WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Modeling Life Expectancy of the Philippines from 2001 to 2019; Exploring the Relationship with Undernourished, Healthcare Expenditure, and Gross Domestic Product

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DOI: https://doi.org/10.55248/gengpi.4.823.50334

A B S T R A C T

Modeling the life expectancy and exploring the factors that can influence this can contribute to policymakers and public health officers to design an efficient and effective program to address the health needs of the nation. This study considers three independent variables that could potentially influence life expectancy namely, the number of undernourished individuals, healthcare expenditure, and gross domestic product of the Philippines from 2001 to 2019. The data that were utilized for the independent variables and life expectancy were collected from Our World in Data. The data were analyzed through regression and time series models namely, linear, exponential, logarithmic, polynomial, power, moving average, exponential smoothing, and autoregression model. Based on the findings of the study, life expectancy is associated with the three independent variables. Moreover, the life expectancy of the country will increase in the year 2024. For the Philippines to continue its progress in improving life expectancy, the government must focus on addressing malnutrition, healthcare expenditure, GDP per capita, and other factors that can influence the country's life expectancy.

Keywords: Philippines, Life Expectancy, Mathematical Modelling, Trend Analysis

1. Introduction

Over the past decades, the Philippines has seen substantial economic and social change, which has improved several health metrics, including life expectancy. The life expectancy of a nation is a fundamental measure that reflects the overall health status of the country, which is also used to evaluate the efficiency of its healthcare systems, socioeconomic progress, and public health initiatives.

However, despite the development, the nation still faced problems with malnutrition, access to healthcare, and resource distribution. And according to studies, these are some of the numerous factors that can influence the life expectancy of a country. The prevalence of undernourished exerts an adverse impact on life expectancy (Nkemgha, et. al., 2019;Djoumessi, Y. F., 2022). While Radmehr and Adebayo (2022), pointed out that healthcare expenditure enhances life expectancy. Moreover, higher GDP is associated with better living standards, improved healthcare infrastructure, and increased access to healthcare, all of which can contribute to longer life expectancies.

Given the Philippines' diverse population and varying socioeconomic conditions, understanding the factors that influence life expectancy, and modeling life expectancy is of utmost importance for policymakers, public health practitioners, and researchers in formulating evidence-based public health policies, planning for future healthcare needs, and estimating future liabilities. Hence, this study aimed to determine whether the number of undernourished individuals and healthcare expenditure in the Philippines predict the life expectancy of the country. Moreover, the study wants to find the best model that can explain the life expectancy of the Philippines. Specifically, this study aimed to:

1. Determine the trend of life expectancy in the Philippines from 2001 to 2019.
2. Find if the life expectancy has a significant linear relationship with (1) the Number of undernourished persons in the Philippines, (2) Healthcare expenditure as a share of the national gross domestic product, (3) Gross Domestic Product per Capita
3. Construct a time series model of the life expectancy of the Filipinos using the following models, (1) Linear, (2) Logarithmic, (3) Exponential (4) Polynomial, (5) Power, (6) Moving Average, (7) Exponential Smoothing, and (8) Autoregression.
4. Determine the best-fit model and predict the life expectancy in the Philippines for 2024

2. Methodology

To accomplish the objectives of the study, quantitative analysis was employed specifically, time-series modeling techniques to assess the trends and interdependencies between life expectancy and undernourishment, healthcare expenditure, and gross domestic product of the Philippines.

The study utilized the available data on undernourished, healthcare expenditure, gross domestic product per capita, and life expectancy in the Philippines from 2001 to 2019, drawing from the database of Our World in Data. Our World in Data is an online data portal produced by the Oxford Martin Programmed on Global Development at the University of Oxford, which focuses on global issues such as poverty, health, and education. The data collected were compiled in Excel and analyzed based on the objectives of the study.

