JURNAL MATEMATIKA, STATISTIKA DAN KOMPUTASI e–ISSN: 2614–8811
Published by Departement of Mathematics, Hasanuddin University, Indonesia
https://journal.unhas.ac.id/index.php/jmsk/index
Vol. 21, No. 1, September 2024, pp. 234-242
DOI: 10.20956/j.v21i1.36177

Covid-19 Vaccination Impact on Four Asean Countries' Stock With Spatial Dependency: A Comparison of Panel and Geographically Weighted Regression

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Abstract
Research about various policies and responses toward COVID-19 cases and its impact on stocks has grown recently. It shows that spatial influence is one of the keys in this research. The pandemic is not free from spatial dependence regarding how it indirectly impacts a country's economy. Each country has different policies to handle COVID-19, such as lockdowns and vaccination. WHO stated that all countries require vaccination to build human immunity against COVID-19 in the future. Naturally, ASEAN implemented this policy; thus, it is crucial to see the extent of the impact of vaccination on the ASEAN economy. However, the residuals have heterogeneity problems when using the panel regression model. One of the reasons is that there is spatial dependence, especially when modeling the COVID-19 pandemic. Therefore, comparing panel regression with a geographically weighted regression panel (GWR-Panel) is substantial when exploring the reaction of stock returns to vaccination and positive cases of COVID-19 in Indonesia, Malaysia, Singapore, and Thailand.
Keywords: GWR Panel, Regression Panel, Vaccination, Stock Returns

1. INTRODUCTION AND PRELIMINARIES

A lot of research regarding the spatial impact of COVID-19 cases has been conducted since 2020 [19] on global-level, a stock market shock in America that happened because of Covid-19 caused a spillover effect on the ASEAN stock market before government policies were implemented regarding lockdown, Eachempati [7] also found that the US stock market has a more significant effect on other countries. Asian countries experience greater negative stock return impacts than others [13]. Within the ASEAN level, the stock markets are mutually influenced by neighboring countries. Behera and Rath [4] found that stock market returns have a close relationship with the volatile stock index of ASEAN countries; the significant transmitters are JSX (Indonesia) and STI (Singapore), and the affected net transmitters are FTSE (Malaysia), PSE (Philippines), and SET (Thailand). Moreover, the impact of the Philippines, Singapore, and Thailand stock markets is found on Vietnam's stock market during the COVID-19 pandemic [12]. It is inevitable that spatial dependency indirectly affects the economy during a pandemic, which is reflected in the stock index. Considering the enormous impact of COVID-19 on the stock market, vaccination is the only hope for economic recovery.

2. LITERATURE REVIEW

2.1 Vaccination Impact on Stock Market Volatility

There is a significant impact on the stock market when human clinical trials for COVID-19 vaccination are initiated, with an increase of 8.08 basis points [6]. In research by Anastasiou, et al. [2] and Hsu, et al. [11] regarding the G20 market, it is stated that positive sentiment about COVID-19 (including vaccination information) also reduced the sentiment crisis experienced by the investors, which caused a fall in stock volatility. Generally, vaccination helped tone down citizens' fear and increase the efficiency of the government's action to reduce pessimism; besides vaccination, Asian investors showed a more significant response toward action taken by the government in response to COVID-19 [14]. This shows that there is a relationship between vaccination and shrinking stock market volatility, which is in line with research by Unal, et al. [17] who proved that countries with rapid COVID-19 vaccination, especially those with 10% and 50% population vaccination rates, show high performance with low volatility on the stock market.

2.2 Geographically Weighted Regression Panel (GWR Panel): Spatial Dependency

Various research has used panel regression to estimate models between stocks and pandemic cases or vaccinations. Panel regression is often used to analyze data with elements of individual influence (cross-section) and time (time-series). However, the drawback of this method is that if it is applied to a regional model, the resulting residuals are heterogeneous. This could result from spatial dependencies that have not been accommodated in the panel regression model. In research by Herlina, et al. [11], it is stated that heterogeneity problems were found in panel regression modeling of stock returns with the variables COVID-19 vaccination and number of COVID-19 positive cases, one of which comes from spatial dependence. Therefore, this research wants to compare the use of the GWR panel and the regular panel model in exploring the stock market reaction to vaccination and positive cases of COVID-19. This research uses a sample of four countries with the largest GDP in ASEAN, namely Indonesia, Malaysia, Singapore, and Thailand, to see stock reactions to vaccination and positive cases of COVID-19.

