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Environmental and Socio-Economic Determinants of Life Expectancy: Empirical Evidence from Indonesia

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Abstract: The objective of this research is to evaluate the influence of several key socioeconomic and public health factors namely, access to clean water and sanitation, the open unemployment rate, education levels, and per capita health expenditure on Life Expectancy in Indonesia. Utilizing panel data from all 34 provinces over the period 2020–2023, the analysis employs a panel regression methodology. The most appropriate model was selected through the Chow Test and Hausman Test, which indicated the Fixed Effects Model (FEM) as the most robust estimator. The findings reveal that access to clean water, access to sanitation, and education have a positive and statistically significant effect on life expectancy. Conversely, the open unemployment rate exerts a significant negative influence. Education emerged as the most dominant variable, with each additional year of mean schooling associated with an increase in life expectancy of 1.41 years. However, per capita health expenditure was not found to have a statistically significant impact. In conclusion, this study affirms that enhancing life expectancy requires an integrated policy approach. This includes improvements in basic infrastructure (water and sanitation), the expansion of educational access, and a reduction in unemployment rates to foster the socio-economic stability that underpins population health.

Keywords: *life expectancy, human capital, socioeconomic determinants, unemployment*

INTRODUCTION

Within the modern development paradigm, a nation's progress is no longer gauged solely by economic growth, but rather by the holistic improvement of its human quality of life. In this context, Life Expectancy holds a pivotal position as a key indicator representing the overall health condition of a population. Defined as the average number of years a person is expected to live from birth, a high life expectancy figure indicates a nation's success in addressing issues of health, nutrition, and the environment (Lawal et al., 2021). Beyond merely being a health metric, Life Expectancy is a core component in the calculation of the Human Development Index (HDI), underscoring the central role of health in evaluating human development progress (Verawaty et al., 2021).

The importance of Life Expectancy has gained considerable traction, in direct correspondence with global commitments under the Sustainable Development Goals (SDGs), specifically Goal 3 on Good Health and Well-being. From this perspective, health is conceptualized

not solely as a final output, but also as a fundamental catalyst for a country's economic growth. A population's good health status and high life expectancy are crucial pillars for economic growth, as they enhance labour productivity, which is a fundamental engine of the economy (Li et al., 2025). Consequently, efforts to improve Life Expectancy represent a strategic step for both accelerating national development and fulfilling the global agenda until 2030.

Empirically, Indonesia has demonstrated positive progress. According to data from Statistics Indonesia (BPS), from 2020 to 2023, the nation's LE increased from 73.37 years to 73.93 years, with an average annual growth rate of 0.25% (BPS, 2023). However, this achievement remains below that of several neighbouring ASEAN countries, such as Singapore (82.89 years) and Malaysia (76.65 years) (World Bank, 2023). A more complex challenge arises domestically, namely the persistent and substantial disparities in LE between regions. For instance, BPS 2023 data records the LE in the Special Region of Yogyakarta at 75.12 years, while in Papua Province, it is only 66.44 years. This disparity indicates that the determinants of health are not distributed equitably and require in-depth analysis at the regional level.

The factors strongly suspected to influence disparities in health and life expectancy are multidimensional. According to H.L. Blum, environmental factors are a key determinant of health, accounting for 40% of its variation. Consequently, enhanced environmental hygiene, particularly through improved waste management systems, can lead to a marked advancement in a population's health status (Subagio et al., 2020). Access to clean water and adequate sanitation, as a cornerstone of public health, has long been recognised for its role in preventing environmentally-based diseases. A study by Irandoust, K et al. (2025) demonstrates a robust positive relationship between the availability of improved drinking water sources and gains in global life expectancy. The implementation of a rural drinking water safety program in China demonstrated that expanding access to clean water successfully raised the average age of death, an indicator reflecting an overall improvement in a population's health conditions (Shen et al., 2025). A comprehensive study by Roy (2025), analysing data from 190 countries from 2000 to 2022, found a positive correlation between improved access to sanitation facilities and life expectancy. Empirical evidence from South Asia indicates that increased access to adequate sanitation facilities is significantly associated with a reduction in under-five mortality rates, particularly in the post-neonatal period (Ly et al., 2022).