For the data analysis, a scatter plot was utilized to illustrate the trend of life expectancy in the Philippines from 2001 to 2019. Wherein, the year 2001 was coded as 1, 2002 was coded as 2, and 2019 was coded as 19. In addition, to determine the presence of a statistically significant linear relationship between life expectancy and the independent variables, namely the number of undernourished individuals in the Philippines, health expenditure, and gross domestic product per capita, a simple linear regression analysis was used. To facilitate a more comprehensive analysis, every 100,000 undernourished individuals were converted as 1 unit.

To construct a time series model for life expectancy, modelling techniques namely linear, exponential, logarithmic, polynomial, power, moving average, exponential smoothing, and autoregressive modelling were employed. Lastly, to determine the best-fit model that can explain the life expectancy in the Philippines from 2001 to 2019, the coefficient of determination and standard error were used.

3. Results

Objective 1

Determine the trend of life expectancy in the Philippines from 2001 to 2019.

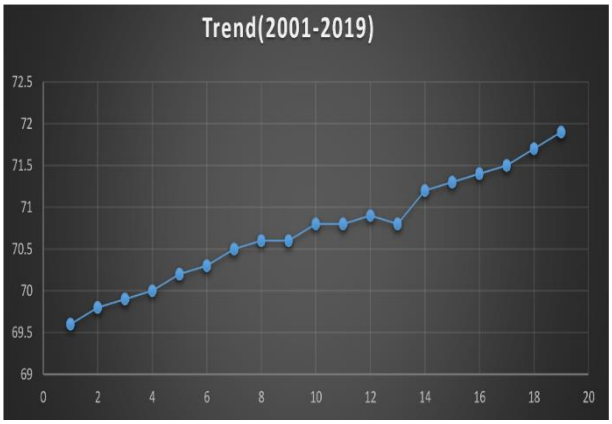

Figure 1. The Trend of Life Expectancy

Figure 1 displays the trend of life expectancy in the Philippines from 2001 to 2019. As can be seen above, the plot for life expectancy shows a linear pattern. This suggests that life expectancy in the Philippines is increasing as the years pass.

Objective 2

Find if life expectancy has a significant linear relationship with the independent variables.

The tables below show the significant linear relationship between the independent variables namely the number of undernourished individuals per 100,000, healthcare expenditure, and gross domestic product, and the dependent variable life expectancy.

Table 1. Life Expectancy and Number of Undernourished Individuals per 100,000

	Coefficients	Standard Error	t Stat	P-value
Intercept	73.457	0.276	265.931	0.000
	-0.025	0.002	-10.117	0.000

F (1) = 102.362, p < 0.01, r = 0.926

Table 1 shows that there is a significant linear relationship between life expectancy with the number of undernourished individuals in the Philippines (F (1) =102.362, p<0.01). The Pearson r 0.926, indicates that the number of undernourished persons and life expectancy have a very strong relationship. Moreover, the slope suggests that as the number of undernourished persons increases by 1 unit (100,000 individuals), the life expectancy decreases by 0.025. This is agreed upon by Liaqat et al. (2021), which state that even in the case of infants, the prevalence of undernourishment has an influence on

life expectancy. To maintain a high life expectancy, the government must continue to support feeding programs and other activities which may help to mitigate malnutrition.

Table 2. Life Expectancy and Healthcare Expenditure

	Coefficients	Standard Error	t Stat	P-value
Intercept	66.952	0.867	77.230	0.000
	1.009	0.230	4.387	0.000

F (1) = 19.247, p < 0.01, r = 0.729

Table 2 conveys that life expectancy and healthcare expenditure have a significant linear relationship (F (2) =19.247, p<0.01). With a Pearson r 0.729, this indicates that there exists a relationship between life expectancy and healthcare expenditure. Moreover, the slope suggests that as the healthcare expenditure as a share of the national gross domestic product increases by 1 unit, life expectancy increases by 1.009.