3. METHODOLOGY

This research uses balanced panel data from 4 countries with the largest GDP in ASEAN, Indonesia, Singapore, Malaysia, and Thailand, with daily periodic from March 15th, 2021 to April 19th, 2022. The variables used in this research are the increasing number of COVID-19 positive cases, vaccination development, and return of stock index from 4 countries. Stock return variable (R_{it}), number of case rise (PK_{it}) and COVID-19 vaccination development (PV_{it}) equation can be seen on 3.1 – 3.3.

$$R_{it} = ln\left[\frac{P_{i,t}}{P_{i,t-1}}\right] \times 100 \quad (3.1)$$

$$PK_{it} = ln\left[\frac{Cases_{i,t}}{Cases_{i,t-1}}\right] \quad (3.2)$$

$$PV_{it} = ln\left[\frac{Vaccine_{i,t}}{Vaccine_{i,t-1}}\right] \quad (3.3)$$

$P_{i,t}$ is stock index price in the i-th country with t period; $Cases_{i,t}$ are total number of cases on the i-th country with t period and $Vaccine_{i,t}$ is number of people first vaccinated on country the i-th with t period. GWR-panel modeling step start by estimating the best panel regression model. The best regression panel model between pooled, fixed and random model will follow equation 3.5, 3.6, 3.7 in order [10,18] and will be estimated for spatial heterogeneity assumption in GWR.

$$R_{it} = x_{it}\beta + v_{it} \quad (3.5)$$

where $v_{it} \equiv c_i + u_{it}$ is combined tools; c_i is individual effect; u_{it} is idiosyncratic error and $t = 1,2, \dots, T$.

$$R_{it} = x_{it}\beta + c_i + \varepsilon_{it} \quad (3.6)$$

where $c_i = z'_i\alpha$ and ε_{it} is error.

$$R_{it} = x_{it}\beta + \alpha + v_{it} \quad (3.7)$$

where $v_{it} = c_i j_T + u_i$; j_T is $T \times 1$ vector valued 1 and u_i is random element for every group (in every country). Where $x_{it} = [\, PK_{i,t}, PV_{i,t}]'$; $c_i = z'_i\alpha$ is individual effect that has specific variable for group. Next, testing will be undertaken to choose which models are appropriate between the three-panel models using the Hausman test and the Chow test. After choosing the best model, the GWR panel analysis begins by selecting spatial weight using equation 3.8. [9]

$$a_{ij} = \begin{cases} \left[1 - \left(\frac{d_{ij}}{h}\right)^2\right]^2, & d_{ik} < h \\ 0, & others \end{cases} \quad (3.8)$$

where $w_{ij} = a_{ij}$ spatial weight; d_{ij} is Euclidian distance between i and j location; h is a value of fixed distance bandwidth as local calibration limit for the distance, obtained by minimizing AIC in equation 3.9.

$$AIC(h) = 2n\, ln(sd) + 2\ln(2\pi) + \frac{n \times [tr(hat) + n]}{[n - 2 - tr(hat)]} \quad (3.9)$$

where n is total observation, sd is deviation standard, hat are hat matrix from estimated model coefficients. Next, residual from the panel model will be tested with Breusch-pagan test to see possibilities of heterogeneity in the residuals, with the hypothesis H_0: ${\sigma_c}^2 = 0$ vs H_1: ${\sigma_c}^2 \neq 0$. If the test result shows H0 is rejected, then the Moran test can also be executed to see the existence of spatial heterogeneity within residual data on the best model panel. Moran I test has the hypothesis of H_0: I = 0 and H_1: I > 0 with local Moran I equation (3.10) and global spatial panel equation (3.11) [4].

$$I_i = \frac{\hat{u}_i \sum_{j \neq i} w_{ij} \hat{u}_i \hat{u}_j}{\frac{1}{N}\sum_i {\hat{u}_i}^2} \quad (3.10)$$

$$\bar{I} = \frac{1}{T}\sum_{t=1}^{T} I_t \quad (3.11)$$

Where w_{ij} is spatial covariance weight; $\hat{u}_i$ and $\hat{u}_j$ are residual from individuals i and k; N is sample size. If residuals are correlated then the Moran I will be more than 0. To test spatial autocorrelation, the distribution will follow equation 3.12.

