Analysis of GDP in Countries neighbors with Indonesia using a Combination of the GSTAR Model and Verification using Statistical Quality Control

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***Abstract*—The Generalized Space-Time Autoregressive (GSTAR) model is used to model GDP growth rates in Indonesia, Malaysia, Singapore, and Brunei Darussalam. Southeast Asian countries have cultural and historical linkages and often share economic tendencies. GSTAR is used because it can represent complex spatial and temporal relationships in GDP dynamics. Historical GDP data for the four countries is collected from 1975 to the present—the GSTAR model models regional interdependence and temporal patterns in these economies' geographical and temporal linkages. A control chart analysis tests the GSTAR model's accuracy and robustness. Control charts help monitor and assess economic model stability. The data used in this study is GDP data in Indonesia, Malaysia, Singapore, Brunei Darussalam, and Thailand, collected from 1975 to 2021. This study discusses GSTAR model projections with actual GDP growth rate data to identify economic abnormalities in these linked countries. This research has significant consequences for regional politicians, economists, and businesses. Policy decisions, investment strategies, and GSTAR model economic forecasts can benefit from understanding these countries' GDP growth interdependencies and patterns. Control chart analysis also assures that the model accurately tracks economic trends. Finally, the GSTAR model and control chart analysis give a complete framework for modelling and testing connected GDP growth rates.**

***Index Terms*—spatial, connected, in-control.**

I. INTRODUCTION

THE Gross Domestic Product (GDP) is a valuable indicator of a nation's economic status, permitting the estimation of its economic size, growth rate, and orientation. The GDP becomes essential for governments, investors, and enterprises to provide insight and affect their strategic decision-making processes [1]. In shaping economic performance such as GDP, space and time correlation play a significant role [2].

The spatial correlation that explores the relationship between geographical location observed among the GDP of Indonesia, Malaysia, Singapore, and Brunei represents the intricate network of economic interactions, geographical connections, and typical regional dynamics that influence the economic performance of these Southeast Asian countries [3]. Indonesia, Malaysia, Singapore, and Brunei are geographically located in Southeast Asia, with their territories sharing land or sea bounds [4]. Their proximity to these things is an essential factor in their economic dependence. Besides that, Singapore and Malaysia are significant participants in global supply chains, mainly depending on acquiring raw materials and components from Indonesia and Brunei [5]. The other spatial correlation can be stated by Brunei's oil and natural gas resources, which play a key role in maintaining the availability of energy throughout the area [6].

The time correlation between the GDP of Indonesia, Malaysia, Brunei, and Singapore can be explained by the multifaceted interaction of historical legacies, global trends, and national responses to economic shocks [7]. The impact of economic shocks, such as the Asian financial crisis in the late 1990s, has shown varying effects on these countries [8]. The combination of both space and time correlations also consequently influences the GDP of each country [9]. For instance, the fluctuations in energy prices, such as oil in Brunei, may cause both direct and indirect effects on the GDP of other countries [10]. Besides that, the participation of Indonesia, Malaysia, Brunei, and Singapore in regional associations such as the Association of Southeast Asian Nations (ASEAN) maintains a significant impact on regional trade patterns and economic growth, such as GDP [11].

Examining and forecasting economic expansion is an essential activity for policymakers, businesspeople, and economists alike, particularly in the context of the global economy. The GDP is a crucial indicator that may be used to evaluate a country's overall economic health as well as its level of performance. It is vital to use advanced analytical techniques to capture the subtle dynamics of GDP data to make informed judgments and design effective policies. The Generalized Space-Time Autoregressive (GSTAR) model exemplifies this highly developed instrument. The GSTAR model, developed within spatial econometrics, offers a practical framework for comprehending the geographical and temporal dependencies inherently present in GDP data [12]. It is essential to remember this while analyzing the dynamic relationship between the economic expansion of various countries or regions over time. Recent research on GSTAR has been carried out a lot [13],

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[14], [15], [16], [17], [18], [19].

