Trajectory of life expectancy and its relation with socio-economic indicators among developing countries in Southeast Asian

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Abstract. Life expectancy is a one of key global health indicators and plays an important role in health policy measures. The status of a country indirectly influences the life expectancy of a nation. Developing countries have slower economic progress compared to developed countries, which in turn affects the well-being of the population. Therefore, this study aims to analyze the trend of life expectancy among developing countries in Southeast Asian and assess the influence of socio-economic indicators in life expectancy. Linear mixed effects model is used to model the association between socioeconomic factors and life expectancy. The results indicate that GDP growth rate, GDP per capita, and unemployment rate have significant impact on life expectancy and the impacts depend on gender. Life expectancy among females is generally higher than males. Prediction of life expectancy in males in year 2025 is found the lowest in Myanmar with average of 64.2 years (95%CI: 60.8-77.1) and the highest in Thailand with average of 76.2 years (95%CI: 60.7-76.9). Meanwhile, prediction of life expectancy in females is found the lowest in Timor Leste with average of 71.1 years (95%CI: 67.8-83.9) and the highest in Thailand with average of 84.3 years (95%CI: 68.7-84.9).

1. Introduction

Humans are living beings that interact with one another and live together in society. They are created with various differences such as gender, ethnicity, language, nationality, and skin color. The purpose of these differences is for humans to get to know each other and unite in a harmonious life, where peace and prosperity are achieved [1]. One indicator to assess the well-being of a society is the Human Development Index (HDI), which encompasses areas such as health, life expectancy, education, economic aspects, and decent living standards. Through the dissemination of HDI, it can be interpreted that economic development and life expectancy are closely related to social well-being. As economic progress occurs, the well-being of society also improves. This can happen due to an expected increase in the availability of healthcare resources, clean water, improved sanitation, and enhanced access to nutritious food. Simultaneously, the improvement in societal well-being will influence economic productivity [1-4].

Life expectancy is an important indicator of overall health and well-being of a nation [5]. Life expectancy can be influenced by healthcare outcomes, which are in turn associated with behavioural, socio-economic, and other factors [6]. In developing countries, the average lifespan of the population represents a strong indicator of disparities people's access to fundamental healthcare, educational options, and economic opportunities. Understanding and addressing these disparities is critically important for the improvement of global health. Previous research related to life expectancy and economic development indicated that countries with higher life expectancy are more susceptible to unemployment rates, while GDP capita correlates positively with increased longevity across the entire distribution of life expectancy [3][7]. Despite these important findings about the relationship between life expectancy and socioeconomic indicators, there is still no full picture of this relationship particularly among developing countries in southeast Asian to our knowledge. We focused on developing countries since socioeconomic factors are more likely to have an impact on life expectancy, where the status of their socioeconomic are in between the lowest and the highest globally [3][8].

In this study, therefore, we seek to analyse the trajectories of life expectancy among developing countries in southeast Asian and investigate the impact of socio-economic factors such as unemployment rate, inflation, and gross domestic product (GDP), on life expectancy. Focusing on developing countries in Southeast Asia allows us to engage in comparative analysis across countries with similar development challenges but differing policies and approaches. This can provide valuable insights into the effectiveness of various socio-economic and healthcare strategies. To address current and future health challenges, life expectancy across developing countries in the Southeast Asia region is predicted 2025. This projection will serve as an evaluation of economic development and help anticipate the healthcare infrastructure and resource need that will be required to meet the healthcare demands of the future population, particularly as new health challenges emerge in developing countries in Southeast Asia.

2. Methods

2.1 Data

The data used in this study are secondary data obtained from the World Bank. The dataset consists of 10 developing countries in Southeast Asia from the years 2010 to 2020. The response variable is country's life expectancy, which is collected separately for males and females. Life expectancy is defined as the average number of years a person can expect to live from birth. The predictor variables include inflation (X_1), unemployment (X_2), gross domestic product (GDP) growth rate (X_3), GDP per capita (X_4), which are collected yearly from 2010 to 2020 for each country.

