REGRESSION ANALYSIS: RELATIONSHIP BETWEEN COVID-19 VACCINATION AND POSITIVITY RATE IN INDONESIA

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Abstract
Covid-19 has become a global epidemic since it first emerged in late 2019. Indonesia has made various efforts to prevent Covid-19, both through government policies and mass vaccination. Vaccine availability in mass vaccination policies is not sufficient because vaccines must be well accepted by the general public. One way to gain public trust is to make the impact of vaccination transparent by modeling its impact on the proportion of Covid-19 positive cases. In this study, we performed modeling using two main data sets. The first data is the number of people who received the first or second vaccine between July 1, 2021 and January 1, 2022. The second data is the positive rate (%) from July 15, 2021 to January 15, 2022. The results of this study show that increasing the proportion of the population vaccinated against Covid-19 with both 1st and 2nd doses can reduce the prevalence of Covid-19 cases in Indonesia. Moreover, increasing the proportion of second vaccinations further reduces the prevalence of Covid-19 cases compared to increasing the proportion of first vaccinations.

Keywords: Covid-19, Positivity rate, Regression, Vaccination.

Abstrak

Kata kunci: Covid-19, Persentase kasus positif, Regresi, Vaksinasi

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INTRODUCTION

In 2019, Coronavirus Disease 2019 (Covid-19) emerged as a global epidemic, spreading widely in 215 countries around the world. Many countries are taking different strategies and measures. From lockdowns and local quarantine guidelines, social distancing, working, and studying from home, crowd limits, community activities, mask use, increased hygiene, and disinfection, tracking and action, to mass vaccination programs. To slow down such confirmed pandemic cases, Indonesia’s local and central governments have adopted policies like lockdowns (Syuhada et al., 2021). This policy consists of the Covid-19 Task Force, PSBB1, Transitional PSBB, New Normal, Micro PSBB, PPKM, PPKM Levels 1-4 and finally formation of Mass Vaccination.

A secure vaccine is the long-time period method to the Covid-19 pandemic. Dozens of vaccines are already in development, some in clinical trials (Rowland et al., 2020). Vaccination program offers best and brightest prospects for ending Covid-19 pandemic (Mathieu et al., 2021). Given the fact that not everyone is eligible for Covid-19, vaccination coverage will be increased by an acceptable margin of approximately 10% is needed. The Covid-19 vaccination application in Indonesia commenced on January 13, 2021. In the primary batch, the vaccine was administered to health care workers, civil servants, and the elderly. In the second batch, vulnerable groups and other members of the general public will be targeted for vaccination, with the government aiming to have 181.5 million people vaccinated against Covid-19 by March 2022. Statistical data in Indonesia show that, at the beginning of the second week of August 2021, when the number of people receiving their first and second doses of the vaccine increased, cure rates began to rises. Daily cases and deaths are still high, but positivity rate and rate of deaths are slowing (Our World in Data, 2023).

However, vaccine availability alone is not sufficient to ensure broad immune protection. Vaccines must be accepted by the public. Ichsan et al. (2021) conducted a survey among adults (16 years and older) in Central Sulawesi. The results showed that 99.6% of respondents used masks and kept their distance in the past, 95.9% avoided crowds, 95.5% washed their hands with soap and 96.2% washed their hands with running water. Only 35.3% of the population were willing to receive the vaccine. One reason is the many false reports about the effectiveness of the Covid 19 vaccine. To combat false reports circulating on social media, the government is raising awareness by explaining four benefits of Covid-19 vaccination through its official website (Unit Pelayanan Kesehatan Kemenkes, 2021). Vaccines, which consist of various biological products and attenuated viral parts and are injected into humans, stimulate the development of human immunity and resistance. A vaccinated person's body learns to recognize the weakened virus by stimulating antibodies. This exposes the body to the virus and reduces the risk of exposure. In immune disorders that recognize viruses, a person's immune system weakens, and subsequent exposure weakens the effects and symptoms of the virus, acquire
herd immunity. Herd immunity thresholds for Covid-19 variety from 55% to 82% of the population (Sanche, 2020).

A study by Pastorino et al. (2021) found that Covid-19 is having a negative impact on public health, making vaccine development a top priority. Additionally, Haryanto and Addini (2022) study shows that the average age of a person infected with Covid-19 has decreased. Resistance to vaccination is a primary impediment to accomplishing the network immunity had to guard the maximum susceptible populations. Public acceptance of the COVID-19 vaccine is therefore critical. One way of overcoming public trust is by increasing transparency about vaccine efficacy and side effects to increase public trust and hope for a Covid-19 vaccine. Several countries have conducted studies demonstrating vaccine efficacy (Dagan et al., 2021; Hall et al., 2021).