The GSTAR model, in its most fundamental form, performs the function of a bridge between conventional time series analysis and spatial econometrics. This allows for the presentation of an all-encompassing viewpoint on the dynamics of economic expansion. Since it considers spatial and temporal relationships, it provides analysts and policymakers with a more comprehensive toolkit for analyzing, forecasting, and influencing GDP patterns. The GSTAR model is an excellent instrument for unravelling the complex web of economic linkages that support the global financial landscape in an increasingly linked global economy. These links are the foundation of the global financial landscape. As a spatial object for examination in this study is the case of GDP between four countries that are allies: Indonesia, Malaysia, Singapore, and Brunei Darussalam. In this study, the GDP of these four countries will be modelled from a spatial and temporal viewpoint. In the following step, a statistical control chart will be used to determine whether the model just obtained is statistically controlled. Many researchers have carried out research related to control charts, one of which is [20]. The modification made in this research was to combine the GSTAR model and control chart. The GSTAR model is used to model data spatio-temporally. Meanwhile, the control chart is used to test the residuals produced from the GSTAR model so that the resulting GSTAR model is optimal and can be used for predictions.

II. RESEARCH METHODS

A. Gross Domestic Product (GDP)

The GDP is an important economic statistic that determines the entire value of all products and services produced inside a nation's borders during a particular time, commonly an annual or quarterly average [21]. It helps gain an understanding of the overall economic performance of a nation as well as the size of its economy. The GDP is calculated by adding all the money spent by consumers, businesses, and governments and deducting all the money spent on imports. The following calculation can be used to arrive at the actual GDP figure after inflation has been considered [22]:

$$\text{Real GDP} = \frac{GDP}{1 + \text{inflation since base year}}$$

A base year that is regularly kept up to date by the government and serves as a point of comparison for economic data such as the GDP is called the base year. The following formula is used to calculate the real GDP growth rate, which is based on the real GDP [22]:

$$\text{Real GDP growth rate} = \frac{\text{most recent year's real GDP} - \text{the last year's real GDP}}{\text{the previous year's real GDP}}$$

When inflation is subtracted from nominal GDP, another method that can be used to determine real economic growth is presented. The inflation rate is factored into calculating nominal but not real economic growth. To accomplish this calculation, a GDP deflator must first be incorporated. Because a GDP deflator is calculated by taking the quotient of nominal GDP divided by real GDP divided by 100, this method can only be used to accurately calculate real GDP if the GDP deflator has already been determined [22],

$$\text{Real GDP} = \frac{\text{Nominal GDP}}{\text{GDP Deflator}} \times 100$$

A country's real economic growth rate is useful information for policymakers to have when making decisions regarding fiscal or monetary policy. These decisions could be used to either stimulate economic growth or bring inflation under control. The figures we use for the real economic growth rate serve two purposes [23]:

1) The real economic growth rate is the figure used to compare the current rate of economic growth with the rate of growth seen in prior periods to determine the overall growth pattern over time.
2) When comparing the growth rates of economies that are very similar but have significantly different inflation rates, it is important to compare the growth rates of the real economy. Since nominal GDP does not take inflation into account, comparing the nominal GDP growth rate of a country with inflation of only 1%

When looking at the geographical and economic elements that influence the interaction between two nations, such as Indonesia, Malaysia, Singapore, and Brunei, it is possible to have a better understanding of the relationship between their respective GDP. Even though these nations are geographically located in proximity to one another and share some cultural traits, there are substantial disparities between them in terms of their GDP levels, economic structures, and other factors that influence the growth of their economies. The following are some examples of spatial connections between them [24]:

1) **Trading and Investment**
Because these four countries are close, they have robust trading links. Because Singapore is the financial hub for the area, Indonesia, Malaysia, and Brunei frequently conduct their commercial and investment activities there. The rate of economic expansion in each nation can be affected by international trade and investment as well as exports and imports.
2) **Dependence on Natural Resources**
These nations all have varying degrees of reliance on natural resource industries, such as the oil and gas industries. For instance, Brunei is a large oil producer, whereas Singapore virtually lacks any natural resources. The global price of oil and the amount of oil produced in these locations can influence the expansion of their economies and the trade between them.
3) **Economic Relations**
The rate of economic expansion in one nation can influence the economies of its bordering nations. For instance, robust economic growth in Singapore and Malaysia might generate prospects for business and market expansion for Indonesian goods. On the other hand, economic instability in one nation might harm economic growth in other nations. Cooperation on a Regional Scale These four nations are active participants

in various frameworks for regional cooperation, one of which is the Association of Southeast Asian Nations (ASEAN). Because of this cooperation, trade, investment, and economic rules between these countries can be influenced, which can influence their GDP.