The result corroborates with studies of Cavusoglu and Gimba (2021), health expenditure has a positive relationship with life expectancy. Increasing spending on healthcare amenities leads to faster and more efficient access to healthcare services. In addition, it has the potential to boost the motivation of healthcare workers.

Table 3. Life Expectancy and Gross Domestic Product

	Coefficients	Standard Error	t Stat	P-value
Intercept	67.949	0.186	365.635	0.000
	0.0005	0.000	15.311	0.000

F (1) = 234.441, p < 0.01, r = 0.966

Table 3 reveals that there exists a significant linear relationship between life expectancy and the Gross Domestic Product per Capita in the Philippines (F (1) =234.441, p< 0.01). Furthermore, there is a very strong relationship between life expectancy and Gross Domestic Product per Capita (r=0.966). The slope suggests that as the gross domestic product per capita increases by 1 unit, life expectancy also increases by 0.0005. This finding is supported by Guzel et al. (2021), life expectancy is associated with per capita income, wherein, a higher level of per capita income suggests a higher level of life expectancy.

If a country has a high Gross Domestic Product per capita, it can imply that the nation has more funds to invest in healthcare facilities and equipment. With sufficient resources allocated to healthcare, it becomes more likely that there will be positive outcomes in the health of its citizens, which in turn leads to an increased life expectancy.

Table 4. Life Expectancy with the Number of Undernourished, Healthcare Expenditure, and GDP

	Coefficients	Standard Error	t Stat	P-value
Intercept	69.12	0.58	118.67	0.00
Undernourished	-0.01	0.00	-3.40	0.00
Healthcare expenditure	0.17	0.08	2.20	0.04
GDP per capita	0.0003	0.00	7.94	0.00

$F(3)$ = 197.428, p < 0.01 $adjusted\ r^2$ = 0.97

Table 4 shows that there is a significant linear relationship between the independent variables (undernourished, healthcare expenditure, and GDP per capita) and the dependent variable (life expectancy), F (3) =197.428, and a p-value of less than 0.01. Moreover, undernourished (t=-3.40, p<0.01), healthcare expenditure (t=2.20, p<0.01), and GDP per capita (t=7.94, p<0.01) are significant predictors of life expectancy. The regression model that can explain life expectancy in the Philippines from 2001 to 2019 with respect to independent variables is $y = -0.01(x_1) + 0.17(x_2) + 0.0003(x_3)$, where y, x_1, x_2, $and\ x_3$ represents life expectancy, number of undernourished individuals per 100,000, healthcare expenditure, and GDP per capita respectively.

Moreover, the adjusted R-squared reveals that 97% of the variances can be explained by the model.

Objective 3

Construct a time series model of the life expectancy of Filipinos using the following models:

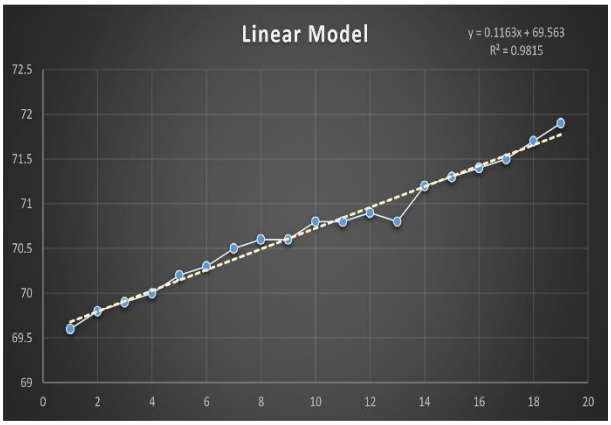

Figure 2. Linear Model

Figure 2 shows the linear model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.1163x + 69.563$. This suggests that the life expectancy in the Philippines increases by 0.1163 as the year increases. Furthermore, the value of r^2 0.9815 with a standard error of 0.0924, indicates that 98.15% of the variances can be explained by the linear model.