Although national achievements for access to improved drinking water and sanitation are relatively high, at 91.72% and 82.36% respectively (BPS, 2023), interregional disparities remain a serious issue. Data from the 2023 National Socio-Economic Survey (Susenas) reveals wide variations between provinces. For access to improved drinking water, the figures range from

99.42% in DKI Jakarta to 66.49% in Papua. Similarly, access to improved sanitation also varies significantly, from 96.42% in D.I. Yogyakarta to 43% in Papua. Various prior empirical studies have consistently demonstrated a positive correlation between access to clean water and sanitation and increases in life expectancy. However, research by Setyadi et al. (2023) produced a contrasting finding, indicating that access to clean water and sanitation did not prove to have a significant effect on LE. This discrepancy in results is likely attributable to variations in the geographical scope of the studies and local conditions.

The various determinants of life expectancy remain a subject of ongoing debate among experts in medicine, public health, health economics, and political science (Muntaner et al., 2011; Selck and Deckarm, 2015; Setyadi et al., 2023). Research confirms that a population's life expectancy is not solely dependent on healthcare services but is also influenced by various supporting factors, including socio-economic conditions (Jiang, 2023). Michael Marmot's Status Syndrome theory posits that an individual's socio-economic position within society influences their health (Rodríguez-González & Repetto, 2024). One critical social determinant affecting population life expectancy is the level of education (Gómez-Ugarte & García-Guerrero, 2023). Consistent with this, Cauvel & Sanchez (2025) found a positive and significant effect of education on life expectancy.

The theoretical foundation for the education-health relationship is rooted in Michael Grossman's (1972) human capital model (Heryana et al., 2019). This model suggests that education enhances an individual's knowledge capital, which in turn increases their efficiency in producing health (health production efficiency). In other words, more highly educated individuals are assumed to be better equipped to make rational health decisions and to use health inputs such as medical services, time, and lifestyle choices more effectively to maximise their health stock. Over the past two decades in Italy, Denmark, and the United States, changes in the educational structure of the population accounted for 15% to 40% of the gains in life expectancy (Luy et al., 2019). By improving health literacy, education facilitates access to healthcare services and promotes healthier lifestyles, ultimately extending life expectancy (Zhang et al., 2024). Although the causal relationship is complex and difficult to fully disentangle, individuals with higher education typically have access to better-paying jobs and comprehensive health insurance, which can further enhance life expectancy (Kawachi et al., 2010; Danler & Pfaff, 2021).

Beyond education, another significant socio-economic factor is per capita health expenditure, which also correlates significantly with life expectancy (Cauvel & Sanchez, 2025). Evidence suggests that elevated healthcare expenditure is a key determinant of improved population health outcomes, notably declines in infant mortality and gains in longevity (Anwar et

al., 2023). Nketiah-Amponsah (2019) found that higher per capita health expenditure in Sub-Saharan African countries was correlated with a decline in under-five mortality. Increased health expenditure enables better access to and quality of services, such as routine check-ups, treatment, and preventive care, which ultimately positively impact health and raise life expectancy (Cauvel & Sanchez, 2025). Conversely, Dhungana et al. (2024) found that health expenditure financed through direct out-of-pocket payments has a negative effect on life expectancy. High reliance on out-of-pocket financing can have adverse social and economic consequences, particularly for low-income groups who are highly vulnerable, as large health expenditures can erode a household's economic capacity (Owumi & Eboh, 2022).

On the other hand, a high Open Unemployment Rate, as identified in the study by Klärner et al. (2022), is often associated with increased stress, limited access to health resources, and a higher risk of morbidity, which can consequently suppress life expectancy. Globally, high unemployment has been shown to be inversely related to life expectancy. Findings from Monsef & Review (2023) across 136 countries demonstrate that unemployment is not merely an economic burden but also a threat to a population's health and longevity.

However, the literature remains limited in its simultaneous analysis of the influence of socio-economic and environmental variables on life expectancy using panel data in Indonesia. Research that integrates access to sanitation, clean water, unemployment, education, and health expenditure into a single longitudinal analysis for the period 2020-2023 is still scarce, despite these five factors being interrelated in influencing public health. Based on this gap, this study is designed to analyse the impact of access to clean water, access to improved sanitation, the unemployment rate, the education level, and per capita health expenditure on life expectancy across all 34 provinces of Indonesia from 2020 to 2023. Employing a panel data approach, this research can capture variations both across regions and over time. The results are expected to provide comprehensive empirical evidence for policymakers to design more targeted, integrated, and effective interventions to increase life expectancy and reduce interregional disparities. This, in turn, will ultimately accelerate the improvement of Indonesia's Human Development Index (HDI) and the achievement of its SDG targets.