4) **Tourism**
The tourism industry is a significant contributor to the economies of each of these countries. The number of tourists who go from one country to its adjacent countries can have a sizeable effect on both the tourism industry and the GDP of those surrounding countries.

However, it is essential to remember that each nation possesses distinct economic characteristics, such as its industrial structure, the rate at which its population is growing, and its economic policies. Therefore, even though these connected countries have economic and geographical connections, major variances contribute to the disparities in their GDP levels.

B. GSTAR Model

The GSTAR model, which stands for "Generalised Space-Time Autoregressive," is a statistical and econometric tool applied to analyse and forecast spatial and temporal data in the form [25]. The GSTAR model is a flexible instrument that may be utilised for various data analysis tasks, including examining complicated datasets with geographical and temporal dimensions. It can be utilised to investigate how variables vary through time and place, recognise patterns, and generate predictions using this information. The following are important parts of the GSTAR model:

1) **Space-Time Autoregressive Structure**
The GSTAR model contains an autoregressive structure, which implies that it also takes the correlation between observations made at various locations in space and times in history. This is accomplished by using a space-time autoregressive structure. It considers both the spatial dependencies (which occur across locations) as well as the temporal dependencies (which occur across time) [25].
2) **Spatial Weighting**
The GSTAR model quantifies spatial dependencies by making use of spatial weights. Spatial weights are meant to indicate the degree to which distinct spatial places connect or interact. These weights are used to capture the spatial autocorrelation, which indicates how close sites influence one another [13], [16], [26], [27], [28].
3) **Temporal Autoregression**
The model also incorporates temporal autoregressive components, which capture the temporal dependencies or autocorrelation in the data over time. These dependencies and autocorrelations can be thought of as a type of temporal autocorrelation. This helps to explain why the observations made at any time point are affected by the observations made at earlier time points [28].

Let $Y_t^{(i)}$ follow the GSTAR(p, λ_p) model for $i = 1, 2, \ldots, N$; $t = 1, 2, \ldots, n$; N is the number of locations and n is the number of observations [29],

$$\mathbf{Y}_t = \sum_{k=1}^{p} \sum_{\ell=0}^{\lambda_k} \Phi_{k\ell} \mathbf{W}^{\ell} \mathbf{Y}_{t-k} + \mathbf{e}_t$$

where

$$\mathbf{Y}_t = \begin{bmatrix} Y_t^{(1)} & Y_t^{(2)} & \ldots & Y_t^{(N)} \end{bmatrix}^t$$
$$\Phi_{k\ell} = diag(\phi_{k\ell}^{(1)}, \phi_{k\ell}^{(2)}, \ldots, \phi_{k\ell}^{(N)})$$
$$\mathbf{e}_t = \begin{bmatrix} e_t^{(1)} & e_t^{(2)} & \ldots & e_t^{(N)} \end{bmatrix}^t$$
$$\mathbf{W}^{\ell} = \begin{bmatrix} 0 & w_{12}^{(\ell)} & \ldots & w_{1N}^{(\ell)} \\ w_{21}^{(\ell)} & 0 & \ldots & w_{2N}^{(\ell)} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1}^{(\ell)} & w_{N2}^{(\ell)} & \ldots & 0 \end{bmatrix}$$

$\mathbf{Y}_t$ denotes the stochastics process for each time t and location i, $\Phi_{k\ell}$ is matrix of parameter for k is autoregressive order and ℓ is spatial order, $\mathbf{W}^{\ell}$ is weight matrix for lag-ℓ, and $\mathbf{e}_t$ is matrix of error for each location i and time t.
If the order GSTAR model is $(1;1)$ then

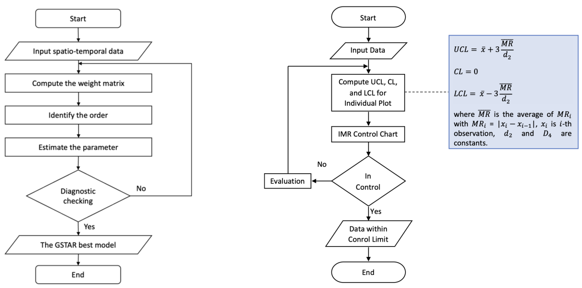
$$\mathbf{Y}_t = (\Phi_{10} + \Phi_{11}\mathbf{W})\mathbf{Y}_{t-1} + \mathbf{e}_t$$

The procedure of modeling GSTAR is shown in Figure 1a.

