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Mathematical Modelling of the Gross Domestic Product of the Philippines

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ABSTRACT

Gross Domestic Product (GDP) reflects a country's economy. The higher the Gross Domestic Product (GDP), the healthier is the economy. Th objective of this study is to determine the best fit model to forecast the Gross Domestic Product (GDP) of the Philippines for the next five years (2022 – 2026). Using simple linear regression and multiple linear regression, the researcher found that there is significant linear relationship between the Gross Domestic Product (GDP) and unemployment rate, population, household expenditure, and government expenditure. Multiple linear regression also showed that the only significant predictors are population, household expenditure, and government expenditure. By the results of graphing and using formulas available in the Microsoft excel, the researcher determined that the best fit model is sextic. This study can be considered by the government of the Philippines in making decisions in implementing policies for economic growth and stability.

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Keywords:
Mathematical Modelling, Best Fit Model, GDP, Regression

1. INTRODUCTION

Gross Domestic Product (GDP) says the most about the health of a country's economy. A country with large GDP has great amount of goods and services generated within them, and also has a high standard of living (Fernando, 2023). It is important to track GDP as it provides a general assessment of a country's economic state. When GDP is growing, it generally implies that companies are expanding and that there are more available jobs (Asian Development Bank, 2017).

Philippine Statistics Authority (2017) stated during its 28th National Statistics Month that the country transitioned from being an economic laggard of Asia to one of the region's best performing economies. The Philippines was one of the prosperous countries in the world in terms of economy. It finally shed its "sick man of Asia" reputation. However, the country's economy falter during the COVID-19 pandemic. Philippine's economic model is vulnerable to disease outbreak. It's because it relies on mobility of people, thus tourism, services, and remittances were affected during the lockdown and consumer confidence declined as well (Mendoza, 2021). The Philippines had its worst GDP in 2020 as it shrank to 9.5%. (Venzon, 2021).

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Looking back at the Philippines' past economic performance, the country's economy was flourishing since 2010, as it was growing over 6% on average per year. The country's real GDP was more than doubled between 2001 and 2018, growing 5.6% per year on average. The Philippines was one of the top performers in the East Asia Pacific region. However, it still has over 20% of the population living below national and international poverty line (Qian, 2018). Also, in the late 1980s and early 1990s, Philippines began to undertake political and economic reforms. The GDP growth has increased to about 5 percent a year since 1994. With this, the number of Filipinos that were below the poverty line were decreasing. However, agricultural reform and the rise in investment in human assets would have made a more drastic reduction in the poverty rate (International Monetary Fund, 1998).

The Philippines has this long-term vision and aspirations called the *Ambisyon 2040.* It tells the way people want to live and the state of the country by 2040. In particular, government must use its tools of fiscal, monetary, and regulatory policies to guide the development path in facilitating Filipinos in attaining their *Ambisyon*, be it economic, human and physical capital, institutional and social and cultural. No one will be poor by 2040, instead, the country will be a prosperous middle-class society. The Philippines' economic growth must be relevant, inclusive, and sustainable. The per capita income must increase by at least three-fold. It is also envisioned that more than the increase in income, economic growth must continuously

improve the standard of living of the majority of the citizens (National Economic and Development Authority (NEDA), 2016).

Socioeconomic Planning Secretary Arsenio Balisacan said that Philippines expects a delay in achieving the *Ambisyon* 2040 due to the impact of COVID-19 pandemic. In 2022, Philippines aimed to 6.5 to 7.5 percent GDP growth and for the year 2023 to 2028, it is targeting 6.5 to 8 percent GDP growth. Balisacan stated that the prime concern for the medium term 2023 to 2028 are revitalizing job creation, prompt rapid poverty reduction and accelerate economic transformation. He concluded that the obstacles we face are not too great to overcome (The Philippine Star, 2022). With regards to this, the researcher aims to determine the best fit model to predict the GDP of the country that may serve as basis of the government in constructing a plan to acheive its goal by 2040.