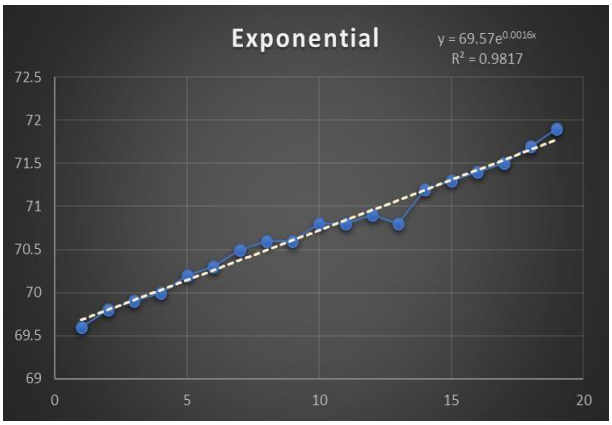

Figure 3. Exponential Model

Figure 3 presents the exponential model of life expectancy in the Philippines from 2001 to 2019, with $y = 69.57e^{0.0016(x)}$. This suggests that the life expectancy in the Philippines increases by 0.11 as the years increase. Furthermore, the value of r^2 0.9817 with a standard error of 0.0924, indicates that 98.17% of the variances can be explained by the exponential model.

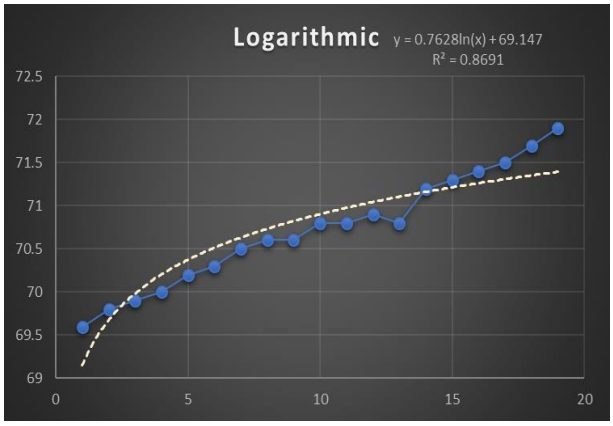

Figure 4. Logarithmic Model

Figure 4 reveals the logarithmic model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.7628\,ln(x) + 69.147$. Furthermore, the value of r^2 0.8691 with a standard error of 0.24593, indicates that 86.91% of the variances can be explained by the logarithmic model.

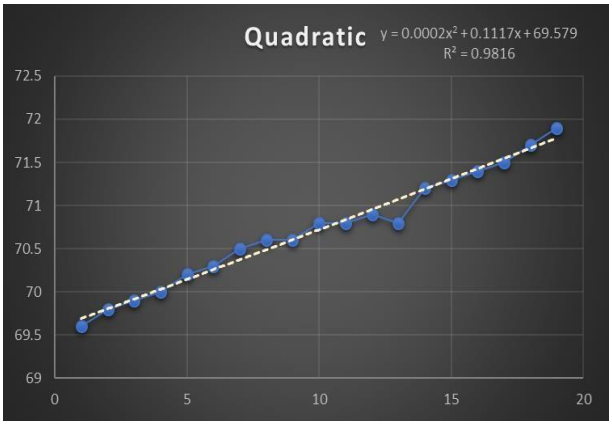

Figure 5. Quadratic Model

Figure 5 unveils the quadratic model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.0002x^2 + 0.1117x + 69.579$. This suggests that the life expectancy in the Philippines increases by 0.11 as the years increase. Furthermore, the value of r^2 0.9816 with a standard error of 0.09217, indicates that 98.16% of the variances can be explained by the quadratic model.