$$\frac{\bar{I}}{V} \sim N(0,1)\ ;\ V^2 = \frac{N^2 \sum_i \sum_j w_{ij}^2 + 3\left(\sum_i \sum_j w_{ij}\right)^2 - N \sum_i \left(\sum_j w_{ij}\right)^2}{T(N^2-1)\left(\sum_i \sum_j w_{ij}\right)^2} \quad (3.12)$$

If H_0 is rejected on the Moran I test, there is spatial autocorrelation, which means the GWR panels are fit to use. Then, the selection of the GWR panel model between pooling, fixed effect (FEM), and random effect model (REM) will be carried out using the local Breusch Pagan Lagrange Multiplier (BP-LM) test and the local Hausman test. After that, estimation from GWR panel model with FEM will follow equation 3.13 [6].

$$y_{it} = \sum_k X_{itk} \beta_k (u_i, v_i) + \epsilon_{it} \quad (3.13)$$

Where $k = 1,2,\dots,p$; $i = 1,2,\dots,n$ and $t = 1,2,\dots,T$; (u_i, v_i) is the coordinate point of i-th country; $\beta_k\ (u_i, v_i)$ is coefficient parameter of k-th variable in the geographical location of i-th country; estimated by equation 3.14. X_{itk} is the independent variable of k, in i-th country, at time t.

$$\hat{\beta}(u_i, v_i) = (X^T W_i X)^{-1} X^T W_i y \quad (3.14)$$

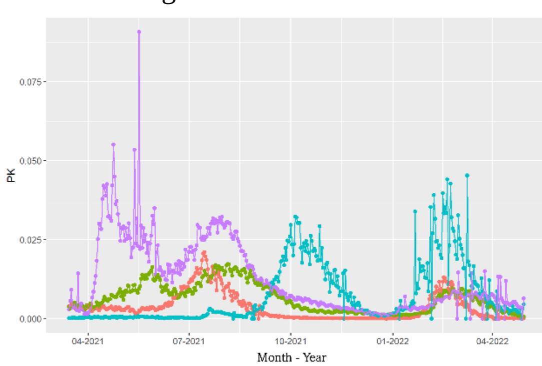
Where W_i is a diagonal matrix of geographical weight for every data in i location; X and y is data after transformation using equation 3.15 based on the chosen model through the previous test.

$$X' = \begin{cases} X & ;\ pooled\ model \\ X - \bar{X} & ;\ FEM \\ X - \theta \bar{X} & ;\ REM \end{cases} \text{ and } y' = \begin{cases} y & ;\ pooled\ model \\ y - \bar{y} & ;\ FEM \\ y - \theta \bar{y} & ;\ REM \end{cases} \quad (3.15)$$

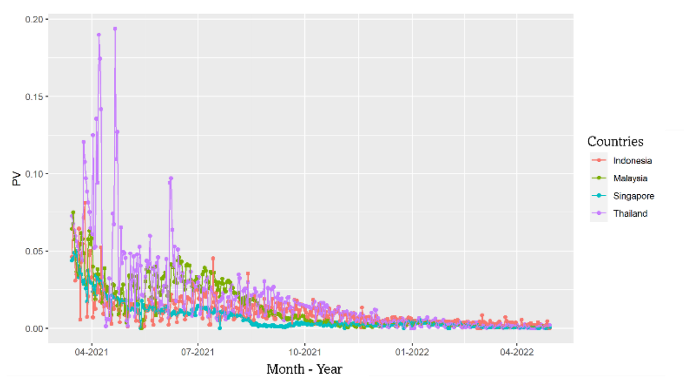
After estimation is done, R^2, RMSE and AIC will be used to compare which model are better between panel regression and GWR panel.

