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Effect of climate change on rainfall pattern

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ABSTRACT

This study aims to analyze the effects of climate change on rainfall patterns. The data used are secondary data consisting of quantitative data. With a period of 24 years (1993-2017) measured monthly by data interpolation techniques. This research data is panel data. With cross-sections namely months. The research data were obtained from the Makassar Climatology and Geophysics Meteorology Agency (BMKG). Data analysis was done using panel data regression. The research findings obtained effect of temperature is very small on rainfall patterns. While wind velocity are the most influential predictors on the rainfall patterns.

Key word : *Temperature, Wind velocity, Rainfall, Panel data regression*

Introduction

Rainfall can be interpreted as the amount of sky water falling to the earth after experiencing the process of weather phenomenon. This form of rainfall includes several commonly known terms, including rain drops, snow, crystals, and dew. The term belongs to the group of rainfall in different forms, both solid and liquid. Rainfall is useful for many activities in human life, such as agriculture, marine, public services, and so on (Corominas and Moya, 1999; Neher, 2018; Keja-Kaereho and Tjizu, 2019). In Indonesia, rainfall varies depending on place, time and other physiographic factors.

In reality, the current weather becomes difficult to predict due to several factors, among others the effects of global warming, the burning of fossil fuels, and other human activities that cause residuals for the environment, such as forest burning, industrial activities, and waste pollution (Demirbas, 2004; Kurz *et al.,* 2008; Maunder, 2019; Li *et al.,* 2019). These activities more or less have contributed to air pollution in the atmosphere due to increase the production emissions of CO_2, N_2O and CH_4 which are harmful to health if inhaled in large quantities.

The decline in air quality is exacerbated by the depletion of green open land due to continuous development and felling of trees without regeneration. (Adams *et al.,* 2000). The reduction in the number of green plants as the oxygen-producing ultimately worsens air quality due to the loss of carbon dioxide absorber.Further result, the condition of the earth's atmosphere is getting hotter over time.Noted by IPCC (Intergovernmental Panel on Climate Change) that every year carbon dioxide in the atmosphere has increased from 280 ppm to 379 ppm. Even predicted in 2100, air temperatures can increase from 1.8 to 2.9 ^{0}C (Ernyasih, 2012:48). Obviously, this has an impact on weather conditions, in this case rainfall which becomes difficult to predict.

The discussion of the weather-forming elements that influence rainfall is inseparable from the physiographic factors that play a role in the process of rain formation. The physiographic factors, among

others the influence of air humidity, air temperature, air pressure, and wind velocity (Marni and Jumarang, 2016). These elements together affect on the process of rain.

According to Wilson (1993: 7) in the case of rainfall there is a relationship of other weather elements such as temperature, humidity, and wind speed/ velocity. The linkage of rainfall with other weather elements is reflected in the hydrological cycle that affects on human life. Air humidity has an important role in the hydrological cycle, namely in the formation and growth of clouds associated with rainfall events. Temperature is also much related to the humidity of the air in an area which will also affect rainfall. Wind is one of the factors that influence rainfall. This can be seen in the water cycle, where the wind plays a role to bring clouds, so that the clouds eventually release water drops called rain. There are several elements of weather (temperature, humidity, and wind speed) that affect rainfall so that need to be conducted a forecast using the multivariate model.

The significant decrease in rainfall due to extreme climate has also had a significant impact on the agricultural sector, especially food crop production. This has become one of the reasons that has led to the development of rain forecast models as an effort to anticipate extreme climate events. The rain forecast model, which was originally based only on time series data, has now evolved considering the aspects of climate anomalies, such as the rain forecast model using the Kalman filter method. One of the global indicators that can be used as an indicator of climatic anomalies is the sea surface temperature. From various research results it is known that sea surface temperature has a relationship with the occurrence of rainfall (Estiningtyas *et al.*, 2007). Therefore it is necessary to be conducted the study on the factors that influence rainfall patterns.