II. STATEMENT OF THE PROBLEM

This study aimed to determine the best fit model to predict the main variable. Specifically, this aimed to:

1. Determine the trend of the Gross Domestic Product (GDP) of the Philippines, unemployment rate, population, household expenditure, and government expenditure from 2007 – 2021.
2. Find if GDP has a significant linear relationship with the following variables:
   a. Unemployment rate
   b. Population
   c. Household expenditures
   d. Government expenditures
   e. Unemployment rate, population, household expenditure, and government expenditure all together.
3. Construct a time series model of the GDP using the following models to predict its value for 2022 – 2026.
   a. Linear
   b. Quadratic
   c. Exponential
   d. Polynomial (cubic, quartic, quantic, sextic)
   e. Power
   f. Moving Average
   g. Exponential Smoothing
   h. Autoregression
4. Determine the best fit models and predict the main variable for 2022 – 2026.

III. RESULTS

In this chapter, the researcher analyzed the data in order to find out the final results. The study was based on the time series data covering the period from 2007 to 2021.

Figure 1. The trend of the GDP, Unemployment Rate, Population, Household Expenditure, and Government Expenditure from 2007 – 2021.

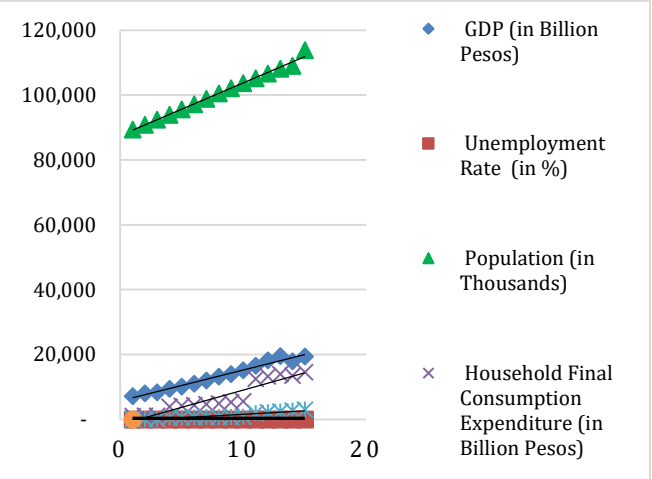


Figure 2. Simple Linear Relationship of the GDP and Unemployment Rate

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.714198
R Square	0.510079
Adjusted R Square	0.472393
Standard Error	3113.825
Observations	15

ANOVA

	df	SS	MS	F	Significance F
Regression	1	1.31E+08	1.31E+08	13.5349	0.002779254
Residual	13	1.26E+08	9693903		
Total	14	2.57E+08			

	Coefficients	tandard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	29051.96	4422.721	6.636629	1.62E-05	19797.25065	38306.66421	19797.25065	38306.66421
Unemployment Ra	-5233.32	1422.491	-3.67898	0.002779	-8306.42424	-2160.21289	-8306.42424	-2160.21289

The summary results showed that there is statistically significant linear relationship between the GDP of the Philippines and unemployment rate as significance F value is 0.002779254 which is less than at alpha of 0.05.

Figure 3. Significant Linear Relationship of the GDP and Population

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.982515
R Square	0.965335
Adjusted R Square	0.962868
Standard Error	828.2792
Observations	15

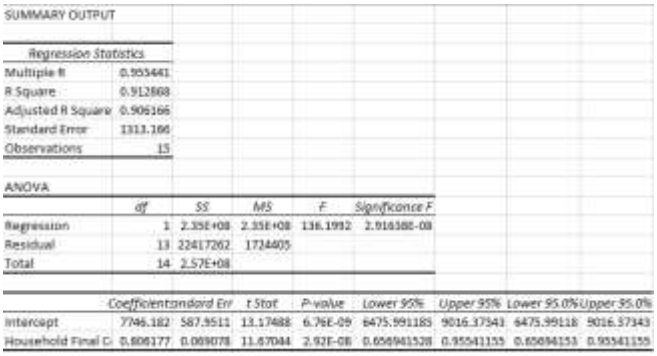
ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.48E+08	2.48E+08	362.0181	7.12105E-11
Residual	13	8918605	686046.5		
Total	14	2.57E+08			

	Coefficients	tandard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-44743.9	3060.854	-14.6181	1.9E-09	-51356.4702	-38131.322	-51356.47	-38131.322
Population (in Tho	0.578072	0.030382	19.02677	7.12E-11	0.512435844	0.6437087	0.51243584	0.64370868

The summary results showed that there is statistically significant linear relationship between the GDP of the Philippines and population as Significance F value of 0.0000000000712105 is less than at alpha of 0.05.