C. Control Chart

A control chart, also known as a process used in quality control and process monitoring control chart, is a statistical tool to evaluate the consistency and performance of a process over time [30]. In the 20th century, Walter A. Shewhart developed control charts [31]. Since then, control charts have become crucial in manufacturing, health care, and services for maintaining and enhancing product quality and process efficiency [32]. The purpose of control charts is to detect deviations from expected behaviour and aid in determining when a process is out of control or producing nonconforming products [33]. Individual/Moving Range Charts (I-MR), X-bar and R Charts, X-bar and S Charts, P-charts (for proportional data), NP-charts (for count data), and C-charts (for number of defects) are the different forms of control charts [34].

IMR control charts are handy when working with continuous data, such as measurements from manufacturing processes in which data points are collected sequentially [36]. IMR graphs consist of I (individual) graphs, which display measurement data points carried out over time, where each data point represents one observation of the process and MR (Moving Range) graphs, which display the range of movement between consecutive data points on the I graph which helps monitor the spread of the process and detect changes in variability [37]. The control chart utilized in this study was the IMR control chart, but only individual plots were employed. IMR control charts are a standard statistical tool used in quality control and process improvement [35]. The IMR control chart flowchart is displayed in Fig 1b. To model the spatio-temporal data used in this investigation, the GSTAR model will be used as the modelling process (see Fig. 1a). After that, a control map for each location used is built by sampling the residuals acquired



(a) (b)

Fig. 1: Flowchart (a) GSTAR Model and (b) Control Chart

in the GSTAR model (see Fig. 1b). Constructing a control chart verifies the model by determining if the model residuals are within the control limits or fall outside of the control limits. Verifying a model, on the other hand, involves determining the degree to which the model used to evaluate the data also fits the data collected. This may include validating the fundamental assumptions underpinning the statistical model and testing the accuracy to which the model accurately describes the data. Fig. 2 provides a summary of the modelling work that was done.

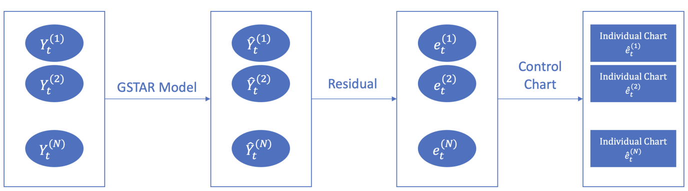


Fig. 2: Flowchart

III. RESULT AND DISCUSSION

This study used GDP growth statistics (in per cent) from four different countries: Brunei Darussalam (1), Indonesia (2), Malaysia (3), and Singapore (4). The data was collected over an entire year. Data on GDP was collected from 1975 to 2021, yielding 45 observations. Indonesia, Malaysia, and Singapore all have GDP values that are roughly comparable to one another, specifically in the range of 5 to 6%. However, Brunei Darussalam has the lowest average of the four countries, coming in at 1.62%. The other three countries all have averages above 2%. It is due to numerous issues, including a lack of economic diversification: heavy dependency on the oil and natural gas sector has delayed efforts to diversify the economy. It is one of the causes of the problem. Diversification is crucial for mitigating the adverse effects of economic uncertainty and fostering sustained expansion. Although Brunei has tried to diversify its economy by developing industries such as tourism and manufacturing, these efforts have not yet reached sufficient levels. The restrictive economic policies of Brunei Darussalam are another contributor to the country's low average GDP. Although Brunei Darussalam has a robust economic system, there are frequent roadblocks to innovation and entrepreneurship. The growth of the economy can be stunted by overly restrictive laws or a lack of incentives for the private sector to expand. The economy of Brunei Darussalam expanded by a revised -0.392 per cent in 2015 and -2.478 per cent in 2016, respectively, in the years 2015 and 2016. The economic growth rate in Brunei Darussalam improved again in 2017, fell to 0.052 per cent in 2018, and then increased to 3.689 per cent in 2019. In 2019, the economic growth rate is expected to improve once more. Based on the time series plot of the data shown in Fig. 3, it is possible to see that the GDP in the four nations follows a generally comparable pattern. In 1998, Indonesia, Malaysia, and Singapore experienced a significant drop in their economies. It occurred because of the effects of the financial crisis in 1990 and the monetary crisis in 1998. The GDP value, then, is an anomaly that emerges from this investigation. For Brunei Darussalam, one of the years that stood out was 1981, which was the year with the lowest GDP value throughout the observation period. It came about as a direct result of the drop in the price of crude oil, which is the state's principal revenue source. Fig. 3 additionally presents a boxplot of the data in addition to the time series plot that was previously discussed. It can be seen from the boxplot that the distribution of data from the four countries is not symmetrical. Furthermore, there is a disparity between the middle value of the data and the average value of the data. Aside from that, it is apparent from the boxplot that the data contains some extreme values, sometimes known as outliers. The presence of outliers in this research can serve as an initial indicator that the model that was utilized yields less accurate predictions when applied to the subsequent few periods; hence, it is necessary to make efforts to verify the obtained model. The descriptive statistics are shown in Table I.