2.2 Linear mixed-effects model

The linear mixed effects model, also known as the mixed-effects model, is an extension of the simple linear model that allows for both fixed effects and random effects. This method is used when dealing with data that has repeated observations within subjects and aims to explain the relationship between the response variable and several covariates in data grouped based on one or more classification factors. The general form of the linear mixed effects equation is as follow:

$$\begin{cases} \boldsymbol{y_i} = \boldsymbol{X_i\beta} + \boldsymbol{Z_i b_i} + \boldsymbol{\varepsilon_i} \\ \boldsymbol{b_i} \sim \boldsymbol{N}(\boldsymbol{0}, \boldsymbol{D}), \ \boldsymbol{\varepsilon_i} \sim \boldsymbol{N}\left(\boldsymbol{0}, \boldsymbol{\sigma^2 I_{n_i}}\right) \end{cases} \quad (1)$$

where $\boldsymbol{X_i}$ is the design matrix for the *i*-th individual, $\boldsymbol{\beta}$ is the vector of fixed effects, $\boldsymbol{b_i}$ is the vector of random effects, $\boldsymbol{Z_i}$ is the covariate matrix for the random effect $\boldsymbol{b_i}$ of the *i*-th individual, $\boldsymbol{\varepsilon_i}$ is the residual vector, $\boldsymbol{D}$ is the variance-covariance matrix of the random effects, $\boldsymbol{\sigma^2}$ is the error variance, $\boldsymbol{I}$ is the identity matrix, $\boldsymbol{b_i}$ dan $\boldsymbol{\varepsilon_i}$ are assumed to be independent of each other[9][10].

In linear mixed effects models, there are two commonly used methods for parameter estimation: Maximum Likelihood (ML) and Restricted Maximum Likelihood (REML). In ML estimation, both fixed effects and random effects (variance components) are estimated simultaneously. However, ML estimation tends to be biased when estimating the variance components because it estimates all parameters together, including the fixed effects[11][12].

REML estimation separates the fixed effects from the estimation process and focuses solely on estimating the variance components associated with the random effects. REML estimation provides estimates only for the variance components, without including the fixed effects. By excluding the fixed effects, REML estimation eliminates the bias caused by estimating the fixed effects and provides less biased estimates for the variance components[11][12].

In the selection of the linear mixed effects model, the Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), and Likelihood Ratio Test (LRT) are commonly used methods. After determining the best model through model selection, the model is further examined to assess whether the random effects have a significant influence using Interclass Correlation Coefficients (ICC)[10][13].

2.3 Bootstrap prediction interval in mixed models

In this study, parametric bootstrap is used to construct prediction intervals of life expectancy. The steps of parametric bootstrap in linear mixed effects are as follows [14] :

1. Estimate the fixed effects ($\widehat{\boldsymbol{\gamma}}$), residual standard deviation ($\widehat{\boldsymbol{\sigma}}_{\boldsymbol{\varepsilon}}$), and random effects variance ($\widehat{\boldsymbol{\theta}}$) from linear mixed effects model (1).
2. For each of the B bootstrap samples, generate $\boldsymbol{\varepsilon}_i^* \sim \boldsymbol{N}\left(\mathbf{0}, \widehat{\boldsymbol{\sigma}}_{\boldsymbol{\varepsilon}}^2\right)$ and $\boldsymbol{b}_i^* \sim \boldsymbol{N}\left(\mathbf{0}, \Sigma(\widehat{\boldsymbol{\theta}})\right)$ to calculate bootstrap replication of $\boldsymbol{y}_i^*$, where $\boldsymbol{y}_i^*$ expressed as follows:

$$\boldsymbol{y}_i^* = \boldsymbol{X}_i\widehat{\boldsymbol{\gamma}} + \boldsymbol{Z}_i\boldsymbol{b}_i^* + \boldsymbol{\varepsilon}_i^*$$

3. Estimate $\boldsymbol{\gamma}$, $\boldsymbol{\sigma}_{\boldsymbol{\varepsilon}}$, and $\boldsymbol{\theta}$ from model (1) on the bootstrap sample $(\boldsymbol{y}_i^*, \boldsymbol{X}_i, \boldsymbol{Z}_i)$ to produce $\widehat{\boldsymbol{y}}^*$.
4. Construct the 95% percentile bootstrap prediction interval using B bootstrap replicates of $\widehat{\boldsymbol{y}}^*$:

$$(\widehat{\boldsymbol{y}}_L^*, \widehat{\boldsymbol{y}}_U^*)$$

where $\widehat{\boldsymbol{y}}_L^*$ and $\widehat{\boldsymbol{y}}_U^*$ are the lower and upper endpoint of confidence interval at 2.5^{th} and 97.5^{th} percentile, respectively, of the $\widehat{\boldsymbol{y}}^*$ distribution.

