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ANALYSIS OF THE VACCINATION'S IMPACT ON THE INCREASE IN COVID-19'S DAILY NEW AND RECOVERED CASES USING THE VECTOR AUTOREGRESSIVE (VAR) MODEL (CASE STUDY: WEST KALIMANTAN)

Yundari [1], Nur'ainul Miftahul Huda[2*]

[1,2] *Department of Mathematics, Universitas Tanjungpura,*
Prof. Dr. H. Hadari Nawawi St., Pontianak, 78124, Indonesia

Corresponding author's e-mail: [2]nur'ainul@fmipa.untan.ac.id*

Abstract. *One of the efforts to suppress the increasing number of COVID-19 cases is the government's provision of a COVID-19 vaccine. This study examines the effects of the number of people who have been vaccinated, the first dose of vaccine, on the addition of new cases and cured cases. The three variables were analysed simultaneously using the help of the Vector Autoregressive (VAR) model. The data is on the number of new, recovered cases and people vaccinated per day from January 13 to December 30, 2021, in West Kalimantan Province. The main steps in this study are order identification, parameter estimation, and interpretation of the results. In this study, the order selection of the VAR model is limited to a maximum of the fourth order. Parameter estimation uses the Ordinary Least Square (OLS) method from several possible orders. Furthermore, the model selection is based on the smallest AIC and BIC values. The result is that the second-order VAR model has the smallest AIC and BIC values, so this model is said to be the best model. The interpretation of the equation obtained is that 74.1% of the factors adding new cases, the number of people being vaccinated, and the addition of cured cases at one and two last times affect the addition of new cases on that day. Meanwhile, the addition of new cases today was only influenced by 42.2% by new cases, the number of people being vaccinated, and the addition of recovered cases in the previous one and two days.*

Keywords: *vaccine, covid, VAR model.*

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1. INTRODUCTION

Vaccination is an artificial way to activate the immune system to protect the body from infectious diseases. Activation occurs through the immune system's exposure to immunogens, which are substances that can trigger the immune system. Vaccines contain bacteria, viruses, or other components that technological advances have controlled. Vaccines contain the same antigens as the antigens that cause disease, but the antigens present in the vaccine can be controlled (attenuated) so that the administration of the vaccine does not cause people to suffer from disease as if they were exposed to the same antigen naturally. The primary purpose of all types of vaccines is to activate the immune system in the person's body to fight the antigen so that if the antigen re-infects, a more robust immune reaction will occur [1].

Until now, the vaccine is again being discussed, namely the COVID-19 vaccination. We do not forget, of course, the big event that hit the world, namely the spread of the coronavirus in China at the end of 2019. The virus spread rapidly until the WHO (World Health Organization or World Health Organization) officially declared the coronavirus (COVID-19) as a pandemic on March 9, 2020. That is, the coronavirus has spread widely throughout the world. Various countries are looking for solutions to suppress the spread of this virus while implementing various policies, such as lockdowns. One solution that is considered effective in conquering this virus is the provision of vaccines. On January 19, 2020, the global pharmaceutical industry announced a commitment to tackle COVID-19 [2]. Until March 2020, several studies were developed to develop a COVID-19 vaccine. In late February 2020, the World Health Organization (WHO) said that a vaccine against the virus that causes COVID-19, SARS-CoV-2, would not be available in less than 18 months [3]. As of September 2020, there are 321 trial vaccines under development [4]. In 2021, nine different technologies and several other undefined technologies started in the research and development phase to create an effective vaccine against COVID-19 [5].