With this in mind, this study models the effect of Covid-19 vaccination on the positive case rate in Indonesia. The model also takes into account the government's ongoing lockdown policy. Modeling is performed using a multivariate regression model with dummy variables.

**METHOD**

The research method used in this study is a quantitative non-experimental study. Quantitative non-experimental means studies that do not manipulate the independent variables, control for other variables by randomization, or both. There are three types of non-experimental studies used in this study. That is, research that focuses on relationships between variables. The model used in this study is a multivariate regression model. A regression model shows the relationship between one or more variables with known values and variables with unknown values (Novika et al., 2022). If a simple linear regression model consists of only one independent and one dependent variable, then in multivariate linear regression the number of independent variables is greater than one dependent variable (Ningsih and Dukalang, 2019).

The dependent variable of this study is the positive rate of Covid-19 cases in Indonesia. Meanwhile the independent variables were the percentage of the population receiving the first dose of vaccine, the percentage of the population receiving the second dose of vaccine, and government policy. The variables used are shown in Table 1. The government policy independent variable is a dummy variable that represents current government policy. A dummy variable is an independent variable in a regression used to quantify a qualitative variable (e.g., gender, race, religion, policy changes, situational differences, etc.). The number of dummy variables formed is \( n - 1 \), where \( n \) is the number of categories of the variable.

| Table 1. *Dependent variable and independent variables* | 790 |
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<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Description / Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positivity Rate</td>
<td>Y</td>
<td>Positive rate of Covid-19 (%)</td>
</tr>
<tr>
<td><strong>Independent Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Vaccine</td>
<td>X₁</td>
<td>Number of people who received the first vaccination divided by the total population of Indonesia</td>
</tr>
<tr>
<td>Second Vaccine</td>
<td>X₂</td>
<td>Number of people who received the second vaccination divided by the total population of Indonesia</td>
</tr>
<tr>
<td>Government Policy (Dummy variable)</td>
<td>X₃₁, X₃₂</td>
<td>(X_{31} = 0, X_{32} = 0) means National Micro PPKM Level 1-4&lt;br&gt;(X_{31} = 1, X_{32} = 0) means PPKM Levels 1-4&lt;br&gt;(X_{31} = 0, X_{32} = 1) means After PPKM</td>
</tr>
</tbody>
</table>

Two primary data were used in this study (Our World in Data, 2023). The first data are on the number of people who received one or two doses of vaccine from July 1, 2021 to January 1, 2022. The second data is the positive rate (%) data from July 15, 2021 to January 15, 2022. There is a difference of 14 days (2 weeks) between the day of inoculation and the positive rate used. This is done on the premise that the body's immunity is formed after vaccination (CNN Indonesia, 2021). Additionally, a third piece of data is required in the form of the implementation date of the government's policy that was in effect at the time the second piece of data was collected.

<table>
<thead>
<tr>
<th>Table 2. Regression models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Model</strong></td>
</tr>
<tr>
<td>Dependent Variable</td>
</tr>
<tr>
<td>Independent Variables</td>
</tr>
<tr>
<td>First Vaccine</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Second Vaccine</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Based on the independent and dependent variables, two regression models were constructed as shown in Table 2. This is because one of the assumptions of regression models is the lack of multicollinearity between each independent variable. The two independent variables \(X_1\) and \(X_2\) are
used in different models, as the number of people receiving the second vaccination is strictly dependent on the number of people who received the first vaccination. In addition, we performed data analysis using RStudio according to the following procedure.

1. Preliminary analysis based on data received.
2. Perform classical assumption tests for multivariate regression models.
3. Determine the equations of the multivariate regression model.
4. Perform analysis based on model equations.

RESULTS AND DISCUSSION

Before mass vaccination was introduced, the Indonesian government had issued some guidelines. These include closing schools and colleges, working from home, praying at home, implementing mass rapid testing, providing social assistance, and implementing mass social restrictions with calls for social and physical distancing, named the enforcement of restrictions (PPKM). PPKM itself is not a single policy. As of early 2021, there are at least four variants of PPKM. PPKM (Volumes I and II), Micro PPKM (Volumes I-XII), Emergency PPKM to PPKM Levels 1-4. PPKM Volume I will run from January 11 to 25, 2021, and PPKM Volume II will run from January 26 to February 8, 2021. The Micro PPKM will consist of 12 volumes from February 9th to July 2nd, 2021. Emergency PPKM will then take place from 3 July to 20 July 2021. Also, from July 21st to August 26th, PPKM levels 1-4 will be implemented.

