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Modelling Economic Growth: Panel Data Approach

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ABSTRACT

The Gross Domestic Product (GDP) plays a pivotal role as a key economic indicator. There are numerous factors that contribute to the formation of GDP. Hence, this research attempts to identify the best-fit panel model for GDP among selected countries in Southeast Asia and determine the significant factors influencing their GDP. The data used is the panel data that consist of GDP, Consumer Price Index (CPI), Unemployment Rate (UR) and population growth (POP) from 2003 to 2022 for Malaysia, Thailand, Indonesia, Brunei and Singapore. The methods of pooled, fixed and random effects models are employed. The fixed effects model reveals substantial impacts of variables like UR, POP, and CPI on GDP. The random effects model, validated through the Breusch-Pagan test, demonstrates superior adaptability to country heterogeneity. The Hausman test supports the random effects model as a more reliable framework than fixed effects. The unemployment rate and population growth affect significantly towards GDP.

Keywords: economic growth, fixed effects, panel regression, random effects

1 INTRODUCTION

Macroeconomic indicators play a crucial role in analyzing and understanding the overall performance of an economy [1]. These indicators provide valuable insights into the various aspects of an economy, including its growth rate, inflation rate, employment levels, fiscal and monetary policies and international trade. Economic growth research provided useful information to policymakers, traders/investors, government and future planning.

Gross Domestic Product (GDP) is widely recognized as a key indicator of a country's economic growth and overall performance. It measures the total monetary value of all goods and services produced within a country's borders over a specific period, typically quarterly or annually. The effects of population growth, Consumer Price Index (CPI), and unemployment rate on GDP are significant as they reflect key economic dynamics.

The relationship of GDP among Malaysia, Indonesia, Singapore, Thailand, and Brunei showcases the economic diversity and interdependence within Southeast Asia and having the highest GDP in this region [2]. The countries are interconnected through trade, resource exchange, investments, labor

mobility, and regional initiatives, creating a dynamic economic relationship that collectively enhances their GDP. All five countries are members of ASEAN, which promotes economic cooperation and reduces trade barriers. This facilitates the free flow of goods, services, and investments, directly impacting their GDP.

Hence, studying the relationship between GDP, CPI, population growth, and unemployment rate in Malaysia, Indonesia, Thailand, Singapore, and Brunei using panel data regression analysis is a critical step toward understanding the economic dynamics of the ASEAN region. The findings can guide policymakers in creating evidence-based strategies to promote sustainable development and economic resilience while fostering regional cooperation.

2 LITERATURE REVIEW

This section explores the relationship between macroeconomic indicators which are Consumer Price Index (CPI), Population Growth (POP) and Unemployment Rate (UR) on Gross Domestic Product (GDP).

The relationship between population growth and GDP is a complex and intricate. According to Balbaa [3], population dynamics can act as both a driver and a challenge for sustainable economic development. GDP has a strong relationship with the total population. The analysis using Granger causality, positive relationship between GDP and total population in Singapore, suggest that number of residents can boost the economic production [4]. Rahman et al. [5] employed the same method also suggested that GDP are positively impacted by population growth. In contrast, the impact of population growth and GDP using Solow Growth model is negative in Indonesia [6]. Abdullah et al. [7] claimed that the increase of population growth is more likely to slow down the rate of GDP in Bangladesh via multiple regression analysis. A larger population size influence larger consumption needs of people thus increases the expenditure on consumption.

The relationship between GDP and the CPI is significant, as both are key economic indicators that help gauge a country's economic performance and stability. Zabri et al. [8] applied Vector Error Correction Model and underscores a significant negative correlation between GDP and CPI, signifying that an escalation in CPI is associated with a subsequent decline in GDP. This inverse relationship implies that as CPI rises, the purchasing power of currency diminishes, resulting in reduced consumption and, consequently, a contraction in GDP [9]. The real GDP performance using Vector Autoregressive in the long run shows changes in the same direction [10].

The unemployment rate can significantly influence a country's Gross Domestic Product (GDP) due to its direct impact on economic activity and productivity. Januri et al. [11] stated that from the findings using co-integration method, unemployment rates have a high influence on the GDP rate in Malaysia. According to Mandel and Liebens [12], decreasing GDP rate through slow economic growth leads to an increasing unemployment rate from the analysis of multiple linear regression model. Many research also found that the relationship between GDP and unemployment rate is vital [13].