3. Result and Discussion

Figure 1 depicts the trajectories of life expectancy by female and male across developing countries in southeast Asian. There is a clearly an increasing trend in life expectancy throughout the years. In addition, female tends to have higher life expectancy than males.

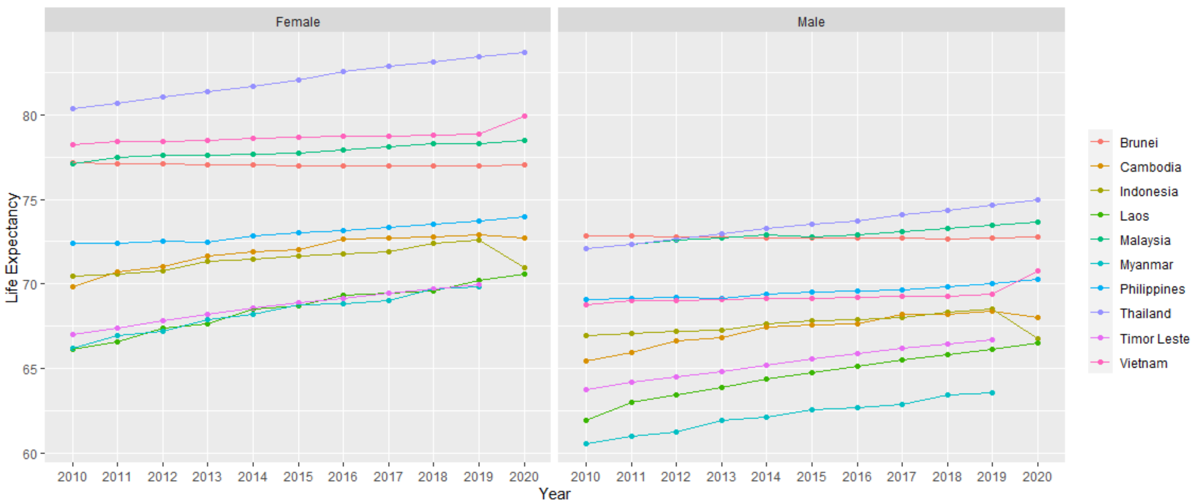

Figure 1. Life expectancy trajectories in developing countries in southeast Asian

A linear mixed effects model is fitted to the dataset with life expectancy as the response variable and socio-economic factors (inflation, unemployment, GDP growth rate, GDP per capita) as the explanatory variables. The possibility of interaction effects between gender and socio-economic factors are included in the model. Furthermore, different random effects are considered in the model. Table 1 summarizes the results of different random-effects used in the model estimated using REML method. According to information criteria, random intercept model is the best model with lowest AIC and BIC values. The LRT also suggests that including a random slope in the model does not fit better than a random-intercept only. Thus, a random-intercept model is selected as the random-effect component in the model.

Table 1. Comparison of random-effects

Random Effects	Model	df	AIC	BIC	Log likelihood	Test	LRT	p-value
Intercept	1	14	655.96	702.413	-313.98			
Intercept and Slope (correlated)	2	16	659.96	713.049	-313.98	1 vs 2	1.07×10^{-7}	1.000
Intercept and Slope (uncorrelated)	3	15	657.96	707.731	-313.98	2 vs 3	1.23×10^{-9}	0.999

Table 2 presents the comparison of the estimated fixed effects between the full and the reduced model using ML method. The selected fixed effects in the linear mixed effects model are unemployment rate, gender, GDP growth rate, and GDP per capita. Additionally, the model includes an interaction term between gender and the selected fixed effects since the p-values is less than 0.05, indicating its statistical significance. The interaction between gender and unemployment rate significantly influences life expectancy. Some of the estimated parameters in the full model are not significant and thus they are eliminated from the model, resulting a reduced model. The result of LRT indicated that the reduced model fits better to the data than the full model ($LRT = 7.473, p = 0.0582$). The calculated ICC value for the selected model is 96.13%, indicating that the random intercept is an important component to be included in the model.