The Indonesian government officially vaccinated for the first time on January 13, 2021. The type of vaccine used was the Sinovac vaccine. This program was implemented after the Food and Drug Supervisory Agency (BPOM) issued an emergency use approval (EUA) for vaccines on January 11, 2021, and the issuance of a halal fatwa by the Indonesian Ulema Council on January 8, 2021. COVID-19 vaccination in Indonesia takes place in four stages. Phase 1 and phase 2 will be implemented from January to April 2021. Meanwhile, phase 3 and phase 4 will be implemented from April 2021 to April 2022. The division of these stages is carried out considering the vaccine's availability, arrival time, and safety profile [6]. The first phase targets personnel. Health workers, assistants for health workers, support staff, and professional medical students who work in health care facilities [7]. At this stage, it is targeted that around 1.4 million health workers will receive the COVID-19 vaccination [8].

The second phase of the national vaccination program begins on February 17, 2021, targeting five priority groups. Apart from senior citizens over 60 years old, public workers, teachers, TNI, Polri, security workers, public transportation workers, and traders are also targeting this stage [9]. Until February 25, 2022, the percentage of vaccination stages 1 and 2 in Indonesia was 91.48% and 68.80%. The provision of this vaccine is evenly distributed to all provinces in Indonesia, including West Kalimantan. It has been recorded that 83.28% and 59.79% of people in West Kalimantan have vaccinated doses 1 and 2. With more than 50% already vaccinated with dose 2, it is hoped to reduce the number of deaths caused by this virus. It was recorded that 2.15% of cases died, and the addition of new cases continued to grow. Giving this vaccine is certainly expected to provide immunity to suppress the addition of new cases and cases of death [10].

In general, the effect of vaccination on the number of cases per day or vaccination on the number of recovered cases per day can be seen using regression. Nevertheless, of course, it requires time series analysis techniques to analyze the case because it relates to historical data. In this study, three random variables were used: the random variable of vaccination, the number of new cases per day, and the number of recovered cases per day. The three variables will be analyzed simultaneously using a vector time series. More specifically, vector autoregressive (VAR) time series models. The VAR model combines several AR models where these models form a vector whose variables influence each other [11]. The VAR model is a system of equations that considers each variable as a linear function of the constant and the lag value of the other variables. In this study, the dependency between vaccination and the number of new cases or between vaccination and the number of recovered cases was analyzed using the VAR model. The autoregressive order used is limited to a maximum of order four. The restriction of this order is based on the ability of the virus to infect more quickly.

This study aims to analyze the effect of vaccine administration on the addition of new cases and cured cases involving time lag using the VAR model. The first section explains the background and objectives of the research. An explanation of the VAR model is given in the second section. Next, the third section provides the results of a discussion on the analysis of COVID cases using the VAR model. Finally, the conclusion is given in the fourth section.

2. RESEARCH METHODS

2.1 Vector Auto Regression (VAR)

Vector Auto Regression (VAR) is used to project a system with time series variables and analyze the dynamic impact of the disturbance factors on the variable system. VAR analysis is the same as a simultaneous equation model because we consider several endogenous variables together in a model in VAR analysis. This analysis is like the ordinary simultaneous equation model. It is just that in the VAR analysis, each variable is explained by its past value. It is also influenced by the past values of all other endogenous variables in the observed model. In general, the VAR model can be formulated as follows [12]:

$$\left(\boldsymbol{I} - \boldsymbol{\Phi}^{(1)}\boldsymbol{B} - \cdots - \boldsymbol{\Phi}^{(p)}\boldsymbol{B}^{p}\right)\boldsymbol{Z}_{t} = \boldsymbol{e}_{t} \tag{1}$$

where

- $\boldsymbol{I}$ is identity matrix,
- $\boldsymbol{Z}_t$ is a random variable at time t,

  $$\boldsymbol{Z}_t = [Z_{1,t} \quad Z_{2,t} \quad \cdots \quad Z_{n,t}]^t$$

- $\boldsymbol{\Phi}^{(p)}$ is an autoregressive parameter at order p,

  $$\boldsymbol{\Phi}^{(p)} = \begin{bmatrix} \phi_{11}^{(p)} & \phi_{12}^{(p)} & \cdots & \phi_{1n}^{(p)} \\ \phi_{21}^{(p)} & \phi_{22}^{(p)} & \cdots & \phi_{2n}^{(p)} \\ \vdots & \vdots & \ddots & \vdots \\ \phi_{n1}^{(p)} & \phi_{n2}^{(p)} & \cdots & \phi_{nn}^{(p)} \end{bmatrix}$$

