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Abstract

Indonesia's territory consists of a large number of islands stretching from Sabang to Merauke. This condition causes different levels of development between regions. The eastern region of Indonesia is relatively slow when compared to the western region. This has resulted in the eastern region being in pristine condition and filled with forests. The climate in eastern Indonesia tends to be humid, resulting in high development of the female Anopheles mosquito, the cause of malaria. This study aims to analyze the effect of rainfall on the development of malaria cases. The use of the instrumental variable method is necessary, because the model has endogeneity problems. The data used in this study comes from the results of the 2018 Podes data and climate data. The results of this study indicate that rainfall affects the number of malaria incidents and has a positive impact on mortality due to malaria, with coefficients of 0.0000779 and 0.0000142, respectively. Education is needed for the community to minimize malaria, which often occurs, generally in the Papua region. Through health promotion, it is hoped that the community will be able to live cleanly and healthily, as well as change their behavior in life, considering that the area is vulnerable to malaria.

Key words: Rainfall; Malaria; Instrumental variable

1. Introduction

The spread of malaria cases in Indonesia is increasingly worrying, amid advances in technology and information as well as increasingly adequate health facilities. Based on data from the 2018 Podes data, it is known that 1,497 villages experienced malaria cases in 2018. From these malaria cases, it is known that 82 people died from the outbreak.

(BPS, 2018). If classified based on the islands in Indonesia, the eastern region of Indonesia has the largest portion when compared to the western region.

Malaria is caused by the plasmodium parasite which is spread by the bite of a female Anopheles mosquito. After the mosquito bite, the parasites enter the body and occupy the liver, where the parasites can grow and reproduce. When these parasites grow and become adults, they leave the liver and destroy red blood cells. Damage to red blood cells will cause symptoms of anemia in sufferers. Apart from being bitten by mosquitoes, the spread of malaria parasites can also occur due to exposure to the blood of malaria sufferers. Some conditions that can cause a person to be exposed to malaria due to human-to-human exposure include an infected fetus from his mother, receiving blood transfusions, sharing needles, and receiving organ donations (Despommier et al., 2012; Handayani, 2012; Husin, 2007; Sinden & Gilles, 2002).

The severity of the malaria symptoms that arise varies from person to person. People who live in areas with a lot of malaria cases have better immunity, so their symptoms will be less severe. However, this immunity can be lost once a person moves to an area where malaria is not common. People who do not have immunity can experience more severe symptoms of malaria. Symptoms of malaria can generally be severe and can cause complications if they occur in infants, the elderly, pregnant women and their fetuses (Doolan et al., 2009; Najera et al., 1996; Schofield & Mueller, 2006).

There are many types of malaria which are differentiated according to the type of parasite plasmodium that infects. However, only five types of plasmodium infect humans, namely: (i) malaria falciparum, caused by the parasite Plasmodium falciparum. This type of malaria is the most dangerous because it causes severe malaria with complications. Most of the deaths due to malaria are associated with this type of malaria. (ii) malaria vivax, the plasmodium vivax parasite that causes vivax malaria, can survive in an inactive state in the liver for several months or years. Thus, this type of malaria can recur when the parasites become active again. (iii) malaria ovale, this type is caused by the parasite Plasmodium ovale and the symptoms are not severe, and sometimes get better without treatment. (iv) malaria malariae, this type of malaria only causes symptoms after being infected with the Plasmodium malariae parasite for a long

time. Therefore, sufferers of this type of malaria will experience chronic infections and are also associated with impaired kidney function. (v) malaria knowlesi, the same as malaria falciparum, malaria due to Plasmodium knowlesi can also progress quickly to become severe, even though the initial symptoms are mild (Mohring et al., 2014; Tadei & Dutary Thatcher, 2000).

Based on data from the Annual Parasite Incidence, there were 250,644 malaria cases recorded in 2019 in Indonesia. The highest case, 86 percent, occurred in Papua Province with 216,380 cases. This was followed by East Nusa Tenggara Province with 12,909 cases and West Papua Province with 7,079 cases. One of the things that causes eastern Indonesia to remain prone to malaria is geographic and cultural factors. In some areas in the region, there are still many people who live close to gardens, swamps, and trees that can become mosquito breeding grounds. This can increase the risk of malaria through mosquito bites (Kenangalem et al., 2019; Yawan, 2006).

In addition, the hotter air at night can also affect this risk. In fact, residents in the area are reluctant to use a mosquito net that prevents mosquitoes from biting because it will block the wind to sleep better. In fact, mosquito nets contain insecticides that can kill mosquitoes when they get caught in the nets. In addition, education regarding the risks from the dangers of malaria is still limited due to a lack of information distribution. In addition, the lack of people who get immunized makes the risk of people being attacked continues to increase. That way, the health role of the government is very important so that these infectious diseases can be overcome immediately.