Table 2. The estimated parameters for linear mixed effects model

Variable	Full Model		Reduced Model	
	Estimate (se)	p-value	Estimate (se)	p-value
Intercept	-511.75 (73.283)	<0.0001	-439.81 (59.664)	<0.0001
Time (year)	0.286 (0.036)	<0.0001	0.251 (0.029)	<0.0001
Gender*	166.885 (83.846)	0.048	9.676 (0.383)	<0.0001
Inflation	-0.042 (0.033)	0.200	-	-
Unemployment rate	0.155 (0.126)	0.221	0.167 (0.125)	0.182
GDP growth rate	2.66 (0.613)	<0.0001	2.450 (0.609)	<0.0001
GDP per capita	-2.68 (0.621)	<0.0001	-2.478 (0.616)	<0.0001
Year × Gender	-0.078 (0.042)	0.062	-	-
Inflation × Gender	0.044 (0.041)	0.282	-	-
Unemployment rate × Gender	-0.257 (0.065)	<0.0001	-0.274 (0.063)	<0.0001
GDP growth rate × Gender	-3.16 (0.285)	<0.0001	-2.955 (0.276)	<0.0001
GDP per capita × Gender	3.174 (0.293)	<0.0001	2.989 (0.286)	<0.0001

Gender is a dummy variable with male as the reference category, se: standard error

The estimated linear mixed effects model can be written as follows:

$$y_{ij} = -439.81 + 0.251\text{Year} + 9.676\text{Gender} + 0.167\text{Unemployment} + 2.45\text{GDPGrowthRate} - 2.478\text{GDPperCapita} - 0.274\text{Unemployment} \times \text{Gender} - 2.955\text{GDPGrowthRate} \times \text{Gender} + 2.989\text{GDPperCapita} \times \text{Gender}$$

Substituting dummy variable of Gender, where Gender = 0 for males and Gender = 1 for males, then we get the following estimated model for both genders:

$$y_{ij} = \begin{cases} 439.81 + 0.251\text{Year} + 0.167\text{Unemployment} + 2.450\text{GDPGrowthRate} \\ \quad -2.478\text{GDPperCapita} + b_{oi}, \quad \text{if males} \\ -430.37 + 0.251\text{Year} - 0.106\text{Unemployment} - 0.505\text{GDPGrowthRate} \\ \quad +0.512\text{GDPperCapita} + b_{oi}, \quad \text{if females} \end{cases}$$

The model indicates that time has a significant impact on life expectancy where an increase of one year would lead to increase of life expectancy by 0.251 year. In other words, as the year progresses, we can anticipate a corresponding increase in life expectancy by approximately 0.251. The impact of unemployment rate, GDP growth rate, and GDP per capita on life expectancy appear to depend on gender. Unemployment rate has a positive influence on life expectancy in males and has a negative influence on life expectancy in females. Similarly, GDP growth rate has different effects on males' and females' life expectancy in both equations. For a one-unit increase in the GDP growth rate, life expectancy is expected to increase by 2.450 year among males. On the other hand, for a one-unit increase in GDP growth rate life expectancy is expected to decrease by 0.505 year among females. The impact of GDP per capita on life expectancy appears to be different across gender as well. Tt has a negative influence on males' life expectancy and positive influence on females' life expectancy.

The best model is used to predict the trend of life expectancy from 2021 to 2025. The performance of the fitted model for prediction is assessed using MAPE (mean absolute percentage error) by comparing the actual life expectancy in the most recent years in 2021 (available from the World Bank data) to the prediction value. The model was found to have a good performance with MAPE value of 2.4%. Table 3 and Figure 2 present the prediction and its corresponding 95% prediction interval for life expectancy in males and females across 10 developing countries in southeast Asian. Life expectancy exhibits an upward linear trend across the years for all countries. The findings in this study support previous researches that the average length of life among females continues to be higher than males in the future. Prediction of life expectancy in males in year 2025 is the highest in Thailand with average of 76.2 years (95%CI: 60.7-76.9), followed by Malaysia (75.7 years, 95%CI: 64.0-79.5) and Brunei (75.3 years, 95%CI: 63.4-79.3). Meanwhile, the lowest predicted life expectancy is in Myanmar with average of 64.2 years (95%CI: 60.8-77.1). Prediction of life expectancy in females is also found the highest Thailand with average of 84.3 years (95%CI: 68.7-84.9), while the lowest in Timor Leste with average of 71.1 years (95%CI: 67.8-83.9).