- $\boldsymbol{e}_t$ is a noise term,

  $$\boldsymbol{e}_t = [e_{1,t} \quad e_{2,t} \quad \cdots \quad e_{n,t}]^t$$

- $\boldsymbol{B}$ is backshift operator matrix,

  $$\boldsymbol{B} = \begin{bmatrix} B & 0 & \cdots & 0 \\ 0 & B & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & B \end{bmatrix}$$

  so that,

$$\boldsymbol{B Z_t} = \boldsymbol{Z_{t-1}}$$

$$\begin{bmatrix} B & 0 & \cdots & 0 \\ 0 & B & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & B \end{bmatrix} \begin{bmatrix} Z_{1,t} \\ Z_{2,t} \\ \vdots \\ Z_{n,t} \end{bmatrix} = \begin{bmatrix} Z_{1,t-1} \\ Z_{2,t-1} \\ \vdots \\ Z_{n,t-1} \end{bmatrix}$$

$$\boldsymbol{B^2 Z_t} = \boldsymbol{B(BZ_t)} = \boldsymbol{BZ_{t-1}} = \boldsymbol{Z_{t-2}}$$

$$\vdots$$

$$\boldsymbol{B^p Z_t} = \boldsymbol{Z_{t-p}}$$

Furthermore, Eq. (1) can be written as

$$\boldsymbol{Z_t} = \boldsymbol{\Phi}^{(1)}\boldsymbol{Z_{t-1}} + \cdots + \boldsymbol{\Phi}^{(p)}\boldsymbol{Z_{t-p}} + \boldsymbol{e_t}$$

In addition to having an order of p, the uniqueness of the VAR model is that it has several variables. If the $VAR(1)$ model has one variable, then the model formed is as follows,

$$Z_{1,t} = \phi Z_{1,t-1} + e_{1,t}$$

This model is the same as the Autoregressive (AR) model of order 1. If the $VAR(1)$ model has two variables, then the equation formed is as follows,

$$Z_{1,t} = \phi_{11}^{(1)} Z_{1,t-1} + \phi_{12}^{(1)} Z_{2,t-1} + e_{1,t}$$
$$Z_{2,t} = \phi_{21}^{(1)} Z_{1,t-1} + \phi_{22}^{(1)} Z_{2,t-1} + e_{2,t}$$

Next for the VAR(1) model with n variables is

$$Z_{1,t} = \phi_{11}^{(1)} Z_{1,t-1} + \phi_{12}^{(1)} Z_{2,t-1} + \cdots + \phi_{1n}^{(1)} Z_{n,t-1} + e_{1,t}$$

$$Z_{2,t} = \phi_{21}^{(1)} Z_{1,t-1} + \phi_{22}^{(1)} Z_{2,t-1} + \cdots + \phi_{2n}^{(1)} Z_{n,t-1} + e_{2,t}$$

$$\vdots$$

$$Z_{n,t} = \phi_{n1}^{(1)} Z_{1,t-1} + \phi_{n2}^{(1)} Z_{2,t-1} + \cdots + \phi_{nn}^{(1)} Z_{n,t-1} + e_{n,t}$$

The parameters of the VAR model are estimated using Ordinary Least Square (OLS) [13],

$$\boldsymbol{\Phi} = (\boldsymbol{X^t X})^{-1}\boldsymbol{X^t Y}$$

for

$$\boldsymbol{Y} = \boldsymbol{X\Phi} + \boldsymbol{e}$$

3. RESULTS AND DISCUSSION

The data used is secondary data obtained by the Indonesian National Disaster Management Agency[10]. There are three variables used

1. the number of new cases per day (N),
2. the number of recovered cases per day (R), and
3. the number of people vaccinated with the first dose (V).