Panel data regression is a statistical method used to analyze data that varies across entities (e.g., countries, regions) and over time. It combines cross-sectional data (data across entities) and time-series data (data over time), allowing researchers to control for unobserved heterogeneity and

capture both spatial and temporal effects. There are many research employed panel data regression analysis on GDP [16, 17, 18, 19].

In conclusion, GDP is intricately connected to population growth, CPI, and the unemployment rate, each of which significantly influences a country's economic performance. Population growth drives GDP by expanding the labor force and consumer base, though its benefits depend on how effectively resources are utilized. The CPI reflects changes in price levels and plays a critical role in determining real GDP, highlighting the importance of maintaining stable inflation for sustainable economic growth. Lastly, the unemployment rate directly impacts GDP by influencing production levels and consumer spending, with high unemployment often leading to economic contraction. Together, these factors underscore the complex and dynamic nature of GDP, requiring balanced policies to promote growth while managing inflation, employment, and population trends. Hence, this research was conducted to employ panel data analysis and determine the significant factors that affect GDP.

3 METHODOLOGY

3.1 Description of Data

In this research, the secondary data used is a set of panel data from five countries in Southeast Asia (Brunei Darussalam, Indonesia, Malaysia, Singapore and Thailand) that includes GDP, CPI, UR and POP. Time period taken into consideration are between 2003 to 2022 in yearly form. Data was obtained from World Bank Data website retrieved on 1st April 2023. The variable of interest in this research is Gross Domestic Product and denoted as GDP. Independent variables and their measuring units are listed in Table 1.

Table 1: Variables and Measuring Units

Code	Variables	Unit
POP	Population Growth	Percent
UR	Unemployment Rate	Percent
CPI	Consumer Price Index	Index
GDP	Gross Domestic Products	USD

3.2 Method of Analysis

This study applied panel regression analysis to examine the factors that affect economic growth in five selected Southeast Asian countries. Three widely used static linear panel data analysis models were employed: pooled Ordinary Least Squares (OLS) model, the fixed effects model and the random effects model.

3.2.1 Pooled Ordinary Least Square, Fixed Effect and Random Effect

Pooled Ordinary Least Square (OLS) is commonly used techniques in panel data analysis. This panel model was applied for a study when the cross-sectional units were homogeneous. The pooled ordinary least square model is [14]:

$$GDP_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 UR_{it} + \beta_3 CPI_{it} + \varepsilon_{it} \quad (1)$$

where

$\beta_0, \beta_1, \beta_2$ and β_3 are parameters to be estimated and ε_{it} are error terms normally distributed.

Here, i represents the country number, t represents the year. In the absence of country-specific effects in the model, it transforms into a pooled OLS regression.

A fixed group effect model explores individual variations in intercepts, presuming uniform slopes and constant variance across individuals, denoted as groups and entities. To assess fixed effects, an F-test is employed, examining the loss of goodness-of-fit. The null hypothesis posits the absence of individual or time-specific effects, indicating their negligible contribution to the variation in the dependent variable. This is mathematically expressed as $\alpha_1 = \alpha_2 = \cdots = \alpha_n = 0$ for individual fixed effects or $\tau_1 = \tau_2 = \cdots = \tau_t = 0$ for time fixed effects, where α represents individual fixed effects, τ represents time fixed effects, and n and t are the number of entities and time periods, respectively. Rejection of the null hypothesis implies the existence of significant effects influencing the observed variation in the dependent variable. Consequently, the inference is drawn that the fixed effect model surpasses the pooled Ordinary Least Squares (OLS) model.

The random effect model investigates the impact of group or time on error variances. This model, often referred to as group regression, utilizes aggregate group means of variables. The representation of the random effects model is as follows:

$$GDP_{it} = \beta_0 + \beta_1 POP_{it} + \beta_2 UR_{it} + \beta_3 CPI_{it} + (\alpha_{it} + \varepsilon_{it}) \quad (2)$$

The random effects model, also known as an error component model, characterizes country-specific effects as a random draw uncorrelated with both the regressors and the overall error term.