METHOD

This study employs data from all 34 provinces in Indonesia for the period spanning 2020 to 2023. The data utilised is secondary data in the form of a panel dataset, which integrates both time-series and cross-sectional dimensions across the Indonesian provinces. The specific data used in this research are as follows:

Tabel 1. Variables used

Notation	Variable	Sources
LEX	Life Expetacy	Statistics Indonesia
WAT	Acces to clean water	Statistics Indonesia
SAN	Defined adequate sanitation access	Statistics Indonesia
UE	Unemployment	Statistics Indonesia
EDU	Education	Statistics Indonesia
HE	Per capita health expenditure	Statistics Indonesia

The definitions of the variables are as follows: (1) Life Expectancy (LEX) serves as a key statistical measure representing the mean anticipated lifespan for a given population, measured in years; (2) Access to Clean Water (WAT) represents the average proportion of households with adequate access to safe drinking water from improved sources, measured as a percentage; (3)Access to Adequate Sanitation (SAN) refers to the percentage of households with access to improved sanitation facilities, measured as a percentage; (4) Open Unemployment Rate (UE) is the proportion of the labour force that is not employed but is actively seeking work, measured as a percentage; (5) Education Level (EDU) is the average number of years of schooling completed, measured in years; (6) Health Expenditure (HE) denotes the average per capita household out-of-pocket health expenditure, measured in Indonesian Rupiah.

This study applies a panel data regression methodology via Stata to assess the effects of the aforementioned independent variables on health measures. This methodology was selected because it can accommodate a data structure with both time-series and cross-sectional dimensions. This allows the model to control for unobserved individual heterogeneity, thereby yielding more robust and accurate parameter estimates. The panel data regression model is formally specified by the following equation:

$$LEX_{it} = \beta_0 + \beta_1 WAT_{it} + \beta_2 SAN_{it} + \beta_3 UE_{it} + \beta_4 EDU_{it} + \beta_5 LnHe_{it} + U_{it} \quad \text{.....(1)}$$

Where LEXit is the dependent variable representing Life Expectancy in province i and period t. β_0 is the constant (intercept). β_1WATit is the regression coefficient for the Clean Water Access variable in province i and period t. β_2SANit is the regression coefficient for the Sanitation Access variable in province i and period t. β_3UEit is the regression coefficient for the Unemployment Rate variable in province i and period t. β_4EDUit is the regression coefficient for the Education Level variable in province i and period t. β_5LnHE_it is the regression coefficient for

the natural logarithm of per capita Health Expenditure in province i and period t. uit is the error term.

The statistical analysis in this study employs both partial and simultaneous approaches. Partially, the t-test is applied to measure the individual significance of each independent variable's influence on the dependent variable. Simultaneously, the F-test is used to analyse the joint influence of all independent variables on the dependent variable and to assess the coefficient of determination (R-squared).

Prior to interpreting the panel regression results to ensure robust findings, a series of prerequisite tests must be conducted. The estimation strategy proceeds in two stages. First, three competing panel models (CEM, FEM, REM) are evaluated and the most suitable one is selected via statistical tests. Second, the selected model is subjected to diagnostic analysis for violations of classical assumptions—multicollinearity, heteroskedasticity, and autocorrelation to confirm the validity of the inference (Gujarati & Porter, 2009).

RESULT

Indonesia's heterogeneous geographical and demographic background creates complex challenges in achieving equitable health development, where economic, infrastructural, and socio-cultural disparities are strongly suspected to be the determining factors behind interregional variations in health outcomes. Based on unbalanced panel data from 34 provinces over the period 2020–2023 (136 observations) presented in Table 2, the national average life expectancy was 70.33 years with a standard deviation of 2.46. This value, coupled with a narrow min-max range, indicates that extreme interregional disparities in life expectancy were not particularly pronounced during this period.

Aggregately, the basic infrastructure variables access to improved sanitation (SAN) and access to clean water (WAT) show national averages exceeding 80%. However, these aggregate figures mask underlying disparities, particularly in sanitation access, which has a standard deviation of nearly 10% and a minimum value of 40.31%. Conversely, per capita health expenditure (HE) is relatively homogeneous across provinces (standard deviation of 0.45), while the open unemployment rate (UE) is highly heterogeneous with a standard deviation of 1.79 from a mean of 5.28%, reflecting diverse labour market conditions.