Research Methods

The data used are secondary data consisting of quantitative data. With a period of 24 years (1993-2017) measured monthly by data interpolation techniques. This research data is panel data. With cross-sections namely months. The research data were obtained from the Meteorology Climatology and Geophysics Agency. For panel data analysis there are three models namely, Common Effect, Fixed Effect and Random Effect. This study uses panel data regression analysis techniques, namely the combination of cross sections and time series. Cross section data is observational data on several research subjects at one time, for example in one year. While time series data are observational data on one research subject observed in a period of time, for example for nine years. In panel data, observations made on several subjects then analyzed from time to time. The model equation using cross section data is shown by:

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i; \quad i=1, 2,...., N$$

Where "N" is the amount of cross section data. While the model equation with time series can be written as follows:

$$R_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it} + \varepsilon_{it}; \quad i = 1, 2,...., T$$

Where "T" is the amount of time series data. So that the panel data equation which is a combination of cross section and time series data can be written as follows :

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \varepsilon_{it}$$

$$i = 1, 2, ..., N; t = 1, 2, ..., T$$

In the model, Y is the dependent variable while X is the independent variable. N indicates the number of observations while T indicates the amount of time analyzed. So that the variables in this study were applied in a model as follows:

$$R_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 W_{it} + \varepsilon_{it}$$

Information:

R = Rainfall

T = Temperature

W = Wind velocity

i show the subject to -i, and t shows the time of year to-t

In panel data regression there are four models that can be used. These models among others: OLS pooled model, the fixed effects least square dummy variable (LSDV) model, within-group fixed effects model and the random effect model (Gujarati: 2013). The selection of models that will be used is selected by the model specifications test. There are two test specifications, namely fixed effects or random effects.

a. Common Effect

The model assumes that intercepts and slope coefficients are constant over time and individual, and

the error term explains the differences of intercepts and slope coefficients over time and the individual. Regression conducted by combining time series data and cross section (pooled).Estimation conducted namely by Ordinary Least Square (OLS) regression. This method is called Pooled Regression or Common Effect. Thus, in this model there is no individual effect.

b. Fixed Effect

The model that assumes the existence of intercept differences for each individual is known as the Fixed Effect regression model. The term Fixed Effect comes from the fact that although intercept is different in each individual, each individual intercept does not vary or is fixed all the time (time invariant). In addition, the model also assumes that the slope coefficient is constant over time and individual. Estimation conducted by using dummy variable technique for individuals. Furthermore, because of the use of dummy for the Fixed Effect estimation, then the literature calls it the Least Square Dummy Variables (LSDV) technique.

Random Effect

The panel data method with the Fixed Effect approach above has a problem in terms of degree of freedom if there are many individuals in the regression. n this case, it is said that the individuals in the estimated sample are taken from a large population of individuals and they have a general average value for intercept, namely â1and individual differences in the intercept values for each individual expressed in error term åi.

Results and Discussion

Panel Data Regression

Hypothesis testing in research is very important, this can determine whether the research conducted is scientific or not. To determine the feasibility of the model, based on the three model estimation that have been conducted namely *pooled least square*, *fixed effect model*, and *random effect model*. Based on the comparison of*output*, seen from the value of*t test*, *f test*, *determinant coefficient* (*R2*), *coefficient* and *constant*. *The random effect model* is a suitable approach compared to the *fixed effect model* and *pooled least square*. However, testing on the classic assumptions of econometrics shows that the *random effect model* has been shown the experience of autocorrelation problems.Violation on this classic assumption makes the estimation results biased and the validity is doubtful so that could produce an incorrect analysis.

Based on these facts, then the use of *fixed effect model* and *random effect model* is not possible to be the basis of analysis on the rainfall patterns, so that in this study it was decided to use a *cross-sectional time series feasible generalized least square* regression as a treatment from the *fixed effect model*.The results are shown in Table.

T test

This test is conducted to find out how much influence of one independent variable individually in explaining the dependent variable. In this research will be proven the effect of each of independent variables, namely temperature, and wind speed/ velocity on rainfall patterns. The independent variable is said to has a significant effect on the dependent variable or *Ho:* $\beta_{xy} = 0$ and *Ho:* $\beta_{xy} \neq 0$ accepted if the value of {$p > |z|$}<from the value of α namely amounted to 0.05 or *ttest>ttable*. This test is conducted by looking at the probability of t calculate, if prob < sig level of 5%, then Ho rejected. So it can be concluded that the independent variable significantly influences the dependent variable.