The period for the three variables is from January 13 to December 31, 2021. January 13 is the first date of vaccination in Indonesia. While the population object used is the province of West Kalimantan. Table 1 shows a summary of the data used.

3.1. Descriptive Statistics

During the 2021 period, West Kalimantan did not record the addition of new cases, but the highest ever reached was 779 cases per day in mid-July. The month of July could be the second wave of the COVID-19 cycle in West Kalimantan and Indonesia. The average number of cases per day is 108. For recovered cases, at most 66 recovered cases per day occurred around August. Twelve cases, the average cure for COVID-19 patients per day. Furthermore, the first dose of vaccine administration has reached 44,971 people per day, with an average vaccine administration of 7,582 people per day. Complete information on descriptive statistics can be seen in Table 1.

Table 1. Descriptive Statistics

Variable	Minimum	Maximum	Median	Mean	Variance	Deviation Std.
New Cases	0.00	779.00	51.00	108.47	18807.61	137.14
First Vaccine	0.00	44971.00	3342.00	7582.28	74599370.00	8637.09
Recovered	0.00	66.00	5.00	12.28	234.35	15.31

In addition to the data information from descriptive statistics, historical data charts are also presented in Figure 1. There are three charts: daily new, the first vaccine, and new recovered cases. The graph with the red line shows an increase in the movement from June to July. The peak occurred on July 13, 2021. Furthermore, cases continued to rise for almost three months and then declined in September. Until the end of 2021, the number of new cases is expected to decrease. Meanwhile, the graph with the green line shows an uptrend; although it has been down, it does not look significant. From the time the vaccine appeared until June, the number of people who had been vaccinated remained constant. Nevertheless, the line starts to rise from June to July. One of the indications of an increase in the number of people being vaccinated is that several mandatory vaccine policies have been issued for the general public, for example, as a condition for flights and entering crowd centres. The number of people vaccinated continues to increase until it peaks at the end of 2021. The number of vaccinated people is in line with the number of people who recover. This is evidenced by the blue line, which began to show an upward trend since June. The peak occurs in August. This is also caused by giving vaccines, which result in better human immunity.

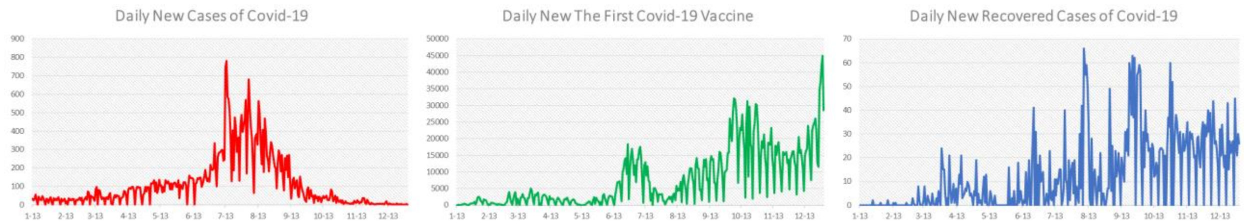


Figure 1. Data Plot of (a). Daily New, (b). The First Vaccine, (c). New Recovered Cases of COVID-19