Figure 1. Number of people who received their vaccine in Indonesia

In addition to PPKM, vaccination has become an important part of fighting the Covid-19 pandemic. Based at the quantity of human beings vaccinated, Indonesia joins the listing of pinnacle 10 nations with the very best quantity of Covid-19 vaccinations. Figure 1 shows the number of people
receiving their first or second dose of vaccine in Indonesia.

Figure 2 shows the Covid-19 positivity rate and the percentage of the Indonesian population who received the first and second doses of vaccine. Comparing the two figures, it can be seen that the trend in positivity decreased as the proportion of the vaccinated population increased during the period of vaccination and PPKM.

![Figure 2. Positivity rates and percentage of people who received their vaccine in Indonesia](image)

Classical Assumption Tests

Theoretically, multivariate linear regression analysis yields valid parameter estimates if the classical assumptions are met. The classical assumptions of regression according to Olive (2017):

1. Normality test: A good regression model has normal or near-normal residual values. One of the normality tests is the Kolmogorov-Smirnov (KS) test. The data are normal if the p-value for the test is > 0.05.
2. Multicollinearity test: A good regression model should show no multicollinearity. It can be obtained from the Variance Inflation Factor (VIF) value, which VIF < 10 means no multicollinearity.
3. Heteroscedasticity test: A good regression model has no heteroscedasticity. The Breusch-Pagan (BP) test can be used to detect the presence of heteroscedasticity, results with p-values > 0.05 show no indication of heteroscedasticity.

A classical assumption of regression was performed for each model. The results are shown in Table 3. Based on these results, the two models used satisfy the classical assumption test of multivariate linear regression models.

Table 3. Classical assumption tests results
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Tests | First Model | Second Model |
---|---|---|
Normality test | Satisfy | Satisfy |
| KS test p-value is 0.3302 > 0.05 | KS test p-value is 0.1026 > 0.05 |
Multicollinearity test | Satisfy | Satisfy |
| VIF $X_1 = 1.3851 < 10$ | VIF $X_2 = 1.4222 < 10$ |
| VIF $X_{31} = 3.5003 < 10$ | VIF $X_{31} = 3.4394 < 10$ |
| VIF $X_{32} = 4.1908 < 10$ | VIF $X_{32} = 4.1888 < 10$ |
Heteroscedasticity test | Satisfy | Satisfy |
| BP test p-value is 0.02 < 0.05 | BP test p-value is 0.022 < 0.05 |

Multivariate Regression Model

The coefficients and values for the first regression are shown in Table 4. All independent variables are significant to the alpha 10% sign (marked with *) in the partial or significance test of the $\beta$ coefficient for each variable. Based on the table, the equations for the first regression model $Y$ are:

$$Y = 36,33652 - 0.55478 \cdot X_1 - 11,93974 \cdot X_{31} - 4,70605 \cdot X_{32}$$

The coefficients and values for the second regression are shown in Table 5. All independent variables are significant to the alpha 10% sign (marked with *) in the partial or significance test of the $\beta$ coefficient for each variable. Based on the table, the equations for the second regression model $Y$ are:

$$Y = 33,49103 - 0.69950 \cdot X_2 - 13,4944 \cdot X_{31} - 5,2994 \cdot X_{32}$$

Table 4. Regression model results for the first model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>36,33652</td>
<td>2,31798</td>
<td>15,676</td>
<td>2e-16*</td>
</tr>
<tr>
<td>First Vaccine</td>
<td>-0.55478</td>
<td>0.03301</td>
<td>-16,806</td>
<td>2e-16*</td>
</tr>
<tr>
<td>Government Policy</td>
<td>-11,93974</td>
<td>2,42877</td>
<td>-4,916</td>
<td>1,97e-06*</td>
</tr>
<tr>
<td>Dummy1</td>
<td>-4,70605</td>
<td>3,08847</td>
<td>-3,524</td>
<td>0,00129*</td>
</tr>
</tbody>
</table>

Table 5. Regression model results for the second model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>33,49103</td>
<td>2,3757</td>
<td>14,097</td>
<td>2e-16*</td>
</tr>
</tbody>
</table>
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The above regression results show that vaccination (1st or 2nd dose) has a significant effect on reducing the positive rate. Relatively speaking, if government policy such as PPKM are implemented, the impact on prevalence will be greater. So, if the goal of vaccination and policy is to reduce the value of prevalence, that goal will be met. Reducing positivity rates requires more careful and cautious steps in immunization programs and local implementation of PPKM guidelines. The large number of cases in this field indicates the need for more precise and careful screening when determining vaccination targets.