Figure 4. Significant Linear Relationship of the GDP and Household Expenditure



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.955441
R Square	0.912868
Adjusted R Square	0.906166
Standard Error	1313.166
Observations	15

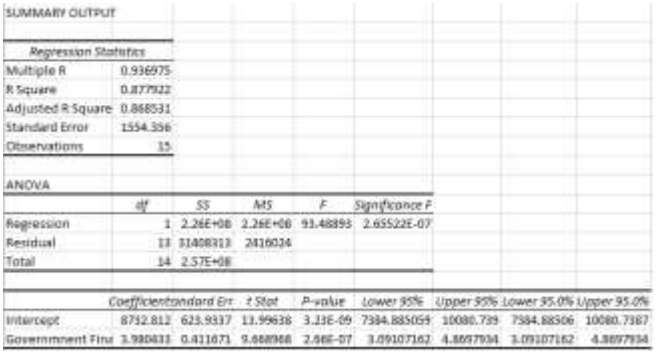
ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.35E+08	2.35E+08	136.1992	2.91638E-08
Residual	13	22417262	1724405		
Total	14	2.57E+08			

	Coefficients	tandard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	7746.182	587.9511	13.17488	6.76E-09	6475.991183	9016.37343	6475.99118	9016.37343
Household Final C	0.806177	0.069078	11.67044	2.92E-08	0.656941528	0.95541155	0.65694153	0.95541155

Summary results showed that there is statistically significant linear relationship between the GDP of the Philippines and household expenditure as Significance F value of 0.0000000291638 is less than at alpha 0.05.

Figure 5. Significant Linear Relationship of the GDP and Government Expenditure



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.936975
R Square	0.877922
Adjusted R Square	0.868531
Standard Error	1554.336
Observations	15

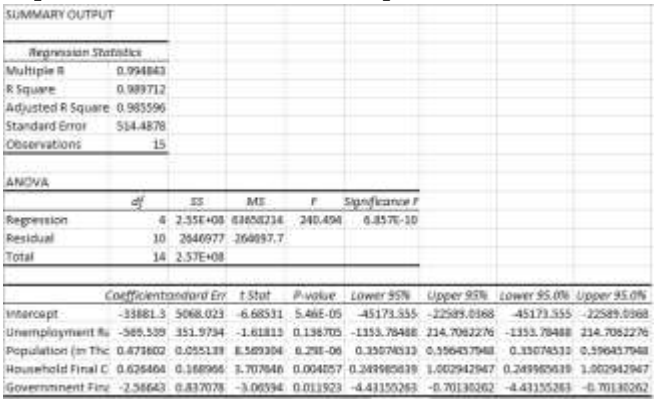
ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.26E+08	2.26E+08	93.48893	2.65522E-07
Residual	13	31408313	2416024		
Total	14	2.57E+08			

	Coefficients	tandard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	8732.812	623.9337	13.99638	3.13E-09	7384.885059	10080.739	7384.88506	10080.7387
Government Fina	3.980433	0.411671	9.668968	2.66E-07	3.09107162	4.8697934	3.09107162	4.8697934

The summary results showed that there is statistically significant linear relationship between the GDP of the Philippines and government expenditure as Significance F value of 0.000000265522 is less than at alpha of 0.05.