3.2. Data Analysis

The model used to analyze the effect of the vaccine on the increase in new and cured cases is the vector autoregressive (VAR) model. In this model, the determination of the autoregressive order is limited to the fourth order. The limitation of this order takes into account the case used, namely the speed with which the virus transmits. As can be seen in the graph of the increase in cases per day (Figure 1), there is an increase in cases, often referred to as the second wave of COVID-19. One of the contributing factors is the COVID-19 virus, which has mutated into the delta variant of the COVID-19 virus. Researchers at the Center for Disease Control and Prevention in Guangdong, China, suggested that the delta variant could be detected immediately within four days of infection in the human body. In comparison, the original coronavirus took six days to be detected. Those four days are used as one of the bases for limiting the autoregressive order for the VAR model. In general, the determination of the autoregressive order is determined based on the criteria for the ACF and PACF patterns [14]. This study also shows each variable's ACF and PACF values (Table 2). The first line for each variable is the ACF value; the second is the PACF value. The writing in red indicates a significant decrease in the PACF value, or if it is plotted in ACF and PACF, it is commonly known as a cut-off. In contrast, the blue writing indicates a decrease in value but not significantly. A significant decrease occurred from the first to the second lag for variables N and V. Meanwhile, the R variable experienced a significant decrease in the second to third lag. The thick line in the table indicates a fourth-order limitation. The fifth-order and so on can be ignored. The use of orders that are too high is also not good for the model. The complete ACF and PACF values for each variable from lag 1-2 can be seen in Table 2.

Tabel 2. Autocorrelation and Partial Autocorrelation Function

Lag (k) / Variable	1	2	3	4	5	6	7	8	9	10	11	12
N_k	.840	.782	.765	.726	.714	.742	.804	.716	.709	.694	.657	.679
	.840	.261	.219	.050	.117	.230	.370	-.280	.063	-.031	.031	.148
V_k	.819	.709	.622	.589	.615	.680	.767	.642	.570	.508	.485	.525
	.819	.117	.043	.142	.238	.279	.341	-.429	-.006	.043	.044	.108
R_k	.478	.589	.448	.439	.451	.415	.560	.339	.400	.306	.315	.309
	.478	.467	.123	.060	.152	.084	.304	-.138	-.086	-.020	.008	.017

Let $\boldsymbol{Y}_t$ be random variable at time t follows the $VAR(p)$ model,

$$\mathbf{Y}_t = \boldsymbol{\Phi}^{(1)}\mathbf{Y}_{t-1} + \boldsymbol{\Phi}^{(2)}\mathbf{Y}_{t-2} + \cdots + \boldsymbol{\Phi}^{(p)}\mathbf{Y}_{t-p} + \mathbf{e}_t \tag{2}$$

In matrix, Eq. (2) can be written as,

$$\begin{bmatrix} N_t \\ V_t \\ R_t \end{bmatrix} = \begin{bmatrix} \phi_{11}^{(1)} & \phi_{12}^{(1)} & \phi_{13}^{(1)} \\ \phi_{21}^{(1)} & \phi_{22}^{(1)} & \phi_{23}^{(1)} \\ \phi_{31}^{(1)} & \phi_{32}^{(1)} & \phi_{33}^{(1)} \end{bmatrix} \begin{bmatrix} N_{t-1} \\ V_{t-1} \\ R_{t-1} \end{bmatrix} + \begin{bmatrix} \phi_{11}^{(2)} & \phi_{12}^{(2)} & \phi_{13}^{(2)} \\ \phi_{21}^{(2)} & \phi_{22}^{(2)} & \phi_{23}^{(2)} \\ \phi_{31}^{(2)} & \phi_{32}^{(2)} & \phi_{33}^{(2)} \end{bmatrix} \begin{bmatrix} N_{t-2} \\ V_{t-2} \\ R_{t-2} \end{bmatrix} + \cdots + \begin{bmatrix} \phi_{11}^{(p)} & \phi_{12}^{(p)} & \phi_{13}^{(p)} \\ \phi_{21}^{(p)} & \phi_{22}^{(p)} & \phi_{23}^{(p)} \\ \phi_{31}^{(p)} & \phi_{32}^{(p)} & \phi_{33}^{(p)} \end{bmatrix} \begin{bmatrix} N_{t-p} \\ V_{t-p} \\ R_{t-p} \end{bmatrix} + \begin{bmatrix} e_{N,t} \\ e_{V,t} \\ e_{R,t} \end{bmatrix}$$

