficient of -0.988981 and a p-value of 0.0002, which is below the 5% significance level. This negative association may appear counterintuitive, but it can be explained by various factors within the domains of health, nutrition, and lifestyle. Physiological and psychological health can deteriorate due to excessive caloric intake, particularly when not balanced with proper nutrition. This can lead to obesity and related health issues that reduce productivity and life quality. Additionally, lifestyle and environmental factors contribute significantly; for instance, populations with high caloric intake but poor health behaviors, such as low physical activity levels, are likely to experience adverse health outcomes. These health detriments, in turn, diminish human development progress despite high energy intake. Socioeconomic indicators are one of several elements that contribute to negative average levels of calorie consumption. Supriyanto (2012) states that a food and nutrition system approach, which comprises subsystems for processing, production, distribution, and health and nutrition, can be used to identify nutritional or calorie issues. The first step in achieving the best possible nutritional status for the population is to provide suitable meals. Increasing and leveling domestic food production, particularly for rice commodities, which are the primary source of calories consumed by East Javans, can help ensure an adequate supply of food. In addition, the quantity and kind of food that individuals eat—whether

they cook it themselves or buy it—have a significant impact on how many calories they consume. Additionally, nutritional preferences vary from person to person. Therefore, the average amount spent on food consumption can be used as a gauge to find out how many calories a population consumes on average. Aisyah and associates. Malnutrition issues can also be caused by indicators of poverty and unemployment, such as a daily average calorie intake per capita that falls below the Adequate Nutritional Value (ANV) minimal level. The improvement of human resource quality, which is a prerequisite for progress in all domains, is another significant aspect. The reason for this is that good This is because proper and balanced nutritional health significantly impacts the attainment of higher quality human resources, particularly concerning initiatives to enhance intelligence, productivity, and creativity among these resources

5.4. The influence of protein consumption on the human development index (HDI) in six provinces of Sumatra Island

Protein consumption, on the other hand, exhibits a strong positive and statistically significant relationship with HDI. The regression coefficient for this variable is 30.23544 with a p-value of 0.0000, indicating a highly significant effect at the 5% level. This robust impact is grounded in the role of protein in health and development. Adequate protein intake supports the formation of body tissues, hormones, and immune functions, thereby improving overall health and life expectancy. Furthermore, sufficient protein consumption is vital for cognitive development, particularly in children and adolescents, which in turn enhances educational outcomes. Unlike calorie intake, which can be derived from nutrient-poor sources, high protein consumption often reflects healthier dietary patterns. Thus, regions with higher and better-quality protein intake, accompanied by good healthcare and education, tend to experience greater improvements in human development indicators.

5.5. The joint influence of life expectancy, literacy rate, caloric consumption, and protein consumption on the human development index (HDI)

The simultaneous testing using the F-test confirms that life expectancy, literacy rate, caloric consumption, and protein consumption collectively exert a statistically significant influence on HDI in the six provinces of Sumatra. The F-statistic value of 18.00781 surpasses the critical value of 2.75871, and the associated p-value is 0.000000, which is well below the 5% level of significance. This indicates that the combined effect of these four variables can significantly explain variations in HDI across the studied regions. In essence, human development in these provinces is shaped by a combination of health conditions—reflected by life expectancy and nutrition (calories and protein)—and education levels, as indicated by literacy rates. Even though individual variables may vary in significance and impact, their cumulative effect is pivotal in determining the overall human development trajectory of the region.

6. Conclusion

Based on the research findings and discussion, several conclusions can be drawn regarding the relationship between various human development determinants and the Human Development Index (HDI) across six provinces on the island of Sumatra. First, life expectancy was found to have a positive and statistically significant effect on HDI. This result implies that improvements in life expectancy contribute meaningfully to enhancing human development. In other words, when individuals experience longer and healthier lives, it positively reflects on the overall development indicators of the region. Second, literacy rate did not demonstrate a statistically significant impact on HDI. This may be attributed to the already high levels of literacy in the region, which may have reached a saturation point where further increases no longer substantially influence human development outcomes. Most of the population already possesses basic reading and writing skills, which means that improvements in literacy may not be as influential as other variables in driving HDI. Third, calorie consumption was found to have a negative and significant effect on HDI. This counterintuitive finding suggests that higher caloric intake does not necessarily equate to better nutritional status. In some cases, excessive or imbalanced calorie consumption can be linked to poor health outcomes, such as malnutrition or obesity, which ultimately hinder human development progress. Fourth, protein consumption exhibited a positive and significant effect on HDI. This indicates that improvements in the quality of nutritional intake—particularly the consumption of protein-rich foods—play a vital role in supporting human development. Adequate protein intake is essential for physical and cognitive growth, and its presence in the daily diet contributes to better health and education outcomes. Finally, based on the results of the overall model testing, the combined influence of life expectancy, literacy rate, calorie consumption, and protein intake was found to have a statistically significant effect on HDI when considered simultaneously. This finding highlights the multifaceted nature of human development and underscores the importance of a holistic approach that integrates health, education, and nutrition indicators to achieve sustainable progress in human welfare. To conclude, it has been stated that 29.89% of HDI is affected by additional factors. Hence, the author proposes that the income variable might be incorporated in future studies

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