Based on the previous background, it is known that climate factors have a role in the spread of malaria. Indirectly, the rainfall and humidity in the area cause the reproduction rate of anopheles which causes malaria to be higher. Based on previous research, it is known that climate affects the spread of malaria (Lou & Zhao, 2010; Paaijmans et al., 2009, 2010; Zhou et al., 2004). Previous research has used data at both the state and provincial levels. In this study, using data on the number of incidents and the number of victims who died from malaria at the village level, so that the role of rainfall in influencing malaria in Indonesia will be known.

2. Methodology and Data

The data used in this study are raw data from the 2018 PODES data collection, which describes the conditions for the spread of malaria at the village level. The PODES data collection is carried out by BPS and is specifically designed to collect data that can describe conditions in rural areas and sub-districts, as well as prepare future censuses through the collected data and information.

This study uses rainfall data as a variable of interest. The instrument variables in this study were wind speed, humidity, solar radiation, temperature, and air pressure. This study also uses several control variables, namely the village bordering the sea, the number of primary schools, the number of midwife practices, the number of village health centers, the presence of village midwives, and the number of poor families. The first stage model is the number of malaria incidents and the number of malaria deaths caused by malaria:

$$rainfall = \alpha + \beta_1 wind_{velocity} + \beta_2 humidity + \beta_3 sunshine + \beta_4 temperature + \beta_5 air_{pressure} + \beta_i X_i + \varepsilon \quad (1)$$

Instrumental variable model number of malaria incidence:

$$malaria = \alpha + \beta_1 \widehat{rainfall} + \beta_2 border_{sea} + \beta_3 elementary_{school} + \beta_4 midwife + \beta_5 village_{helath} + \beta_6 village_{midwife} + \beta_7 poor_{family} + \varepsilon \quad (2)$$

Instrumental variable model of the number of deaths from malaria due to malaria:

$$death = \alpha + \beta_1 \widehat{rainfall} + \beta_2 border_{sea} + \beta_3 elementary_{school} + \beta_4 midwife + \beta_5 village_{helath} + \beta_6 village_{midwife} + \beta_7 poor_{family} + \varepsilon \quad (3)$$

Ordinary least square model for the number of malaria incidence:

$$malaria = \alpha + \beta_1 rainfall + \beta_2 border_{sea} + \beta_3 elementary_{school} + \beta_4 midwife + \beta_5 village_{helath} + \beta_6 village_{midwife} + \beta_7 poor_{family} + \varepsilon \quad (4)$$

Ordinary least square model for the number of victims who die from malaria:

$$death = \alpha + \beta_1 rainfall + \beta_2 border_{sea} + \beta_3 elementary_{school} + \beta_4 midwife + \beta_5 village_{helath} + \beta_6 village_{midwife} + \beta_7 poor_{family} + \varepsilon \quad (5)$$

This study used the instrumental variable method, because the model that was built had endogeneity problems. Wooldridge (2016) states that instrumental variable analysis is used to overcome the problem of endogeneity. The OLS estimator will be biased and inconsistent if an important variable is not included in the model.

3. Results and Discussion

There are differences in position, causing various climate differences in Indonesia. From Figure 1, it is known that the rainfall on Kalimantan Island is the highest, while Java Island has the highest wind speed. In addition, Kalimantan Island is an island that has high humidity, and Java Island has a high temperature. Apart from different geographical positions, regional characteristics (such as population density, regional economy, and the main source of income for the community) can also influence climatic conditions that occur in an area.

From the regression results, it is generally known that climate plays an important role in the spread of malaria and its impact on the disease. This result is in line with several previous studies which stated that climate has a positive influence on malaria (Bomblies, 2012; Briët et al., 2008; Okuneye & Gumel, 2017). Conditions in areas that have moderate to high rainfall are usually humid. This humidity makes it easier for female Anopheles mosquitoes to breed. In addition, if the area is a wilderness area, the breeding process will be faster. In line with the phenomenon, many malaria cases occur in the Provinces of Papua and West Papua, because these areas have a relatively humid climate and the condition of the area is still a lot of forest. Malaria in Papua and West Papua Provinces has become something that is not surprising, because this disease has experienced quite a lot of local people. It is believed that the local community has immunity against malaria.