TABLE I: Descriptive Statistics

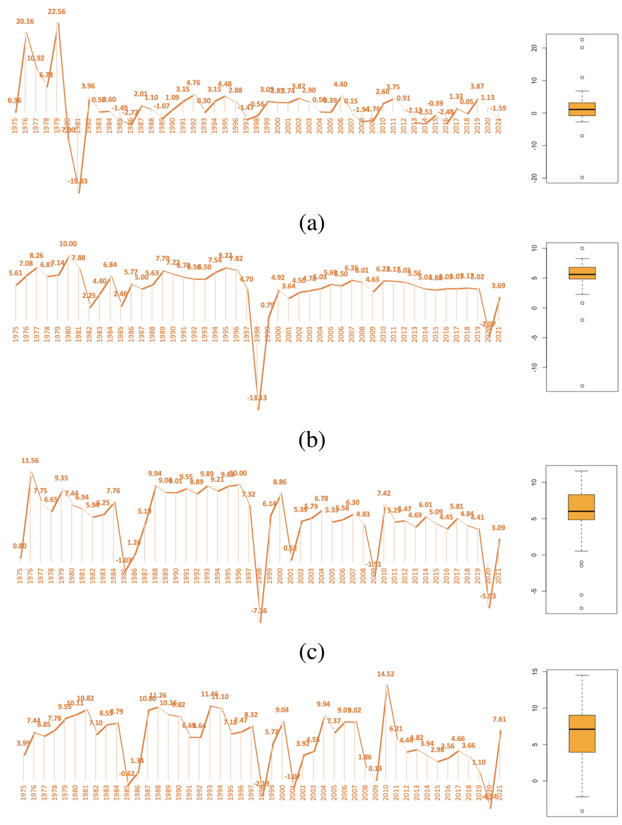
	Brunei	Indonesia	Malaysia	Singapore
Mean	1.624	5.165	5.666	6.239
Variance	35.648	11.467	14.965	16.129
Deviation Std.	5.971	3.386	3.868	4.016
Min.	-19.827	-13.127	-7.359	-4.143
Max.	22.562	10.000	11.563	14.520
Med.	1.089	5.607	6.007	7.102
Skew.	0.598	-3.710	-1.490	-0.565
Kurt.	7.275	18.679	2.822	0.015

The stationary test is done by using the Augmented Dickey-Fuller test for each location. The data is called stationary if the p-value is less than 0.05. The software used in this analysis is R Studio. The result of stationary test is shown in Table II.

TABLE II: Result of stationary test

Country	Brunei	Indonesia	Malaysia	Singapore
p-value	0.01	0.01	0.01	0.01
Decision	Stationary	Stationary	Stationary	Stationary

The choice of weight matrix in a GSTAR model is an extremely important factor in determining how well the model can capture spatial and temporal correlations in the data. When a homogeneous or uniform weight matrix is used, it indicates that each place (or observation) has the same level of influence on its surrounding areas in terms of the spatial and temporal relationships. As a result of the fact that there are four different



(a) (b) (c) (d)

Fig. 3: Time Series Plot and Boxplot for (a) Brunei Darussalam, (b) Indonesia, (c) Malaysia, and (d) Singapore

locations utilized, hence.