Analysis Based on Model Equations

The effect of Covid-19 vaccination on the positive case rate in Indonesia can be read from the coefficient values of the independent variables in the regression model. Variable percentages of the vaccinated population and government policy variables influence the prevalence values of Covid-19 cases. Moreover, this effect is the negative effect seen from the coefficient values of the independent variables in the First Model and Second Model. This negative effect means that as the independent variable value increases, the dependent variable value decreases.

An analysis of the efficacy of dose 1 Covid-19 vaccine from the first model is as follows:

1. The regression coefficient for the percentage of vaccine 1 \( X_1 \) is \(-0.55478\). This means that the positive case rate of Covid-19 cases \( Y \) increases by \(-0.55478\) percent, for every 1 percent increase in the number of people receiving the first dose of vaccination, assuming government policies are also applied in the form of National Micro-PPKM rules.

2. The regression coefficient for government policy dummy 1 \( X_{31} \) is \(-11.93974\). This is a \(-11.93974\) percent reduction in the positive case rate of Covid-19 cases \( Y \) every time we implement a government policy in the form of PPKM Levels 1 to 4.

3. The regression coefficient for government policy dummy 2 \( X_{32} \) is \(-4.70605\). This means that the positive case rate of Covid-19 cases \( Y \) decreases by \(-4.70605\) percent every time we implement government policy in the form of the After PPKM.

4. There is a significant difference in reducing the positive rate of Covid-19 cases between implementing the PPKM Levels rules 1-4 and implementing the After PPKM rules.

<table>
<thead>
<tr>
<th>Second Vaccine</th>
<th>-0.69950</th>
<th>0.04405</th>
<th>-15.878</th>
<th>2e-16*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Policy</td>
<td>-13.4944</td>
<td>2.4903</td>
<td>-5.419</td>
<td>1.97e-06*</td>
</tr>
<tr>
<td>Dummy1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Policy</td>
<td>-5.2994</td>
<td>3.19391</td>
<td>-3.659</td>
<td>0.00988*</td>
</tr>
<tr>
<td>Dummy2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An analysis of the efficacy of dose 1 Covid-19 vaccine from the second model is as follows:

1. The regression coefficient for the percentage of vaccine 1 ($X_2$) is -0.69950. This means that the positive case rate of Covid-19 cases ($Y$) increases by -0.69950 percent, for every 1 percent increase in the number of people receiving the second dose of vaccination, assuming government policies are also applied in the form of National Micro-PPKM rules.

2. The regression coefficient for government policy dummy 1 ($X_{31}$) is -13.4944. This is a -13.4944 percent reduction in the positive case rate of Covid-19 cases ($Y$) every time we implement a government policy in the form of PPKM Levels 1 to 4.

3. The regression coefficient for government policy dummy 2 ($X_{32}$) is -5.2994. This means that the positive case rate of Covid-19 cases ($Y$) decreases by -5.2994 percent every time we implement government policy in the form of the After PPKM.

4. There is a significant difference in reducing the positive rate of Covid-19 cases between implementing the PPKM Levels rules 1-4 and implementing the After PPKM rules.

Based on the analysis of model equations, we see a difference in the effects of Covid-19 vaccination 1st and 2nd doses. An increase of 1 percent people who have been vaccinated with dose 2 will further reduce the percentage positivity rate of Covid-19 cases, compared to an increase of 1 percent people who have been vaccinated with dose 1. Subsequently, implementation of government policy further reduces the proportion of positive Covid-19 cases when populations are vaccinated for the second time compared to populations who receive only the first vaccination.

CONCLUSIONS

Covid-19 vaccination has a significant effect on reducing the positivity rate. An increase in the percentage of the population that has been vaccinated against Covid-19, both dose 1 and dose 2, can reduce the percentage positivity rate of Covid-19 cases in Indonesia. Furthermore, an increase in the percentage of the population that has been vaccinated with dose 2 will further reduce the percentage of the positivity rate of Covid-19 cases compared to the increase in the percentage of the population that has been vaccinated with dose 1.
REFERENCES