Model	Coef.	Std. Err.	Z	P>|z|
Temperature (T)	0.0402427	0.1557931	0.26	0.796
Wind Velocity (W)	0.277229	0.1361547	2.04	0.042*
_cons	1.301716	0.1199206	10.85	0.000**

Prob > chi2	=	0.0000
Wald chi2 (14)	=	718.29
R-sq	=	0.1926

**p<0.05, **p<0.01*

Based on Table 1. Obtained the rainfall model as follows:

$R_{it} = 1.301 + 0.04T_{it} + 0.277W_{it} + \varepsilon_{it}$

The analysis result obtained {$p>|z|$} for temperature variable namely 0.796, means that {$p>|z|$} greater than the value of α amounted to 0.05, so that H_0 accepted, meaning that the temperature does not affect on the rainfall pattern. For the wind velocity variable obtained {$p>|z|$} amounted to 0.0103 less than the value α of 0.05 so that H_0 rejected, means thatwind speed/velocity has a significant effect on rainfall patterns.

F Test

F Test basically indicates whether all the independent variables that are included in the model have influence simultaneously on the dependent variable. The independent variables simultaneously are said to have a significant effect on the dependent variable. F test result obtained the results of prob > F of 0,0000, this number is smaller than the α value of 0,05 and the value of Ftest (Wald chi 2) amounted to 718.29. Thus it can be concluded that all independent variables simultaneously have influence on the rainfall pattern.

Correlation Coefficient (R) Test

The value of the determinant coefficient in this study was 0.1926, so that the correlation coefficient value was$\sqrt{0.1926}$= 0.4388. This means that simultaneously the independent variable can explain the dependent variable equal to 0.4388 or 43.88%.

Determination Coefficient (R2) Test

Determinant coefficient (R2) shows how much percentage of the variation of the independent variable used in the model is able to explain the variation of the dependent variable. The value of determinant coefficient (R2) in research which using the method of *cross-section altime series feasible generalized leastsquare* can be seen from *R-sqwithin* namely amounted to 0.1926 or 19.26% which means the ability of temperature and wind speed variables in explaining the rainfall pattern variable is 19.26%. While the remaining 80.74% is explained by other variables outside of this research variable. This means that the error rate generated in the regression equation from the results of this study is 0.8074 or 80.74%. This means, if there is a change of one unit in the independent variable, then the dependent variable will change by one unit, assuming other variables constant.

Effect of Temperature on Rainfall

The research findings show that the effect of temperature on rainfall is very small and insignificant. One of the factors that influence rainfall is air temperature. Research findings of Nuryanto and Badriyah (2014) states the domination of the effect of changes in sea surface temperature on rainfall of the Indonesian Maritime Continent on land is higher than at sea. This indicates that the influence of sea surface temperature towards the rainfall on land has strengthened compared to at sea (Vizy and Cook, 2001; Fu *et al.,* 2001; Levine *et al.,* 2013). Temperature and rainfall fluctuations are shown in Figure 1.

Based on 1993-2017 monthly rainfall data, then the rainfall pattern with peak rainfall occurs in 2000 on February (378 mm) and the lowest occurs in 1993 on July, 2006 on July, 2011 on July and 2013 on August (1 mm). While the temperature fluctuation between 22.1 ^{0}C-30 ^{0}C. Air temperature associated with conditions of heat or cold of the air in the atmosphere. The air temperature also has fluctuating characteristics so it is susceptible to change according to place and time.

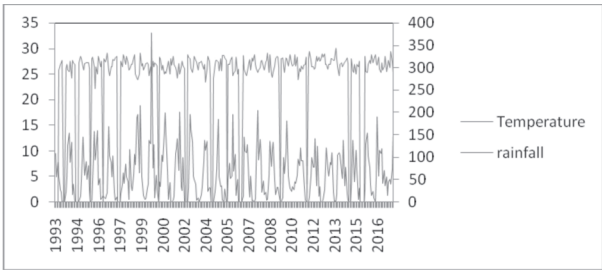

Fig. 1. Fluctuation of Rainfall and air temperature in 1993-2017

Muharsyah (2009) findings suggest that one of the biggest causes of rainfall comes from the factor of evaporation of sea water temperature. Rain plays an important role in the hydrological cycle. The moisture from the sea evaporates, turns into clouds, collected become cloudy clouds, fall back to earth, and finally returns to the sea through rivers and creeks to repeat the recycle.Air temperature affects the formation of rainfall. Estiningtyas, *et al. (*2007) states that changes in sea surface temperature affect on the difference in rainfall (Nicholls, 1989; Xie *et al., 2010*).This assumption is closely related to anomalous patterns of changes in sea water temperature that occur both temporally and spatially.The in-

crease in seawater temperatures causes an increase in evaporation in an area (El-Dessouky *et al.*, 2000).