$$w_{ij} = \frac{1}{3}, \text{ for } i \neq j$$

so that

$$\mathbf{W} = \begin{array}{c} \\ \end{array}\begin{bmatrix} & Brunei & Indonesia & Malaysia & Singapore \\ & 0 & 1/3 & 1/3 & 1/3 \\ & 1/3 & 0 & 1/3 & 1/3 \\ & 1/3 & 1/3 & 0 & 1/3 \\ & 1/3 & 1/3 & 1/3 & 0 \end{bmatrix}$$

Then selecting the order of GSTAR model by identifying the Space-Time Autocorrelation Function (STACF) and Space-Time Partial ACF (STPACF) plot, shown in Fig. 4. The code in RStudio is

```
stacf(data,weight)
stpacf(data,weight)
```

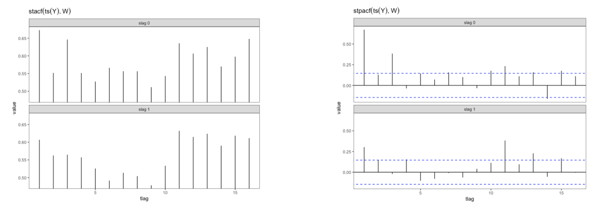
Based in Fig. 4, there are two possible order, hence

1) GSTAR(1;1) model

$$\mathbf{Y}_t = (\Phi_{10} + \Phi_{11}\mathbf{W})\mathbf{Y}_{t-1} + \mathbf{e}_t$$

2) GSTAR(2;1) model

$$\mathbf{Y}_t = (\Phi_{10} + \Phi_{11}\mathbf{W})\mathbf{Y}_{t-1} + (\Phi_{20} + \Phi_{21}\mathbf{W})\mathbf{Y}_{t-2} + \mathbf{e}_t$$



(a) (b)

Fig. 4: (a) STACF and (b) STPACF

TABLE III: Parameter Estimating and Diagnostic Test for Each Model

Parameter		Diag. Test Norm.	Diag. Test Ind.	AIC MSE
GSTAR(1;1)				
Φ_{10}	$diag(0.22; 0.47; 0.23; 0.65)$	**Yes**	**Yes**	1109
Φ_{11}	$diag(0.14; 0.41; 0.72; 0.23)$	No	**Yes**	21.15
		Yes	**Yes**	
		Yes	No	
GSTAR(2;1)				
Φ_{10}	$diag(0.26; 0.27; 0.13; 0.50)$	**Yes**	**Yes**	1068
Φ_{11}	$diag(0.10; 0.40; 0.56; 0.09)$	**Yes**	**Yes**	9.57
		Yes	**Yes**	
		Yes	**Yes**	

where

$$\Phi_{i0} = \begin{bmatrix} \phi_{i0}^{(1)} & 0 & 0 & 0 \\ 0 & \phi_{i0}^{(2)} & 0 & 0 \\ 0 & 0 & \phi_{i0}^{(3)} & 0 \\ 0 & 0 & 0 & \phi_{i0}^{(4)} \end{bmatrix}$$

The important step next is estimating the parameter for each GSTAR model and doing the diagnostic test for residual model. Tabel III shows the result of parameter estimation using Ordinary Least Square and diagnostic test for normality and independency. "Yes" means the model fulfill the assumption and vice versa. The best GSTAR model is a model that meets both diagnostic tests, namely residuals that are normally distributed and independent of each other. The parameter estimation is done manually using *Microsoft Excel*, while diagnostic checking is done using RStudio, the code is

```
checkResiduals(data_residual)
```

Due to the Table III, the model that fulfilled the diagnostic test is **GSTAR(2;1)**. Therefore, the best model is GSTAR(2;1).