Furthermore, parameter estimation for the $VAR(p)$ model is carried out using the Ordinary Least Square (OLS) method. The order of p used is the order of $1 - 4$. Table 3 gives the parameter estimation results in a matrix for each $VAR(p)$ model for $p = 1,2,\ldots,4$. Column two shows the constant values in the $VAR(p)$ model. The next column shows the autoregressive parameters in the VAR model equation above. Writings with yellow, green, blue, and grey shading show significant parameters at the 0.000 correction level; 0.001; 0.05; 0.1. The parameter significance test used is the t-test. Then the penultimate column is the Adjusted R-squared value. This value indicates the influence of the independent variables on the dependent variable. In this case, the independent variable used also involves time lag. For example, if the $VAR(1)$ model's R-squared for row one is 0.706, almost 71% of the current increase in new cases is affected by the increase in the number of vaccinated and cured cases on the previous day. In contrast, the remaining 29% is explained by other variables that are not added to the model. The last column is one of the important points in model selection, namely the AIC and BIC columns. The best model selection is based on the smallest AIC and BIC values. The writing in red indicates the smallest value. This means that the four models analyzed, the best model to see the effect of the vaccine on the increase in new and cured cases is the $VAR(2)$model. More details about the parameter estimation results can be seen in Table 3 (see also Eq. (2) to interpret the model).

Table 3. Parameter Estimation Results

Model	Constant	Parameter ($\boldsymbol{\Phi}^{(p)}$)		Adjusted R-squared	AIC (BIC)
		$\boldsymbol{\Phi}^{(1)}$			
$VAR(1)$	$\begin{bmatrix} 14.098 \\ 1809.807 \\ 4.672 \end{bmatrix}$	$\begin{bmatrix} 0.840 & -0.001 & 0.400 \\ -3.050 & 0.843 & -17.755 \\ 0.001 & 0.005 & 0.332 \end{bmatrix}$		$\begin{bmatrix} 0.706 \\ 0.683 \\ 0.273 \end{bmatrix}$	30.591 (30.723)
$VAR(2)$		$\boldsymbol{\Phi}^{(1)}$	$\boldsymbol{\Phi}^{(2)}$		30.250

Model	Constant	Parameter ($\Phi^{(p)}$)	Adjusted R-squared	AIC (BIC)
	$\begin{bmatrix} 13.567 \\ 1429.0788 \\ 2.977 \end{bmatrix}$	$\begin{bmatrix} 0.634 & 0.003 & 0.499 \\ -4.373 & 0.728 & -38.251 \\ -0.013 & 0.001 & 0.160 \end{bmatrix}$ $\begin{bmatrix} 0.255 & -0.003 & -0.353 \\ 0.889 & 0.108 & 61.768 \\ 0.012 & -0.001 & 0.498 \end{bmatrix}$	$\begin{bmatrix} 0.741 \\ 0.697 \\ 0.422 \end{bmatrix}$	(30.480)
$VAR(3)$	$\begin{bmatrix} 11.326 \\ 1375.803 \\ 2.837 \end{bmatrix}$	$\Phi^{(1)}$ $\begin{bmatrix} 0.559 & 0.003 & 0.572 \\ -2.364 & 0.720 & -52.706 \\ -0.001 & 0.001 & 0.111 \end{bmatrix}$ $\Phi^{(2)}$ $\begin{bmatrix} 0.148 & -0.003 & -0.238 \\ 0.845 & 0.079 & 53.763 \\ 0.001 & -0.001 & 0.001 \end{bmatrix}$ $\Phi^{(3)}$ $\begin{bmatrix} 0.206 & -0.001 & -0.333 \\ -2.367 & 0.029 & 35.359 \\ -0.001 & -0.001 & 0.012 \end{bmatrix}$	$\begin{bmatrix} 0.752 \\ 0.697 \\ 0.423 \end{bmatrix}$	30.236 (30.565)
$VAR(4)$	$\begin{bmatrix} 10.875 \\ 1104.240 \\ 2.249 \end{bmatrix}$	$\Phi^{(1)}$ $\begin{bmatrix} 0.544 & 0.003 & 0.581 \\ -3.180 & 0.720 & -49.743 \\ -0.014 & 0.001 & 0.110 \end{bmatrix}$ $\Phi^{(2)}$ $\begin{bmatrix} 0.135 & -0.002 & -0.211 \\ 2.127 & 0.049 & 70.453 \\ 0.010 & -0.001 & 0.465 \end{bmatrix}$ $\Phi^{(3)}$ $\begin{bmatrix} 0.183 & -0.001 & -0.315 \\ -7.423 & -0.113 & 42.905 \\ -0.016 & -0.001 & 0.116 \end{bmatrix}$ $\Phi^{(4)}$ $\begin{bmatrix} 0.057 & -0.001 & -0.084 \\ 5.465 & 0.235 & -45.245 \\ 0.019 & 0.001 & 0.008 \end{bmatrix}$	$\begin{bmatrix} 0.751 \\ 0.709 \\ 0.431 \end{bmatrix}$	30.227 (30.655)