Table 3. Prediction (95% prediction interval) of life expectancy

Country	Gender	Year 2021	Year 2022	Year 2023	Year 2024	Year 2025
Brunei	Female	78.5 (66.6-82.6)	78.8 (66.9-82.9)	79.0 (67.2-83.1)	79.3 (67.5-83.4)	79.5 (67.8-83.7)
	Male	74.3 (62.5-78.3)	74.5 (62.7-78.6)	74.8 (63.0-78.9)	75.0 (63.2-79.1)	75.3 (63.4-79.3)
Philippines	Female	74.6 (67.1-82.7)	74.9 (67.4-82.9)	75.1 (67.6-83.2)	75.4 (67.9-83.4)	75.6 (68.2-83.7)
	Male	70.9 (63.6-79.1)	71.2 (63.8-79.4)	71.4 (64.0-79.6)	71.7 (64.3-79.8)	71.9 (64.6-80.1)
Indonesia	Female	73.6 (67.0-83.1)	73.9 (67.2-83.3)	74.1 (67.5-83.6)	74.4 (67.8-83.9)	74.6 (68.0-84.1)
	Male	68.4 (61.7-77.6)	68.7 (62.0-77.9)	68.9 (62.2-78.1)	69.2 (62.4-78.4)	69.4 (62.7-78.6)
Cambodia	Female	73.9 (67.4-83.8)	74.1 (67.6-84.1)	74.4 (67.9-84.4)	74.6 (68.1-84.7)	74.9 (68.4-85.1)
	Male	68.3 (61.8-78.3)	68.6 (62.1-78.6)	68.8 (62.3-78.9)	69.1 (62.6-79.2)	69.3 (62.7-79.5)
Laos	Female	70.6 (66.4-82.9)	70.9 (66.7-83.2)	71.1 (67.0-83.4)	71.4 (67.3-83.7)	71.6 (67.5-84.0)
	Male	65.6 (61.4-77.9)	65.8 (61.6-78.1)	66.1 (61.8-78.4)	66.3 (62.1-78.6)	66.6 (62.3-78.9)
Malaysia	Female	79 .0(67.2-82.7)	79.3 (67.4-83.0)	79.5 (67.7-83.2)	79.8 (68.0-83.4)	80.0 (68.2-83.7)
	Male	74.7 (63.0-78.5)	75.0 (63.2-78.8)	75.2 (63.5-79.0)	75.5 (63.7-79.3)	75.7 (64.0-79.5)

Country	Gender	Year 2021	Year 2022	Year 2023	Year 2024	Year 2025
Myanmar	Female	70.4 (67.2-83.4)	70.7 (67.4-83.7)	70.9 (67.7-83.9)	71.2 (67.9-84.2)	71.4 (68.2-84.5)
	Male	63.3 (59.7-76.2)	63.5 (59.9-76.4)	63.8 (60.2-76.7)	64.0 (60.5-76.9)	64.3 (60.8-77.1)
Thailand	Female	83.3 (67.7-83.9)	83.6 (68.0-84.1)	83.8 (68.2-84.4)	84.1 (68.4-84.6)	84.3 (68.7-84.9)
	Male	75.2 (59.6-75.9)	75.5 (59.9-76.2)	75.7 (60.1-76.4)	76.0 (60.4-76.6)	76.2 (60.7-76.9)
Timor Leste	Female	70.1 (66.9-82.8)	70.4 (67.1-83.0)	70.6 (67.4-83.3)	70.9 (67.6-83.6)	71.1 (67.8-83.9)
	Male	67.0(64.0-79.8)	67.3 (64.2-80.1)	67.5 (64.5-80.4)	67.8 (64.8-80.6)	68.1 (65.0-80.9)
Vietnam	Female	78.6 (67.6-84.4)	78.9 (67.8-84.7)	79.1 (68.1-85)	79.4 (68.4-85.3)	79.6 (68.6-85.5)
	Male	72.4 (61.4-78.2)	72.6 (61.7-78.4)	72.9 (62-78.7)	73.1 (62.2-78.9)	73.4 (62.4-79.1)