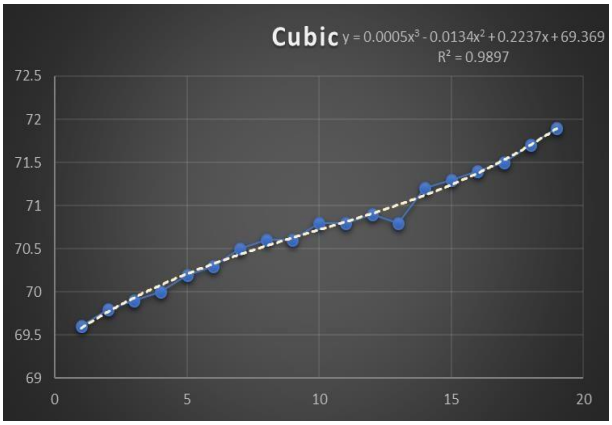

Figure 6. Cubic Model

Figure 6 reports the cubic model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.0005x^3 - 0.0134x^2 + 0.2237x + 69.369$. Furthermore, the value of r^2 0.9897 with a standard error of 0.0766, indicates that 98.97% of the variances can be explained by the cubic model.

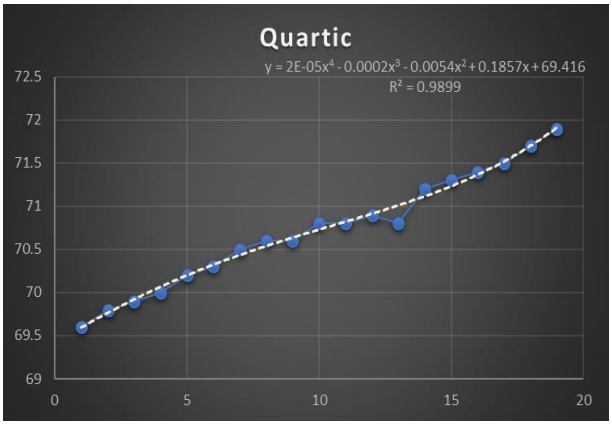

Figure 7. Quartic Model

Figure 7 reveals the quartic model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.0002x^4 - 0.0002x^3 - 0.0054x^2 + 0.1857x + 69.416$. Moreover, the value of r^2 0.9899 with a standard error of 0.298 indicates that 98.99% of the variances can be explained by the quartic model.

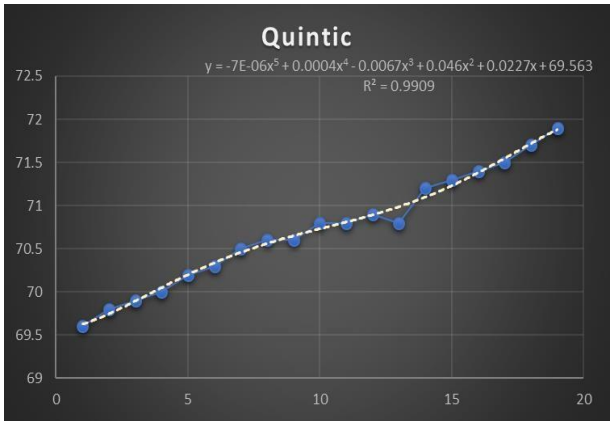

Figure 8. Quintic Model

Figure 8 reveals the quintic model of life expectancy in the Philippines from 2001 to 2019, with $y = -0.000007x^5 + 0.0004x^4 - 0.0067x^3 + 0.06x^2 + 0.0227x + 69.56$. Furthermore, the value of r^2 0.9909 with a standard error of 0.214, indicates that 99.0% of the variances can be explained by the quintic model.