4. MAIN RESULTS

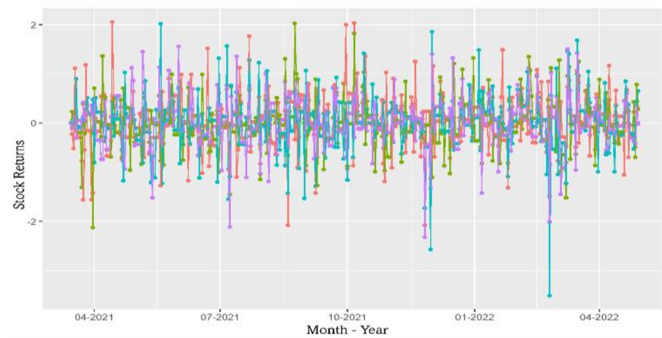
From 1644 day-to-day observation data acquired, number of case rise (PK), COVID-19 vaccination growth (PV), and stock return in Indonesia, Malaysia, Singapura and Thailand can be seen in figure 1.



(a)



(b)



(c)

Figure 4.1. Day-to-day data graphic number of case rise (a), COVID-19 vaccination growth (b) and stock return (c) in Indonesia, Malaysia, Singapore and Thailand from March 15th, 2021 to April 19th, 2022.

Figure 4.1.a shows that the growing number of COVID-19 cases in Indonesia, Malaysia, and Thailand decelerated compared to Singapore in September 2021. During this period, new COVID-19 variants appear, like Alfa, Gamma, and Beta, and reach their peak in May 2021 in ASEAN countries. Indonesia follows a significant rise in Thailand and a slow rise in Malaysia, with the highest peak in August 2021. After that, the wave of omicron variant cases can be seen at the end of January 2022 or the first week of February 2022, and the highest peak happened in the second week of February 2022 in these countries.

Table 4.1. Summary of sample measurements

No	Country	Variable	Minimum	Maximum
1	Indonesia	PK	0	0.022
		PV	0	0.081
		Return	-2.079	2.052
2	Malaysia	PK	0.001	0.018
		PV	1×10^{-3}	0.075
		Return	-2.129	2.026
3	Singapore	PK	0	0.046
		PV	1×10^{-3}	0.051
		Return	-3.508	2.024
4	Thailand	PK	0	0.091
		PV	1×10^{-3}	0.194
		Return	-2.323	1.557

For stock return (figure 4.1.b), Singapore hit its lowest return with -3.508 (Table 4.1) on the last week of February, the same period with the highest omicron case peak in Singapore. For vaccine development (figure 4.1.c), the vaccine development rate is slowly decreasing with the increase in the total number of citizens vaccinated. An increasing number of vaccinations causes a decrease, so the rate will not increase in the meantime and, after a while, will touch 0 points, meaning all citizens are vaccinated.

4.1 Regression Panel Modelling

Regression panel modeling begins with estimating regression analysis to obtain the best model from the regression panel to be compared with the GWR panel. The estimated coefficient model can be seen in Table 4.2. There is no variable affecting stock return significantly.

Table 4.2 Regression Panel Estimation

Variable	Regression Panel Model		
	Pooled	FEM	REM
Intercept	0.02 (0.1901)	-	0.025 (0.2389)
PK	0.75 (0.6179)	-0.12 (0.9343)	0.311 (0.8248)
PV	-1.1 (0.1421)	-0.698 (0.4960)	-0.950 (0.2368)
R^2	0.00133	0.00044	0.00085

Results from the Hausman and Chow test can be seen in Table 4.3; the rejected H_0 in the Chow test and LM test and the accepted H_0 in the Hausman test conclude that the REM model is the best model for panel regression.

Table 4.3. Panel Regression Test Result

No	Test	Hypothesis	Statistic	P-value
1	Chow	H_0: Pooled model is more suitable H_1: FEM is more suitable	2.5236	0.000***
2	Hausman	H_0: REM is more suitable H_1: FEM is more suitable	0.59055	0.7443
3	LM test	H_0: Pooled model is more suitable H_1: REM is more suitable	188.14	0.000***

Information: Reject H_0 on significant level ***1%, **5%, *10%.

4.2 GWR Panel Modelling

First, the h score bandwidth result by minimalizing AIC in equation 9 is 13.6515, with an AIC score of 806.804. Then, the h score is used to find spatial weight so the Moran I test can be executed. The Moran I test comes out to 19.202 with a 0.000 p-value, which means rejected H0 on a significant level of 1%; the GWR panel is a fit model for use because of spatial dependency existence.

GWR panel model selection between pooled, FEM, and REM are identified through the tests in Table 4.4. It shows that every test accepts H0, which means the Pooled model is the best model chosen for the GWR panel; thus, there will be no data transformation to estimate the GWR panel.