3.2.2 Chow Test, Breusch-Pagan Lagrange Multiplier Test and Hausmann Test

This Chow test is instrumental in determining whether there exists homogeneity in the relationships among the entities or time periods being studied [15]. It helped to determine the structural break or heterogeneity in the relationship between macroeconomic indicators across different countries and years. To verify the assumption of random effect, the Breusch-Pagan Lagrange Multiplier (LM) test is employed. If the null hypothesis is rejected, it implies a significant presence of random effects in the panel data. This suggests that the random effect model effectively addresses heterogeneity better than the pooled Ordinary Least Squares (OLS) model. The Hausman specification test compares fixed and random effect models assuming the null hypothesis that the individual-specific effects (random effects) are uncorrelated with the explanatory variables, [16]. In other words, the preferred model is the random effects model.

Table 2 presents a summary of panel model selection criteria. The Chow Test assesses the pooled model choice, recommending the fixed effect model when the p-value is less than α (0.05). Similarly, the Breusch Pagan Test guides the decision-making process, suggesting the adoption of the random effect model if the p-value is below α (0.05). Lastly, the Hausman Test aids in model selection,

favoring the fixed effect model when the p-value is less than α (0.05). These tests collectively offer a robust framework for determining the most suitable panel model based on statistical significance.

Table 2: Summary of Panel Model Selection

Model Comparison Test	Hypothesis	Decision Rule	Conclusion
Chow Test	$H_0: \sigma^2\lambda = 0$ $H_1: \sigma^2\lambda > 0$	If p-value < 0.05, Reject H_0	Choose fixed effect model
Berusch Pagan Test	$H_0: \sigma^2\lambda = 0$ $H_1: \sigma^2\lambda > 0$	If p-value < 0.05, Reject H_0	Choose random effect model
Hausman Test	$H_0: cov(\lambda_i, X_{it}) = 0$ $H_1: cov(\lambda_i, X_{it}) \neq 0$	If p-value < 0.05, Reject H_0	Choose fixed effect model

4 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

The results of this analytical investigation are briefly displayed in Table 3, which includes essential statistical measures for each of the variables that are listed, such as the mean, standard deviation, minimum value, maximum value, skewness, kurtosis, and Jarque-Bera statistics.

Indonesia exhibits a mean GDP of 27.26, with a standard deviation of 0.54, showcasing relatively stable economic performance. Malaysia follows closely with a mean GDP of 26.27 and a standard deviation of 0.39, indicating comparable economic stability. Brunei, with a mean GDP of 23.28 and a standard deviation of 0.28, demonstrates a slightly lower average GDP but still maintains stability. Singapore and Thailand also show stable GDP distributions, with mean values of 26.25 and 26.56, respectively, and relatively low standard deviations.

Population growth (POP) distributions vary across countries. Malaysia has the highest mean POP of 1.70, indicating a larger population size compared to other countries in the analysis. Indonesia follows with a mean POP of 1.12, while Singapore and Thailand have lower mean POP values of 1.50 and 0.55, respectively. Consumer Price Index (CPI) distributions highlight differences in inflation rates and cost of living. Indonesia has the highest mean CPI of 5.63, indicating relatively higher inflation compared to other countries. Malaysia follows with a mean CPI of 2.16, while Brunei, Singapore, and Thailand demonstrate lower mean CPI values, suggesting comparatively lower inflation rates. Unemployment Rate (UR) distributions vary across countries, indicating differences in labor market dynamics. Brunei exhibits the lowest mean UR of 3.43, suggesting a relatively stable labor market. Indonesia and Thailand follow with mean UR values of 5.33 and 0.94, respectively. Malaysia and Singapore have higher mean UR values of 4.20 and 0.78, respectively, indicating potential challenges in their labor markets.