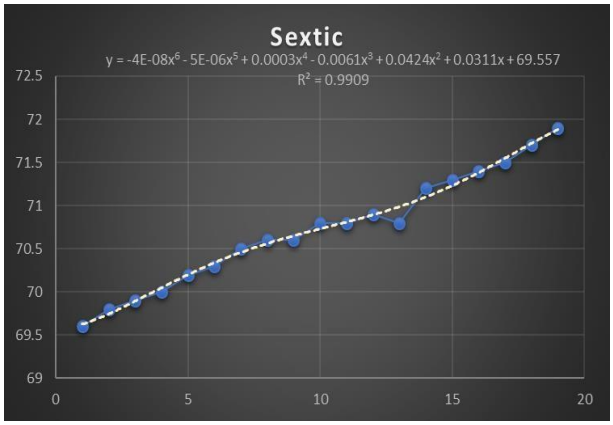

Figure 9. Sextic Model

Figure 9 conveys the sextic model of life expectancy in the Philippines from 2001 to 2019, with $y = -0.00000004x^6 - 0.000005x^5 + 0.0003x^4 - 0.0061x^3 + 0.0424x^2 + 0.0311x + 69.557$. Furthermore, the value of r^2 0.9909 with a standard error of 0.598, indicates that 99.09% of the variances can be explained by the sextic model.

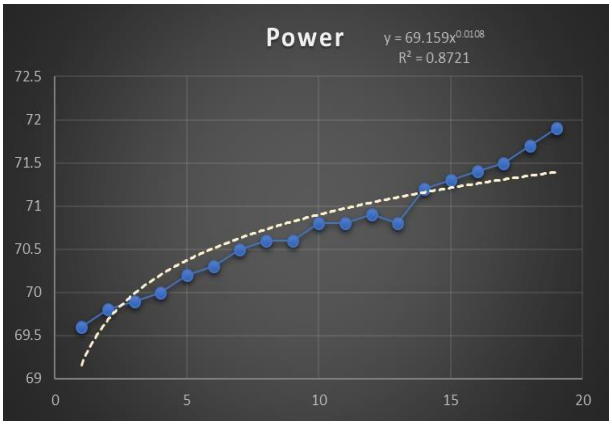

Figure 10. Power Model

Figure 10 shows the power model of life expectancy in the Philippines from 2001 to 2019, with $y = 69.159x^{0}$. 0108. Furthermore, the value of r^2 0.8721 with standard error of 0.243, indicates that 87.21% of the variances can be explained by the power model.

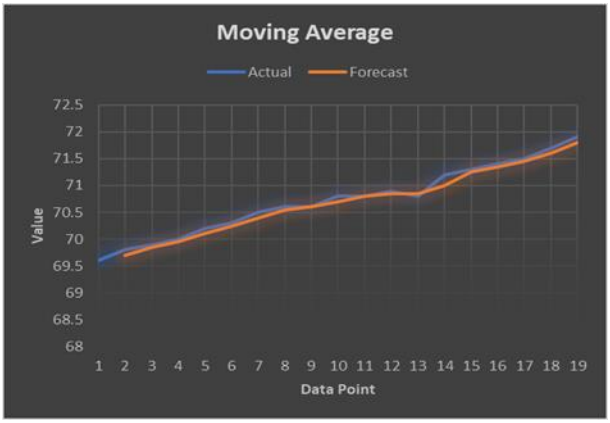

Figure 11. Moving Average

Figure 11 displays the moving average model of life expectancy in the Philippines from 2001 to 2019, with an interval of 2. Moreover, the computed standard error for 2019 is 0.100.

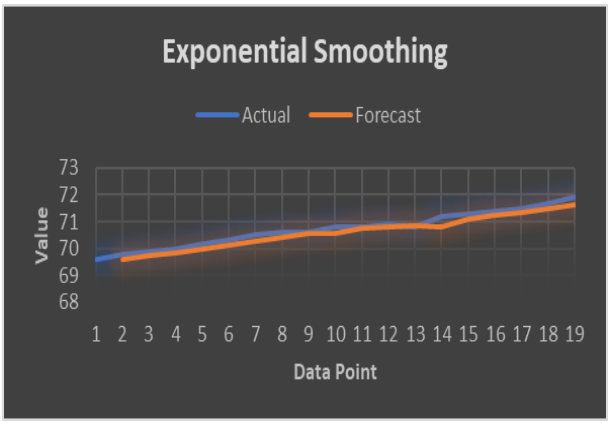

Figure 12. Exponential Smoothing

Figure 12 shows the exponential smoothing model of life expectancy in the Philippines from 2001 to 2019, with $y = 0.75Y_i + 0.25E_{i-1}$ (standard error= 0.179).