$$\begin{aligned}
\hat{Y}_t^{(1)} &= 0.26Y_{t-1}^{(1)} + 0.03(Y_{t-1}^{(2)} + Y_{t-1}^{(3)} + Y_{t-1}^{(4)}) \\
&\quad - 0.20Y_{t-2}^{(1)} + 0.02(Y_{t-2}^{(2)} + Y_{t-2}^{(3)} + Y_{t-2}^{4}) \\
\hat{Y}_t^{(2)} &= 0.27Y_{t-1}^{(2)} + 0.13(Y_{t-1}^{(1)} + Y_{t-1}^{(3)} + Y_{t-1}^{(4)}) \\
&\quad + 0.11Y_{t-2}^{(2)} + 0.05(Y_{t-2}^{(1)} + Y_{t-2}^{(3)} + Y_{t-2}^{4}) \\
\hat{Y}_t^{(3)} &= 0.13Y_{t-1}^{(3)} + 0.19(Y_{t-1}^{(1)} + Y_{t-1}^{(2)} + Y_{t-1}^{(4)}) \\
&\quad + 0.33Y_{t-2}^{(3)} + 0.05(Y_{t-2}^{(1)} + Y_{t-2}^{(2)} + Y_{t-2}^{4}) \\
\hat{Y}_t^{(4)} &= 0.50Y_{t-1}^{(4)} + 0.03(Y_{t-1}^{(1)} + Y_{t-1}^{(2)} + Y_{t-1}^{(3)}) \\
&\quad + 0.07Y_{t-2}^{(4)} + 0.10(Y_{t-2}^{(1)} + Y_{t-2}^{(2)} + Y_{t-2}^{3})
\end{aligned}$$

where $\hat{Y}_t^{(i)}$ is the estimated model for location i ($i = 1, 2, 3, 4$). The interpretation of the GSTAR model obtained

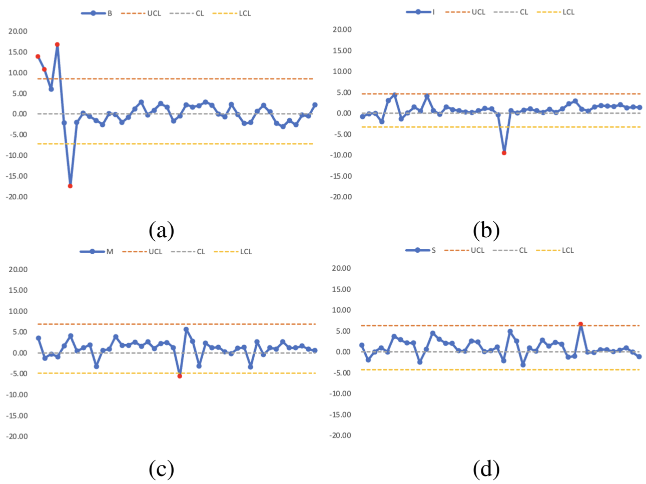


Fig. 5: Control chart for (a) Brunei Darussalam, (b) Indonesia, (c) Malaysia, and (d) Singapore

(for example for location 4, namely Singapore) is that GDP in Singapore at time t is influenced by GDP in Singapore in the previous year by 0.5, in addition to being influenced by its neighboring countries in the previous year by 0.03. In addition to being influenced by GDP in the previous year, GDP in Singapore is also influenced by GDP in the previous two years by 0.07, while its neighboring countries also influence Singapore by 0.10.

However, in Fig. 3 (the boxplot), there are outliers detected in all four locations. To establish whether the model residuals are statistically controlled, further analysis is performed using the GSTAR model that was developed as a result. This analysis makes use of a control chart. Because there were potential outliers at each location, this verification was carried out. Further verification of the model residuals was carried out so that the influence that this fact could have could be determined. The results are shown in Fig. 5. Due to Fig. 5, all countries show that the residuals are out of control (the red knot in Fig. 5). It can be concluded that even the model GSTAR(2;1) shows that the residuals have passed the diagnostic test, but the control chart shows that the residuals are out of control. One of the causes of that problem is the presence of outliers in data. The findings indicate that the model's residuals are not statistically controlled, which is consistent with the findings. As a direct consequence, the GSTAR(2;1) model cannot accurately reflect the GDP case. Since 1975, there have been several external causes and specific events that have the potential to influence GDP data in the countries of Indonesia, Malaysia, Singapore, and Brunei. These nations are related to one another in various ways, such as their history and culture. These factors may include occurrences on a global economic scale, developments on a regional scale, and commercial partnerships. The following is a list of certain external influences and specific occurrences that can influence the data on these countries' GDP [38]:

1) **The Asian Financial Crisis of 1997–1998**
The Asian financial crisis reached its zenith in 1997-1998 and had a tremendous impact across the area, particularly in Indonesia, Malaysia, Singapore, and Brunei. This crisis was the cause of a severe slowdown in economic activity, a crisis in the banking sector, and a sharp decrease in the currency's value.
2) **The Price of Oil**
The global price of crude oil greatly affects Brunei because the country is such a substantial oil and gas producer. Income levels and overall economic expansion are susceptible to oil price fluctuations.
3) **Regional Development and International Trade**
Changes in international trade ties, such as growing economic integration within ASEAN (Association of Southeast Asian Nations) and regional trade agreements, can influence the countries' total GDP and their exports and imports of goods and services.
4) **Foreign Direct Investment (FDI)**
Foreign direct investment (also known as FDI) can influence any nation's economic growth rate. The level of interest shown by overseas investors in particular industries may have a favourable effect on GDP figures.
5) **Environmental Events and Natural Disasters**
Environmental events, such as natural disasters, can harm economic growth, particularly if vital sectors such as agriculture or infrastructure are harmed. This is especially true if a natural disaster occurs in a region prone to these events.
6) **The Development of Technology**
Both the progression of technology and the digitalization of the global economy have the potential to influence facets of the economies of these nations.
7) **Changes in Regional Politics and Geopolitics**
Changes in regional politics or geopolitics, such as regional conflicts, can also influence the economy's stability.

In general, these neighbour nations maintain robust economic and political links with one another and frequently interact with one another within the context of ASEAN and bilateral contacts. Therefore, economic shifts or events in one nation might have repercussions for the economies of other nations in the region.

Finally, predictions were made based on the best GSTAR model and optimized based on the IMR control chart, namely the GSTAR(2;1) model. The prediction results are given in Table IV and Figure 6. In 2022, there was an increase in GDP for all countries, while in 2023, only Singapore experienced a decrease in GDP, while the other three countries experienced an increase from the previous year. Finally, in 2024, all countries are predicted to experience a decrease in their GDP.

TABLE IV: Forecasting result of GDP based on GSTAR(2;1) model

Year	Brunei	Indonesia	Malaysia	Singapore
2022	-0.443	1.518	0.513	3.017
2023	0.683	1.702	1.672	2.662
2024	0.572	1.449	1.259	1.846

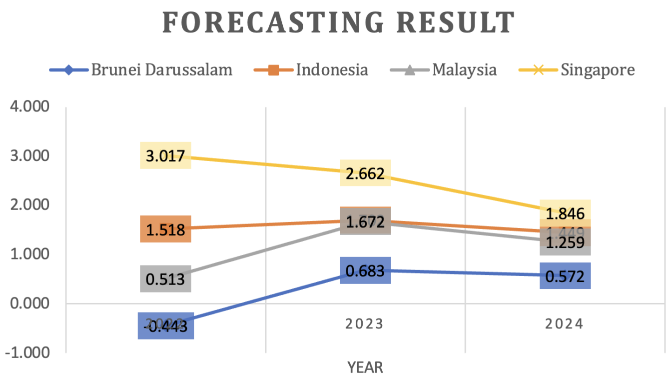


Fig. 6: Visualization of forecasting result of GDP

IV. CONCLUSIONS

The spatial-temporal model, GSTAR, shows that the GDP rate in a nation (from the four connected countries) is affected by the GDP rate 1 and 2 years earlier in that country and its neighbours. In Malaysia, 0.13 GDP from the previous year and 0.50 GDP from the previous two years from Malaysia affect the GDP rate of the previous year. The gross domestic product growth in other connected countries, 0.19 in the year before and 0.05 in the two years before, also affected it. For numerous reasons, Malaysia's GDP may be affected by the GDP of surrounding or connected nations. (1) Malaysia relies substantially on overseas trade. Malaysia's main trading partners are nearby Singapore, Indonesia, and Thailand. (2) Most of Malaysia's FDI goes to allies or neighbours. The exchange rate of the Malaysian ringgit (MYR) against neighbouring currencies like the Singapore dollar (SGD) and the Indonesian rupiah (IDR) can also affect Malaysian exports' global competitiveness. In conclusion, Malaysia's neighbours and allies affect its economic development because it relies on foreign commerce and investment. Due to their tight economic and political ties, changes in neighbouring nations' economic conditions or policies may affect Malaysia's economy, including GDP data. Thus, an economic study of the region and monitoring Malaysia's neighbours' political and social developments are crucial.

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