Increase in the evaporation process which under pressure creates the direction of wind movement. The wind then carries water vapor that can bring rain in large quantities. These fluctuations can be caused by turbulence or active air masses movement due to high wind velocity (Ernyasih, 2012:41). Furthermore Ernyasih added that air temperature is an important element in climate formation.

Effect of Wind Movement on Rainfall

Wind formation occurs because of several processes. Sultan (2018: 10) revealed that the formation of wind is influenced by the process of solar radiation (Le and Tran, 2019; Pushpawela *et al.*, 2019; Al-Dousari *et al.*, 2019). Sunlight that hits the earth basically has a different intensity of radiation from one place to another. The effect of the radiation difference is a factor in the formation of wind. In addition to solar radiation, air expansion also causes differences in the process of wind formation. The difference in temperature due to sunlight causes the air experiencing the expansion. This happens because the air is under pressure in areas with a lot of sunlight so that the air pressure in areas that get little sunlight becomes low. Furthermore, air pressure affects air movement as a result of the difference in air pressure. By its nature, air coming from high pressure areas will move towards low pressure areas. In other words, the lower the sunlight, the more wind in the area will eventually blow to areas with high sunlight intensity. Fluctuations of rainfall and wind speed/velocity are shown in Figure 3.

The highest monthly wind speed/velocity data

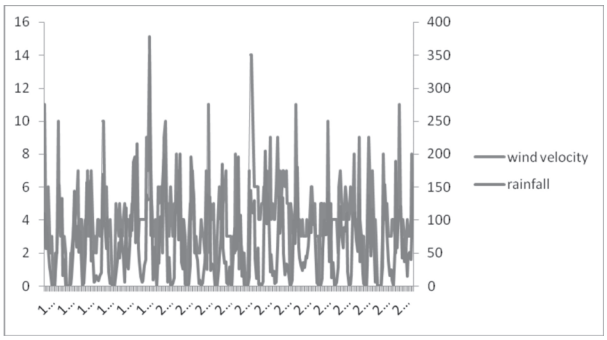

Fig. 3. Fluctuations of rainfall and wind speed/velocity

occurs in 2000 on February, in 2006 on December and in 2007 on January amounted to 14 while the lowest velocity occurs in 2004 on January, in 2006 on March, June and December amounted to 1. Ari in (Sultan, 2018: 11) explains that the wind is formed due to factors, among others barometric gradients, location factors, and altitude factor as well as time. Barometric gradient is a number drawn from two isobars to indicate differences in air pressure at a distance of 111 km. The wind speed/velocity is faster if the barometric gradient is greater. Meanwhile, the location factor is related to its position with the equator. In this case, the wind will be faster when in the equator. The higher the place also causes the wind to blow harder. This event occurs because the higher the place, the smaller the frictional force in the air. The frictional force essentially impedes the rate of air movement because it rubs against mountains, earth's surface, trees, or other topography. The movement of the wind will also be different due to the time difference between day and night. During the day the wind will generally move faster than the night.

In connection with this explanation, Indonesia's geographical location is flanked by the Indonesian Ocean and Pacific Ocean. Indonesia is also located between two continents, namely Asia and the Australian Continent. This position affects the pattern and direction of wind movement in Indonesia.In this case Tukidi (2010: 137) states that the direction of wind movement plays an important role in bringing in more or less rainfall. The wind direction that blows from the Indonesian Ocean to the Pacific Ocean is the wind that carries the humid air so that the Indonesian region experiences rain with high intensity. Conversely, the wind that blows from the Asian Continent and the Australian Continent can be said to be a dry wind because it only carries a little water. These winds bring rainfall in a relatively small amount.

Conclusion

The research findings concluded that wind velocity affect on rainfall patterns. While the air temperature did not affect on the rainfall pattern. The findings of this study recommend the importance of considering climate factors in determining rain patterns.

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