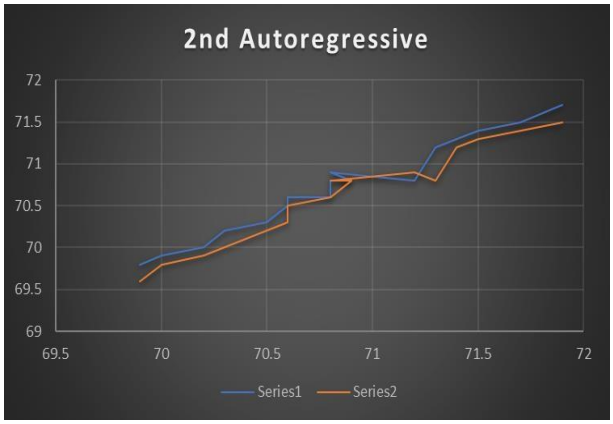

Figure 13. Autoregressive Model

Figure 13 reports the second autoregressive model of life expectancy in the Philippines from the year 2001 to 2019, with $y = -0.7793 + 0.59183Y_{i-1} + .42167Y_{i-2}$. Moreover, the value of adjusted r-squared 0.9674 and a standard error of 0.106, indicates that 96.74% of the variances can be explained by the 2nd autoregressive model.

Objective 4

Determine the best-fit model and predict the life expectancy in the Philippines for 2024.

Table 5. Best Fit Model and Prediction

Model		R^2	Standard Error
Linear	$y = 0.1163x + 69.563$	0.982	0.092
Exponential	$y = 69.57e^{0.0016(x)}$	0.982	0.092
Logarithmic	$y = 0.7628ln(x) + 69.147$	0.869	0.246
Quadratic	$y = 0.0002x^2 + 0.1117x + 69.579$	0.982	0.092
Cubic	$y = 0.0005x^3 - 0.0134x^2 + 0.2237x + 69.369$	0.99	0.077
Quartic	$y = 0.00002x^4 - 0.0002x^3 - 0.0054x^2 + 0.1857x + 69.416$	0.99	0.298
Quintic	$y = -0.000007x^5 + 0.0004x^4 - 0.0067x^3 + 0.046x^2 + 0.0227x + 69.563$	0.991	0.214
Sextic	$y = -0.00000004x^6 - 0.000005x^5 + 0.0003x^4 - 0.0061x^3 + 0.0424x^2 + 0.0311x + 69.557$	0.991	0.598
Power	$y = 69.159x^{0.0108}$	0.872	0.243
Moving Average	–	–	0.100
Exponential Smoothing	$y = 0.75 * (Yi) + 0.25(E_{i-1})$	–	0.179
2nd Autoregression	$y = -0779 + 0.592(Y_{i-1}) + 0.7(Y_{i-2})$	0.967	0.106

Table 5 shows the different models of life expectancy in the Philippines from 2001 to 2019. As can be observed above, the model which possesses the highest r-squared is the quintic and sextic model (r 2 = 0.991). On the other hand, the model which possesses the lowest standard error is the cubic model (standard error= 0.077). The table above reveals that the best-fit model that can explain life expectancy in the Philippines from 2001 to 2019 is the cubic model (standard error= 0.077). The model is y = 0.0005x 3 − 0.0134x 2 + 0.2237x + 69.369. Where y represents life expectancy and x represents the code for the corresponding year. The cubic model suggests that the predicted value for 2024 (x=24) is 73.331.

Summary of Findings

Life expectancy serves as a key measure reflecting the general health status of a country or a population. By constructing a model that can predict life expectancy, public health authorities can proactively anticipate the healthcare needs of the population and design a well-suited health program to address these needs effectively.