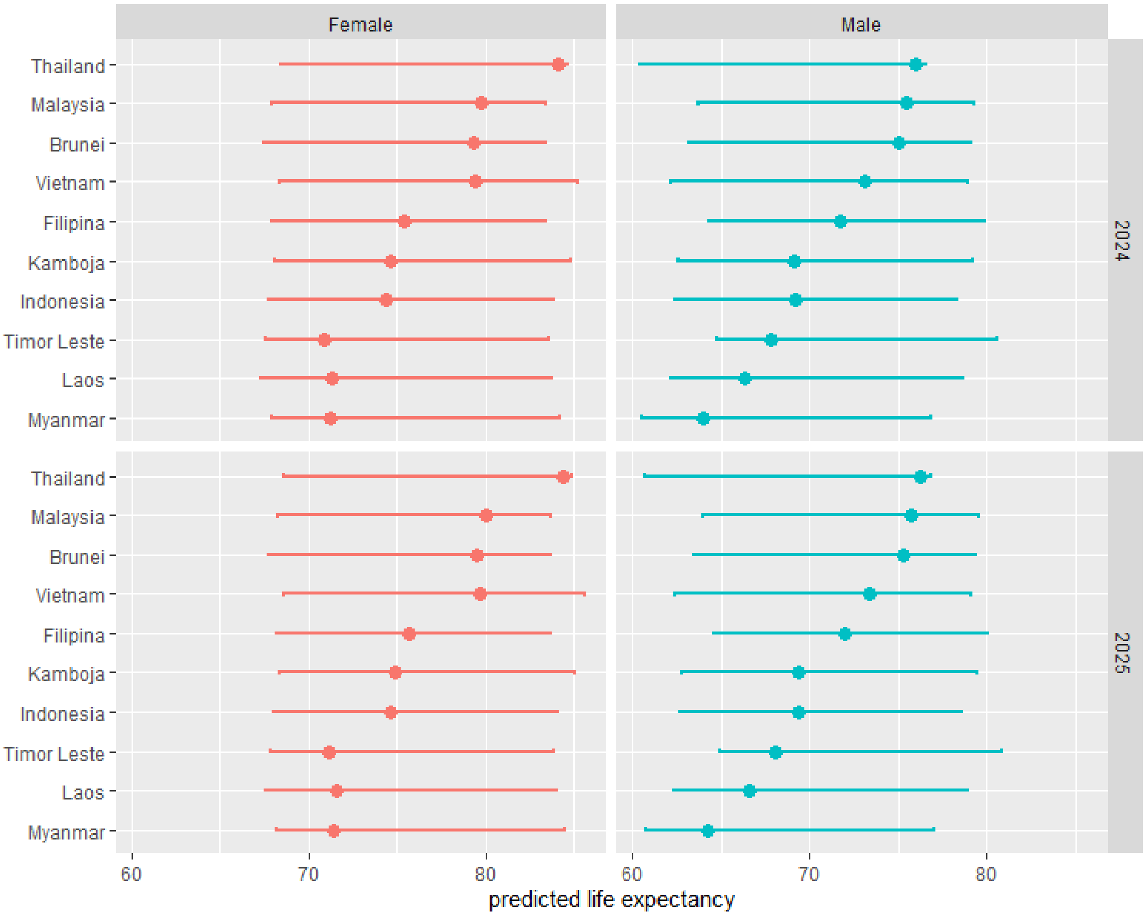

Figure 2. Prediction of life expectancy in 2024-2025 and its associated 95% prediction interval

4. Conclusion

This study investigates the trend in life expectancy and the impact of socioeconomic factors on life expectancy across developing countries in southeast Asian. The results suggests that there is an increasing trend of life expectancy in the future with females' life expectancy is consistently higher than males in all countries. Socioeconomic factors have both positive and negative effects on Life Expectancy and their impact are different between males and females. For males, the positive economic development factors are unemployment and GDP growth rate, while GDP per capita has a negative impact on life expectancy. For females, the positive economic development factor is GDP per capita, while unemployment and GDP growth rate have a negative impact on life expectancy.

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