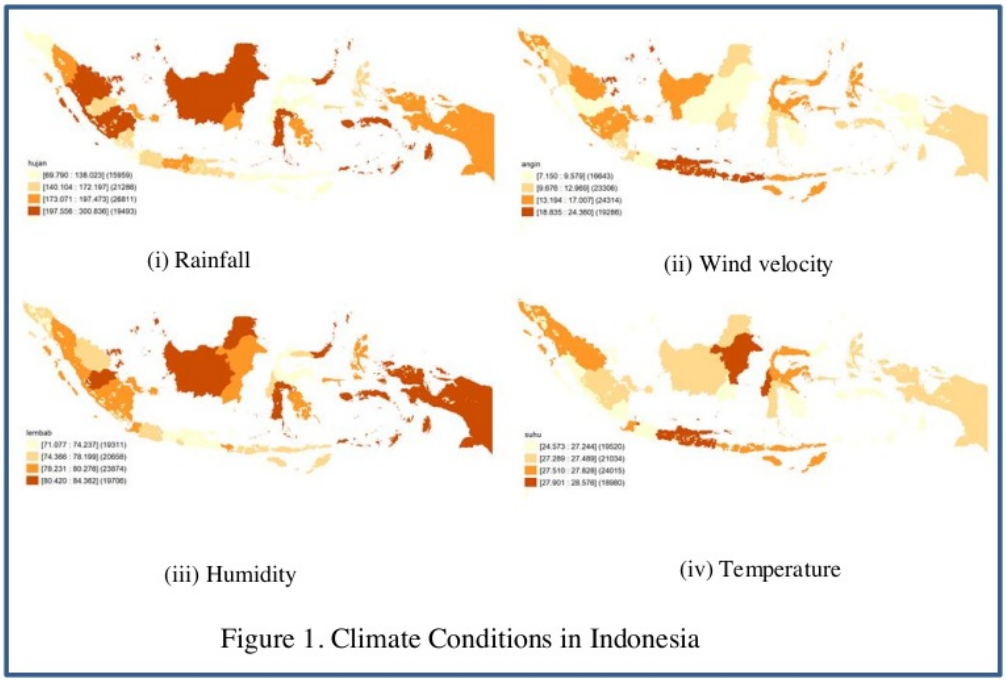

Figure 1. Climate Conditions in Indonesia

The overall result of the calculation using the instrumental variable method is greater than the calculation using the ordinary least square method. This is according to the theory presented, that the instrumental variable method will solve the endogeneity problem, and if traced the coefficient formed will be greater than the ordinary least square method (Wooldridge, 2016).

Table 1. First stage estimation results on the effect of rain on the number of malaria incidence and death tolls from malaria

Variable	**Rainfall**
Wind velocity	4.814315***
Humidity	13.08500***
Sunshine	-1.757957***
Temperature	-16.99906***
Air pressure	0.143320***
Control variable	Yes
R^2	0.4653
Observations	83,931

Source: Results of processing with Stata 16 (processed)
Note: Notation level of significance *** p <1%.

In Table 1, through the first stage on the instrumental variable method, it is known that wind speed, humidity, and air pressure have a significant positive effect on rainfall. Besides, solar radiation and temperature have a significant negative effect on rainfall. According to phenomena, the two groups are opposite each other, for example temperature and humidity. The high temperature of an area causes the humidity to be lower.

Table 2. Estimation results of OLS and IV in general on the number of incidence of malaria

Variable	Number of incidence of malaria	
	OLS	IV
Rainfall	-0.0000008	0.0000779***
Control variable	Yes	
Instrument variable	No	Yes
R^2	0.0046	0.0038
Observation	83,931	

Source: Results of processing with Stata 16 (processed)
Note: Notation level of significance *** p <1%.

From Table 2 it can be interpreted that rainfall has a significant positive effect on the number of malaria incidences. The variable in the regression model that is formed can explain 0.38 percent of the incidence of malaria in an area. These results indicate that there are most of the other variables that can influence the occurrence of malaria. Other things that can affect the disaster include the behavior of the community in protecting the environment, geographical factors, and the level of public knowledge.

From Table 3 it can be interpreted that rainfall has a significant positive effect on the number of victims who died from malaria. The variable in the regression model that is formed can explain 0.07 percent of the number of victims who died from malaria in an area. These results indicate that there are most of the other variables that can affect the number of victims who die from malaria. Other things that can affect the disaster

include, among others, health facilities in an area, previous illnesses, and area access to the nearest health facilities.

Table 3. Results of OLS and IV estimates in general on the number of victims who died from malaria

Variable	The number of victims who died from malaria	
	OLS	IV
Rainfall	-0.0000001	0.0000142**
Control variable	Yes	
Instrument variable	No	Yes
R^2	0.0008	0.0007
Observation	83,931	

Source: Results of processing with Stata 16 (processed)
Note: Notation level of significance ** p <5%.

In this study, the climate variable is still used at the measurement station level, which is limited in number at the provincial level. It is hoped that future studies can use climate indicators at the village level, so that the analysis can be more representative. In addition, the use of other variables as instrument variables and control variables is needed to strengthen the model formed.

4. Conclusion

The high mortality rate due to malaria in Indonesia requires the government to focus on the eastern part of Indonesia. Geographical factors that belong to eastern Indonesia tend to be moist and filled with forests, making it easier for female Anopheles to breed. From the results of this study, it is known that the rainfall factor influences the number of malaria incidents and also has a positive impact on mortality caused by malaria. Education is needed for the community to minimize malaria, which often occurs, generally in the Papua region. Through health promotion, it is hoped that the community will be able to live cleanly and healthily, as well as change their behavior in life considering that their area is vulnerable to malaria.

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