After data analysis, the below are the collected findings in the study:

- The trend of life expectancy in the Philippines had been increasing over the years from

2001 to 2019.

- There is a significant linear relationship between the life expectancy and number of undernourished, healthcare expenditure, and gross domestic per capita in the Philippines. Moreover, when the variables were combined, the findings have shown that there is a significant linear relationship between the variables.
- The time series models using the data of life expectancy in the Philippines from 2001 to 2019 are:

Linear Model: $y = 0.1163x + 69.563$

Exponential Model: $y = 69.57e^{0.0016(x)}$

Logarithmic Model: $y = 0.7628ln(x) + 69.147$

Quadratic Model: $y = 0.0002x^2 + 0.1117x + 69.579$

Cubic Model: $y = 0.0005x^3 - 0.0134x^2 + 0.2237x + 69.369$

Quartic Model: $y = 0.00002x^4 - 0.0002x^3 - 0.0054x^2 + 0.1857x + 69.416$

Quintic Model: $y = -0.000007x^5 + 0.0004x^4 - 0.0067x^3 + 0.046x^2 + 0.0227x + 69.563$

Sextic Model: $y = -0.00000004x^6 - 0.000005x^5 + 0.0003x^4 - 0.0061x^3 + 0.0424x^2 + 0.0311x + 69.557$

Power Model: $y = 69.159x^{0.0108}$

Exponential Smoothing Model: $y = 0.75 * (Y_i) + 0.25(E_{i-1})$

Autoregression Model: $y = -0.779 + 0.592(Y_{i-1}) + 0.4217(Y_{i-2})$

- The best-fit model is the cubic model, which suggests that the predicted life expectancy of the Philippines in 2024 will increase to 73.331.

Conclusions

The trend of life expectancy in the Philippines keeps on increasing over the years from 2001 to 2019, this may indicate a positive development such that the healthcare systems and public health conditions in the country are continuously improving. Furthermore, according to the findings, there is a relationship between the number of undernourished and life expectancy. As life expectancy is increasing, this may indicate a decline in the number of undernourished individuals in the country. Consequently, policymakers and public health officials should consistently focus on improving interventions that can help to mitigate malnutrition in the Philippines. By doing so, it will positively reflect on the country's life expectancy and overall health outcomes. Investing in the healthcare system can also contribute to the improvement of life expectancy. Based on the findings of the study, there is an association between life expectancy and healthcare expenditure. A higher healthcare expenditure can result better access to high-quality healthcare services. In addition, the economic outcome can also contribute to the life expectancy. An increase in the level of economic development can provide greater opportunities to allocate resources toward medical advancement, healthcare infrastructure, and proficient healthcare personnel. Modelling the life expectancy of a country modelling can provide an evidence-based explanation of the trend of life expectancy. It helps the policy makers to formulate interventions and decisions that can cater the healthcare needs of the nation. By formulating the best fit model for life expectancy in the Philippines from 2001 to 2019, it has been revealed that it will increase to 73.331 by the year 2024.

Recommendations

For the Philippines to continue its progress in improving life expectancy, the government must focus on addressing malnutrition, healthcare expenditure, GDP per capita, and other factors that can influence the country's life expectancy. A longer life expectancy can have a positive influence on workforce productivity as it allows for the contribution of healthy and capable individuals for more extended period, thereby fostering economic growth and stability.

As of 2019, the available data collected by the researcher is limited. For future studies, it is highly beneficial to explore data including years when the COVID-19 pandemic occurred. There is a possibility that this period may have an impact on the increase in life expectancy in the Philippines. Additionally, it is advisable to further investigate other variables that could potentially influence the country's life expectancy, as factors are not only limited to the variables used in this study.

Acknowledgement

This research would not have been possible without the invaluable support and resources provided by the Department of Science and Technology in my academic aspirations.

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