Tabel 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LEX	136	70.32537	2.45904	65.06	75.12
WAT	136	86.97787	8.419129	62.47	99.86
SAN	136	81.08757	9.723903	40.31	97.12
UE	136	5.276397	1.791182	2.27	10.95
EDU	136	8.782941	0.9190084	6.69	11.45
LnHE	136	3.22955	0.4475506	2.315995	4.337944

Source: Processed data (2025)

Tabel 3. Model Selection

Type of Test	Result	Conclusion
Chow-Test	0.0000	FEM
Hausman-Test	0.0000	FEM

Source: Processed data (2025)

Diagnostic testing guided the model selection. Both the Chow Test (p=0.0000) and the Hausman Test (p=0.0000) statistically rejected their respective null hypotheses at the 5% level. The Chow Test favoured the FEM over the Pooled OLS, while the Hausman Test indicated the presence of correlated effects, confirming the FEM as superior to the REM. The Fixed Effects Model was therefore selected.

Following the model selection, diagnostic tests for classical regression assumptions were conducted. The multicollinearity test indicated no issues, as the correlation values between all independent variables were below the 0.8 threshold (Gujarati & Porter, 2009). However, tests for heteroskedasticity (prob. 0.0000) and autocorrelation (prob. 0.0000) indicated violations of these classical assumptions. To address these issues and maintain the Best Linear Unbiased Estimator (BLUE) properties of the model, it was corrected using robust standard errors (Stock & Watson, 2019).

Tabel 4. Classical Assumption Test

Type of Test	Result	Conclusion
Multikollinearity	All variables have correlation values below 0.8	No. Multikolliearty Indication
Heterokedasticity	Prob = 0.0000	Heterokedasticity detected
Autocorrelation	Prob = 0.000	Autocorrelation detected

Source: Processed data (2025)

Tabel 5. FEM Estimates After Robustness

Variable	Coefficient	Robust Std. Eror	Prob	Sig *)
WAT	0.0238296	0.0049241	0.000	***
SAN	0.0198856	0.0098963	0.053	*
UE	-0.0754879	0.0252365	0.005	**
EDU	1.409041	0.2315277	0.000	***
LnHE	-0.1224485	0.1087997	0.269	
_cons	55.05848	1.958773	0.000	
R-Square	0.2187			
Adj. R-Square	0.2115			
F-Statistic	96.34			
(Prob.)	(0.0000)			

Note : *) p < 0,1; **) p < 0,05; ***) p < 0,01

Source: Processed data (2025)

The estimation results from the Fixed Effects Model (FEM) are presented in Table 5, which has been corrected for heteroskedasticity using robust standard errors. The model specification is as follows:

LEX_{it} = 55.05848$_{it}$+ 0.0238296WAT$_{it}$ + 0.0198856SAN$_{it}$ – 0.0754879UE$_{it}$ + 1.409041EDU$_{it}$ – 0.1224485LnHE$_{it}$ + u_{it}

The FEM estimates reveal that sanitation (SAN), clean water (WAT), education (EDU), and unemployment (UE) are statistically significant determinants of life expectancy. The coefficient for health expenditure (LnHE), however, is not statistically significant. The coefficient of determination (R-squared) of 0.2187 indicates that the model explains 21.87% of the variation in the data, with the remaining 78.13% accounted for by other variables outside the model. This value is acceptable within the context of macro-health econometrics, given that life expectancy is a multidimensional outcome variable. As posited by Grossman (1972), health status is produced by a multitude of inputs, many of which are non-economic, sociological, and genetic in nature and are difficult to quantify. Consequently, the interpretation of the results places greater emphasis on substantive meaning and theoretical consistency, where goodness-of-fit is not the sole primary criterion for assessment.

An F-statistic of 96.34 with a probability of 0.0000 confirms that, collectively, all independent variables have a statistically significant joint effect on life expectancy. In terms of individual effects: Access to clean water (WAT) has a positive and significant influence (coefficient of 0.02382, prob. 0.0000). Access to sanitation (SAN) exhibits a positive coefficient of

0.019 with a probability of 0.053, indicating a statistical trend where improved sanitation access is marginally associated with higher life expectancy. The education level (EDU) also shows a strong positive and significant effect, with a coefficient of 1.4090 (prob. 0.0000). Conversely, the unemployment rate (UE) exerts a significant negative influence (coefficient of -0.07548, prob. 0.005). In contrast, the natural logarithm of health expenditure (LnHE) is statistically insignificant (coefficient of -0.1224, prob. 0.269), indicating that per capita health expenditure is not proven to affect life expectancy within this model.