The selected model, the $VAR(2)$ model, is then expressed in the form of a matrix equation as follows

$$\begin{bmatrix} N_t \\ V_t \\ R_t \end{bmatrix} = \begin{bmatrix} 13.567 \\ 1429.079 \\ 2.977 \end{bmatrix} + \begin{bmatrix} 0.634 & 0.003 & 0.499 \\ -4.373 & 0.728 & -38.251 \\ -0.013 & 0.001 & 0.160 \end{bmatrix} \begin{bmatrix} N_{t-1} \\ V_{t-1} \\ R_{t-1} \end{bmatrix} + \begin{bmatrix} 0.255 & -0.003 & -0.353 \\ 0.889 & 0.108 & 61.768 \\ 0.012 & -0.001 & 0.498 \end{bmatrix} \begin{bmatrix} N_{t-2} \\ V_{t-2} \\ R_{t-2} \end{bmatrix}$$

If the matrix equation is written in the form of a regression equation, then the equation for each variable can be stated as follows.

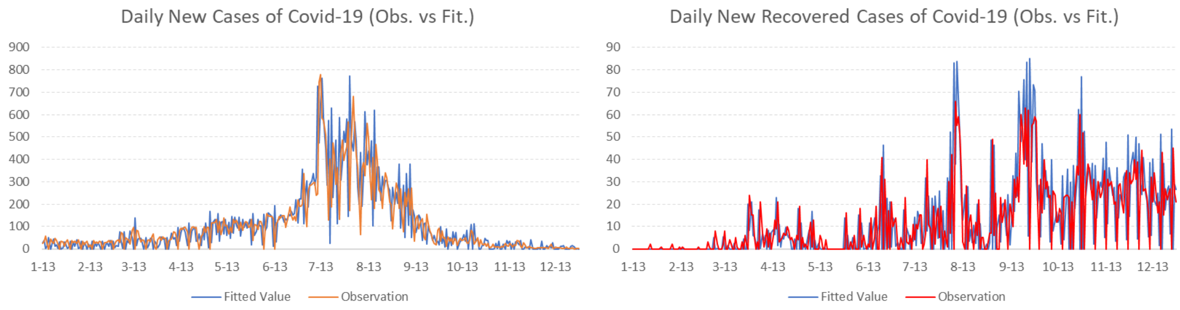
$$N_t = 13.567 + 0.634N_{t-1} + 0.254N_{t-2} + 0.003V_{t-1} - 0.003V_{t-2} + 0.499R_{t-1} - 0.353R_{t-2}$$
$$V_t = 1429.079 - 4.373N_{t-1} + 0.889N_{t-2} + 0.728V_{t-1} + 0.108V_{t-2} - 38.252R_{t-1} + 61.768R_{t-2}$$
$$R_t = 2.977 - 0.013N_{t-1} + 0.012N_{t-2} + 0.001V_{t-1} - 0.001V_{t-2} + 0.160R_{t-1} + 0.498R_{t-2}$$