Figure 6. Significant Multiple Linear Relationship of the GDP, Unemployment Rate, Population, Household Expenditure and Government Expenditure



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.994843
R Square	0.989712
Adjusted R Square	0.985596
Standard Error	514.4878
Observations	15

ANOVA

	df	SS	MS	F	Significance F
Regression	4	2.55E+08	63658214	240.494	6.857E-10
Residual	10	2646977	264697.7		
Total	14	2.57E+08			

	Coefficients	tandard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-33881.3	5068.023	-6.68531	5.46E-05	-45173.555	-22589.0368	-45173.555	-22589.0368
Unemployment Ra	-569.539	351.9734	-1.61813	0.136705	-1353.78488	214.7062276	-1353.78488	214.7062276
Population (in Thc	0.671602	0.055139	8.569304	8.29E-06	0.35076533	0.596457948	0.35076533	0.596457948
Household Final C	0.626464	0.168966	3.707646	0.004057	0.249969639	1.002942947	0.249969639	1.002942947
Government Fina	-2.58643	0.837078	-3.09094	0.011923	-4.43155263	-0.70130262	-4.43155263	-0.70130262

The summary results showed that there is significant multiple linear relationship between the GDP of the Philippines and unemployment rate, population, household expenditure, and government expenditure as Significance F value of 0.0000000006857 is less than at alpha of 0.05. And as also shown by the p-values in each variable, the significant predictors of the main variable are population, household expenditure, and government expenditure as their p-values are less than at alpha 0.05.

SECTION 3: TIME SERIES MODEL

The following are the data collected from World Bank, Statistics Times, Bangko Sentral ng Pilipinas (BSP), and Philippine Statistics Authority (PSA).

Table 1. Data from World Bank, Statistics Times, BSP, and PSA from 2007 – 2021.

Year (2007 – 2021)	GDP (in millime Pesos)	Unemployment Rate (in %)	Population	Household Expenditure (in million Pesos)	Government Expenditure (in million Pesos)
1	7,198	2.43	89,405	1,058	91
2	8,050	3.72	90,902	1,108	94
3	8,390	3.86	92,414	1,150	102
4	9,399	3.61	93,967	3,946	570
5	10,145	3.59	95,570	4,169	528
6	11,061	3.50	97,213	4,443	653
7	12,051	3.50	98,872	4,692	706
8	13,207	3.60	100,513	4,947	718
9	13,944	3.07	102,113	5,267	784
10	15,132	2.70	103,664	5,633	850
11	16,557	2.55	105,173	12,528	1,940
12	18,265	2.34	106,651	13,250	2,200
13	19,518	2.24	108,117	14,027	2,411
14	17,952	2.52	109,035	13,476	2,740
15	19,441	2.63	113,880	14,610	3,021

Based from table 1 and all the results shown in figures 2 to 6, below are the results of the equation of each model.

Table 2. Model Equation

Model	Equation
Linear	$y = 947.42x + 5772.6$
Exponential	$y = 6985.9e^{0.0746x}$
Logarithmic	$y = 5017.1\ln(x) + 4020.4$
Quadratic	$y = 3.0936x^2 + 897.92x + 5912.9$
Cubic	$y = -6.396x^3 + 156.6x^2 - 116.49x + 7478.6$
Quartic	$y = -0.9895x^4 + 25.267x^3 - 176.57x^2 + 1161.3x + 6163.7$

Quintic	$y = -0.0221x^5 - 0.1047x^4 + 12.45x^3 - 95.468x^2 + 949.98x + 6327$
Sextic	$y = 0.0547x^6 - 2.6476x^5 + 48.401x^4 - 419.55x^3 + 1799.1x^2 - 2743.3x + 8639.8$
Power	$y = 5894.6x^{0.412}$
Moving Average	$y = 995.1x + 4419$
Exponential Smoothing	$y = 912.76x + 4385.3$
Autoregression	$y = 1145.427 + 0.97886y_{n-1}$