DISCUSSION

Public health rests upon two interrelated pillars: access to adequate sanitation and clean water. The combination of these two creates a synergistic effect far greater than the mere sum of each intervention alone. This finding concurs with the research conducted by Zakari et al. (2022), which concludes that access to adequate sanitation and clean water significantly impacts life expectancy. Adequate sanitation serves as the first line of defense by preventing environmental contamination from human waste. Open defecation and inadequate wastewater treatment systems are primary factors in the pollution of soil and water sources by harmful pathogens, leading to the transmission of environmentally borne diseases.

On the other hand, access to clean water acts as a direct barrier, as the consumption of safe drinking water prevents disease-causing pathogens from entering the body. Contaminated drinking water is a significant source of diarrheal diseases, particularly among individuals with weakened immune systems and children under five (Khabo-mmekoa & Genthe, 2022). Evidence from South Asia indicates that improvements in access to clean water supply and sanitation systems are linked to a reduced probability of child mortality, with the impact being most pronounced in the post-neonatal period (Ly et al., 2022). Furthermore, clean water serves as an enabler for optimal hygiene practices. The availability of water in sufficient quantity and quality is an absolute prerequisite for practicing Clean and Healthy Living Behaviors (PHBS), such as handwashing with soap at critical moments, which effectively breaks the chain of disease transmission.

Beyond environmental factors, socioeconomic determinants such as education and the open unemployment rate play an equally critical role in shaping life expectancy. The Open Unemployment Rate (UE) variable exhibits a negative influence, with a coefficient of -0.0754. This finding is consistent with the study by Jiang (2023), which also identified a significant negative correlation between unemployment and life expectancy. Unemployment represents more than a mere economic shortfall; it is a systemic issue that initiates a downward spiral in health and

longevity. Its direct consequences poverty and loss of income materially constrain access to essential healthcare services, frequently resulting in delayed treatment and subsequent deterioration of health conditions. This economic pressure also forces hazardous trade-offs, such as a decline in nutritional quality, leading to hidden malnutrition and heightened vulnerability to disease.

The coefficient for education indicates a positive and statistically significant impact on life expectancy, with a coefficient of 1.4090. This implies that a one-year increase in the average years of schooling is associated with an increase in life expectancy of 1.4051 years. This finding is consistent with the research of Gómez-Ugarte & García-Guerrero (2023) and Cauvel & Sanchez (2025), which similarly conclude that education exerts a significant positive impact. Education functions as a socioeconomic variable that is both an investment and a protective factor. A higher level of education not only serves as an indicator of superior socioeconomic status but also actively facilitates access to formal employment that is safer, more stable, and sufficiently remunerated. Beyond this, education equips individuals with health literacy—the ability to comprehend and apply complex health information. This facilitates the adoption of healthy behaviours, a proactive stance towards health screenings, and the cultivation of stronger social networks and mental resilience. Consequently, education builds individual resilience and breaks the intergenerational cycle of poverty and poor health. This aligns with Grossman's (1972) theory, which posits that health is a stock of capital. In this framework, the level of education serves as an exogenous variable that directly influences this capital stock, thereby forging a strong, interlinked relationship between the two within the construct of human capital.

CONCLUSION

Based on a four-year provincial panel dataset for Indonesia, the estimation results show statistically significant effects of clean water access, sanitation quality, education level, and unemployment on life expectancy. Per capita health spending, however, was not a statistically significant factor. Access to clean water and sanitation demonstrated a positive relationship, with education emerging as the most dominant factor each additional year in the mean years of schooling is associated with a 1.41-year increase in life expectancy. Conversely, a high open unemployment rate is associated with a decrease in life expectancy, indicating the necessity of economic and social stability as a foundation for public health. These findings confirm that enhancing life expectancy requires an integrated strategy encompassing improvements in basic infrastructure, the expansion of educational access, and job creation.

However, this study has limitations, as it does not incorporate several other determinant

variables of health, such as air pollution levels, immunization coverage, the distribution of medical personnel, the availability of healthcare facilities, and the practice of Clean and Healthy Living Behaviours (PHBS). The absence of these variables means the model does not fully represent the complex reality of health status determinants in Indonesia. This limitation simultaneously opens avenues for further research to include a more comprehensive set of variables to provide a more complete and in-depth understanding.

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