Table 4.4. GWR Panel model selection in each country.

No	Test	Hypothesis	Country	Statistic	P-value
1	Local Hausman lokal	H_0: REM is more suitable H_1: FEM is more suitable	Indonesia	0.467024	0.791748
			Malaysia	0.190031	0.909359
			Singapore	0.460593	0.794298
			Thailand	0.119527	0.941987
2	Local Breusch-Pagan LM	H_0: Pooled model is more suitable H_1: FEM is more suitable	Indonesia	1.089682	0.296542
			Malaysia	1.765899	0.18389
			Singapore	1.054444	0.304486
			Thailand	0.880947	0.347942
3	Local Chow		Indonesia	0.238986	0.787463

No	Test	Hypothesis	Country	Statistic	P-value
		H_0: Pooled model is more suitable H_1: FEM is more suitable	Malaysia	0.084787	0.96836
			Singapore	0.247897	0.780479
			Thailand	0.126725	0.721944

With that result, GWR estimation can be done, and the coefficient is obtained, as seen in Table 4.5. Indonesia is the only country in which vaccine development affects stock return. Yet, the connection between vaccine development and stock return is negative.

Table 4.5. GWR Panel Estimated Coefficient.

No	Country	Variable	Coefficient	SE	T-value	local R^2	global R^2
1	Indonesia	Intercept	0.061	0.025	2.491**	0.00250	0.0035
		PV	-3.418	1.472	-2.323**		
		PK	0.976	2.784	0.351		
2	Malaysia	Intercept	0.006	0.021	0.3	0.00108	
		PV	-1.318	0.943	-1.398		
		PK	2.251	1.69	1.333		
3	Singapore	Intercept	0.011	0.024	0.441	0.00243	
		PV	-1.397	1.226	-1.14		
		PK	2.171	2.011	1.08		
4	Thailand	Intercept	0.03	0.027	1.128	0.00085	
		PV	-0.425	0.673	-0.632		
		PK	-0.631	1.583	-0.399		

Information: Reject H_0 on significant level ***1%, **5%, *10%.

Comparing the GWR pooled model and the REM panel results in table 4.6, we found that the AIC and RMSE scores show that the GWR pooled model is better than the REM panel due to lower RMSE GWR Pooled scores compared to the REM panel and AIC GWR pooled score are larger than the REM panel.

Table 4.6. Comparison of GWR model and REM.

No	Model Comparison	GWR Pooled	Panel REM
1	RMSE	0.5252147	0.525781
2	AIC	-2107.301	-2109.758

5. CONCLUSION

The result shows that the GWR Panel is more fitted than the REM Panel. R^2 from GWR Panel global is higher compared to REM panel. This aligns with the previous study [10] that found spatial dependency in model assumption. From the GWR pooled, it can be seen that vaccination impacts stock return only in Indonesia. Countries with strict policies and implementing actions like lockdowns, lessening public transportation, and giving economic stimuli positively affect financial immunity [20]. This result also aligns with Agustina's [1] research; within ASEAN countries, Indonesia implements the most policy instruments to recover economic growth and stabilize the economy.

The impact of vaccines on the Indonesian stock market is negative. Indonesia's stock market price is mostly influenced by investor sentiment. If Indonesia's investors are still sceptical about the vaccination effort, it could lead to an adverse reaction [16]. Especially in Indonesia, there were various levels of trust in vaccines due to the limited information on the vaccine and issues about the vaccines' halal status [15], this reflects the condition that there was some scepticism about the vaccination. Otherwise, the negative relationship between stock and vaccine could be a sign that the stock market condition in each country is still unpredictable because of external solid factors like the pandemic and the Russia and Ukraine war that caused uncertainty within the market. Besides, the US, which has a strong influence in the ASEAN stock market, also contributes to stock market volatility, as stated by [7]. According to [4,13] as ASEAN countries impact each other's market, all countries are expected to have negative coefficients in vaccines and stock return relationships. Indonesia is the largest transmitter in ASEAN. The weakness of this research is that the R^2 score still needs to be improved. This can be subdued by adding variables in the model with important roles, like foreign currency (mainly USD).

ACKNOWLEDGEMENT

This research is funded by LPPM Universitas Islam Bandung.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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