Table 3: Descriptive Statistics across Countries

	GDP	POP	CPI	UR
Indonesia				
Mean	27.26	1.12	5.63	5.33
Standard Deviation	0.54	0.21	2.91	1.57
Min	26.18	0.64	1.56	3.55
Max	27.91	1.34	13.11	8.06
Skewness	-0.76	-0.96	0.93	0.52
Kurtosis	-0.94	-0.35	0.29	-1.41
Jarque-Bera	0.26	0.16	0.16	0.31
Malaysia				
Mean	26.27	1.7	2.16	3.43
Standard Deviation	0.39	0.44	1.44	0.37
Min	25.43	1.08	-1.14	2.88
Max	26.73	2.44	5.44	4.54
Skewness	-0.82	0.28	0.01	1.25
Kurtosis	-0.71	-1.39	0.09	1.63
Jarque-Bera	0.24	0.46	0.93	0.01
Brunei				
Mean	23.28	1.28	0.67	3.43
Standard Deviation	0.28	0.34	1.11	0.37
Min	22.6	0.81	-1.26	2.88
Max	23.67	1.88	3.68	4.54
Skewness	-0.62	0.11	0.79	1.25
Kurtosis	-0.05	-0.4	0.55	1.63
Jarque-Bera	0.46	0.52	0.21	0.01
Singapore				
Mean	26.25	1.5	1.88	4.2
Standard Deviation	0.45	2.05	2.17	0.9
Min	25.3	-4.17	-0.53	2.76
Max	26.87	5.32	6.63	5.93
Skewness	-0.63	-0.75	0.92	0.78
Kurtosis	-0.91	1.02	-0.46	-0.48
Jarque-Bera	0.38	0.14	0.19	0.3
Thailand				
Mean	26.56	0.55	2.15	0.94
Standard Deviation	0.39	0.23	2.07	0.37
Min	25.75	0.13	-0.9	0.25
Max	27.02	0.86	6.08	1.54
Skewness	-0.72	-0.43	0.2	0.17
Kurtosis	-0.82	-1.29	-1.04	-1.17
Jarque-Bera	0.32	0.42	0.7	0.64

4.2 Pooled Ordinary Least Square (OLS), Fixed Effect and Random Effect Model

The results presented in Table 4 indicate that the value of F-statistic is 9.040 and its probability value is 0.000 which shows that the model is significant. However, the low R-square value suggests that other variables also significantly contribute to GDP.

Table 4: Summary of statistics of pooled regression

	Coefficient	Std. Error	t-Statistics	p-value
UR	−0.143∗	0.086	-1.662	0.100
CPI	0.272∗∗∗	0.055	4.956	0.000∗∗∗
POP	−0.249∗	0.131	-1.906	0.060*
Constant	26.046∗∗∗	0.314	82.886	0.000∗∗∗
Test	R^2	Adjusted R^2	F-Statistic	p-value
Summary	0.22	0.196	9.040∗∗∗	0.000∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

The p-value of the Chow test is significant (p-value<0.05). The R-square increased significantly (53.5%) compared to ordinary pooled regression analysis. Hence, there are significant differences in the relationships being studied across entities or over time and the instability of Pooled OLS in managing heterogeneity becomes apparent, favoring the consideration of other effects.

Table 5: Summary of statistics of fixed effect model

	Coefficient	Std. Error	t-Statistics	p-value
UR	−0.339∗∗∗	0.035	-9.637	0.000∗∗∗
CPI	0.002	0.015	0.125	0.901
POP	−0.118∗∗∗	0.031	-3.803	0.000∗∗∗
Test	R^2	Adjusted R^2	F-Statistic	p-value
Summary	0.567	0.535	40.228∗∗∗	0.000∗∗∗

Note: ∗p<0.1; ∗∗p<0.05; ∗∗∗p<0.01

The results displayed in Table 5 reveal that the F-statistic, with a value of 40.228 and a probability value of 0.000, indicates the significance of fixed effects. This suggests that the fixed effect serves as an appropriate model in this study.

The presented findings in Table 6 indicate that an elevation in the UR corresponds to a downturn in the GDP of the chosen countries. As expected, the coefficient for this variable stands at -0.337, and with a p-value of 0.000, the UR is deemed statistically significant at the 5% level.

Table 6: Summary of statistics of random effect model

	Coefficient	Std. Error	t-Statistics	p-value
UR	−0.337***	0.035	-9.513	0.000***
CPI	0.003	0.016	0.178	0.859
POP	−0.118***	0.031	-3.782	0.000***
Constant	27.229***	0.644	42.307	0.000***
Test Summary	R^2	Adjusted R^2	F-Statistic	p-value
	0.55	0.536	117.442	0.000***

Note: *p<0.1; **p<0.05; ***p<0.01

Additionally, the results suggest that an upsurge in the CPI is associated with a positive impact on the GDP of the selected countries, amounting to 0.003. However, the p-value for this variable is 0.859, indicating that the CPI is statistically insignificant. In the case of POP, an additional unit of growth leads to a decrease in GDP for the selected countries by 0.118. As expected, the p-value for POP is 0.000, indicating statistical significance at the 5% level of significance. Additionally, the overall goodness of fit, as indicated by the R-square, illustrates that the considered variables collectively account for approximately 55% of the variation in GDP. The F-statistic, with a value of 40.228 and a probability value 0.000, underscores the significance of the random effect. This suggests that the random effect is adept at handling heterogeneity more effectively than pooled OLS.