This study aimed to see the effect of vaccine administration on the increase in new cases and recovered cases. So from the three regression equations obtained, only the first equation (addition of new cases as the dependent variable) and the last (addition of cured cases as the dependent variable) are interpreted. In the second equation, the addition of vaccinated people as the dependent variable is not interpreted. Based on the selected VAR(2) model, the interpretations that can be given are

1. The addition of these new cases influenced 74.1% of the new cases added at this time, the number of vaccinated people, and the addition of recovered cases one day and two days earlier. The remaining 25.9% is influenced by other factors not included in the model. If the number of vaccinated people and the addition of cured cases on one day and the previous two days is zero, then the number of new cases is 14. The effect of the vaccine on the addition of new cases is not so significant that for all the time lag, it is only 0.003. In the previous two days, the addition of vaccinated people resulted in fewer new cases (a negative sign).
2. 42.2% of the addition of cured cases at this time was influenced by the addition of these cured cases, the number of people who were vaccinated, and the addition of new cases one day earlier and two days earlier. The remaining 57.8% is influenced by other factors not included in the model. If the number of vaccinated people and the addition of new cases on one day and the previous two days is zero for all, then the number of cured cases is 3. The effect of the vaccine on the addition of

recovered cases is not so significant; that is, for all time lags, it is only 0.001. On the previous day, the addition of vaccinated people increased the number of recovered cases (a positive sign).

The two regression equations (Nt and Rt), then re-estimated using the equation model to see how well the fitted value follows the actual data. Figure 2 shows a plot of fitted values versus observations based on the VAR(2) model for new cases (a) and cured cases (b) as the dependent variable. It can be seen that the fitted value of the VAR(2) model can approach the actual data pattern.



(a) (b)

Figure 2. Fitted Value based on $VAR(2)$ Model for Daily (a) New Cases and (b) New Recovered Cases

4. CONCLUSIONS

1. Based on the analysis carried out using the VAR model, the addition of people who were vaccinated per day affected reducing the number of new cases for the next two days. In terms of the addition of cured cases per day, the number of vaccinated people per day also has a positive impact for the two days after that. This means that the more vaccinated people per day, the newer cases will be suppressed, and the number of recovered cases will increase per day. The effect of the vaccine given to both factors, new cases and cured cases, is still minimal. One of the reasons is the data on the number of vaccinated people per day, which is the first dose of vaccine. At the same time, a person's immune system will be more immune to the virus after getting the second dose of vaccine. Based on data, the number of residents in West Kalimantan who have just completed the second dose of vaccine is around 60% [15]. However, the effect of the vaccine cannot be ignored. The more people are vaccinated, the more herd immunity will increase. The latest news is that the government has added one stage of the vaccine, namely the third dose of the booster vaccine. This, of course, has been considered the positive side of the vaccine, which can suppress the addition of new cases of COVID-19.

2. Based on the analysis that has been carried out in this study, the addition of new cases today is still dominated by the factor of adding new cases in the previous one or two days. In addition, the factor of the decline in people who recovered in the previous two days also increased in new cases. On the other hand, today's recovered cases were only slightly affected by the addition of new cases in the previous one or two days. However, the addition of recovered cases today is dominated by the number of people who recovered in the previous one and two days. The VAR model with order 2, $VAR(2)$, can describe the situation of the effect of vaccine administration on adding new cases and recovering cases by involving a time lag. In addition, this model also describes the influence of other factors, such as the addition of new cases and cured cases involving time lag, on the addition of new cases itself. The same is true for the addition of recovered cases, which is also influenced by other factors, namely the addition of new cases and the recovered cases themselves, which involve time lag.

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