Table 3. Best Fit Model Prediction

Model	Equation	R^2	SE
Linear	$y = 947.42x + 5772.6$	0.9768	677.505
Exponential	$y = 6985.9e^{0.0746x}$	0.9773	935.463
Logarithmic	$y = 5017.1\ln(x) + 4020.4$	0.8375	1793.383
Quadratic	$y = 3.0936x^2 + 897.92x + 5912.9$	0.977	675.260
Cubic	$y = -6.396x^3 + 156.6x^2 - 116.49x + 7478.6$	0.9861	525.084
Quartic	$y = -0.9895x^4 + 25.267x^3 - 176.57x^2 + 1161.3x + 6163.7$	0.989	467.404
Quintic	$y = -0.0221x^5 - 0.1047x^4 + 12.45x^3 - 95.468x^2 + 949.98x + 6327$	0.989	467.047
Sextic	$y = 0.0547x^6 - 2.6476x^5 + 48.401x^4 - 419.55x^3 + 1799.1x^2 - 2743.3x + 8639.8$	0.9903	472.472
Power	$y = 5894.6x^{0.412}$	0.9124	1291.912
Moving Average	$y = 995.1x + 4419$	0.9916	925.290
Exponential Smoothing	$y = 912.76x + 4385.3$	0.9802	2315.633
Autoregression	$y = 1145.427 + 0.97886y_{n-1}$	0.963669	810.019

As shown in Table 3, the best fit model is sextic. To determine the best fit model, the R^2 must be closer to 1 and its Standard Error must be the lowest. Although sextic and moving average are both closest to 1, sextic model has lower Standard Error, thus it is the best fit model to predict the main variable.

Table 4. Forecasted Yearly GDP of the Philippines from 2022 to 2026.

Year (2022 – 2026)	
16	20, 980.7792
17	25, 157.9163
18	35, 078.7328
19	55, 141.1087
20	91, 573.8

IV. DISCUSSION

There is an increasing trend among the GDP, unemployment rate, population, household expenditure, and government expenditure as shown in figure 1. It is also shown in figure 2 to figure 5 that there is a significant linear relationship between the GDP each independent variable. Figure 6 shows that there is a significant multiple linear relationship between the GDP and the dependent variables. It is also shown by the table that the significant predictors of GDP are population, household expenditure, and government expenditure.

Table 3 shows that the best fit model is sextic since its R^2 value is closest to 1 other than the moving average but comparing the standard error of the two, sextic has lower standard error value, thus making it the best fit model.

The other time series models are linear with equation $y = 947.42x + 5772.6$, exponential with equation $y = 6985.9e^{0.0746x}$, logarithmic with equation $y = 5017.1\ln(x) + 4020.4$, quadratic with equation $y = 3.0936x^2 + 897.92x + 5912.9$, cubic with equation

$y = -6.396x^3 + 156.6x^2 - 116.49x + 7478.6$, quartic with equation $y = -0.9895x^4 + 25.267x^3 - 176.57x^2 + 1161.3x + 6163.7$, quintic with equation $y = -0.0221x^5 - 0.1047x^4 + 12.45x^3 - 95.468x^2 + 949.98x + 6327$, power with equation $y = 5894.6x^{0.412}$, moving average with equation $y = 995.1x + 4419$, exponential smoothing with equation $y = 912.76x + 4385.3$, and autoregression with equation $y = 1145.427 + 0.97886y_{n-1}$.

With sextic equation, $y = 0.0547x^6 - 2.6476x^5 + 48.401x^4 - 419.55x^3 + 1799.1x^2 - 2743.3x + 8639.8$, the researcher was able to predict the GDP of the Philippines from 2022 to 2026 as shown in table 4. The forecasted GDP of the Philippine from 2022 – 2026 will be 20980.7792, 25157.9163, 35078.7328, 55141.1087, and 91573.8 respectively. It is important to predict the GDP of a country as Roser (2021) stated that it reflects the quality and quantity of the goods and services that people need. Though they may seem unfelt or abstract, like the GDP per capita, we shouldn't forget that they are actually a measure of people's reality of material living condition.

V. CONCLUSION

From the results, it is shown that all the variables: unemployment rate, population, household expenditure, and government expenditures have a significant linear relationship with GDP. However, multiple linear regression also showed that only population, household expenditure, and government expenditure are significant predictors of the GDP. The researcher compared the forecasting accuracy of the different models and it was found out that the best fit model in forecasting the GDP was sextic. Using the best fit model, the values of GDP of the Philippines for the year 2022 – 2026 were obtained.

VI. ACKNOWLEDGMENTS

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VII. DISCLOSURE

The researcher declares no potential conflict of interests to disclose.

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