According to the results from the two-ways effect Breusch-Pagan test, the F-statistic and probability values are 497.196 and 0.000, respectively. Given that the p-value is below 0.05, the null hypothesis is rejected. Consequently, it can be concluded that there are significant individual and time effects in this model. The F-statistic and associated probability values for Hausman test are 0.678 and the p-value is 0.878. Given that the p-value exceeds 0.05, fail to reject the null hypothesis. Consequently, in the context of this study, it can be concluded that the random effect model is deemed more reliable compared to the fixed model.

The findings represented in this study align with and extend upon previous research in several significant ways. It is important to note that the testing of GDP trends in Southeast Asia countries which includes Indonesia, Malaysia, Brunei, Singapore, and Thailand over a course of period from 2003 to 2022, endorses with prior studies that emphasized the impact of economic indicators on the overall economic health of nations. To achieve the objectives of the study, identification on the best fit panel model for GDP among Southeast Asia countries was carried out. The observed significant factors that influence GDP of Southeast Asia countries particularly in the Fixed Effects and Random Effects models is consistent with established economic theories in existing literature. Based on the empirical result from the Hausman test, it affirms the superiority of the random effects model. This, aligns with the findings in the previous study, suggests that these effects can be appropriately treated as random, validating the consistency and efficiency of the random effect estimators in capturing the underlying dynamics of the data.

In contrast to the findings of the prior study, the current research reveals a nuanced association between inflation, as gauged by the CPI, and GDP in the selected countries. The analysis implies CPI positively influences GDP by 0.003. However, the corresponding p-value of 0.859 indicates statistical insignificance in this relationship. This outcome assumes significance as it contributes to the ongoing

discourse on the impact of CPI on GDP. The previous study emphasizes the need to keep CPI at a reasonable level by highlighting the negative relationship between CPI and output growth, particularly at extremely high CPI levels [17]. Nevertheless, the study's findings, which show a statistically insignificant CPI coefficient, suggest that the observed beneficial effect on GDP is not statistically significant, casting doubt on the notion that moderate CPI has a growth-promoting effect. This discrepancy emphasizes how complex the relationship between CPI and GDP is and how important context-specific analysis is.

Furthermore, the findings of the relationship of UR and GDP affirm a negative correlation in the five selected countries. The coefficient for this variable is -0.337, and the associated p-value of 0.000 establishes its statistical significance at the 5% level. This resonates with previous research, which emphasizes the crucial role of the UR in shaping GDP trajectories, both globally and locally. The conclusion drawn is that an elevated UR is linked to a decline in long-term GDP [17]. This aligns with the broader perspective that developing countries have room for improvement in correcting and maintaining economic development indicators to ensure sustainable growth.

In relation to POP, an additional unit results in a 0.118 decrease in GDP for the selected countries. The p-value associated with POP is 0.000, indicating statistical significance at the 5% level. This aligns with prior research indicating that POP has a positive and statistically significant impact on GDP [18]. The regression findings suggest that a one million increase in a country's POP corresponds to a 9.598% increase in GDP. The rationale lies in the notion that POP contributes to an expanded labor force, heightened private consumption, and increased investment in human capital, particularly in education and training.

5 CONCLUSION

In general, this research aims to model the panel data of GDP, CPI, Pop, and UR. The countries involved are Indonesia, Malaysia, Brunei, Singapore, and Thailand. The duration of data used is 20 years starting from 2003 to 2022. The analysis conducted on various panel models, namely Pooled OLS, Fixed Effects, Random Effects and selection among them using the Hausman test, Breusch-Pagan test, and F-statistics, offers comprehensive insights into the factors influencing GDP among Southeast Asia countries. The Pooled OLS model is deemed less reliable due to the Chow test indicating significant differences across entities or time. Fixed Effects and Random Effects models provide more nuanced results compared to Pooled OLS model. On the other hand, the Random Effects model underscores the significance of the UR and POP, with CPI being statistically insignificant. Notably, the selection tests favor the Random Effects model, aligning with the objective of identifying the best-fit panel model. This study can be improved by adding more economic indicators and data points. In addition, methods such as panel autoregression where the influence of past values of variables are taken into consideration. In conclusion, the study achieves its objectives by pinpointing significant factors influencing GDP which is POP and UR and identifying the most appropriate panel model to be Random Effect, thus contributing valuable insights for policymakers and researchers in the Southeast Asia region.

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