Estimating the Macroeconomic Impact of Natural Disasters in Indonesia

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Abstract. Macroeconomic losses due to natural disasters can be seen from the amount of the Gross Regional Domestic Product (GRDP). The aim of this study is to determine factors that cause macroeconomic losses due to natural disasters. This study utilize GRDP data and the number of workers obtained from the Central Bureau of Statistics (BPS). This study also utilizes data on the disaster events and amount of damage to public facilities data published by the National Disaster Management Agency (BNPB) from 2001 to 2021 in 34 provinces in Indonesia. The data is processed using panel regression, which is the regression method for panel data. The test results shows that the number of workers and natural disasters influence the macro-economic losses of all provinces in Indonesia. Based on these results, parties related to disaster management need to take more comprehensive steps to reduce the natural disasters impact on economic conditions, especially macroeconomic conditions.

Keywords: Natural Disaster; Regression Panel; Macroeconomics

1. Introduction

Natural disasters have resulted in damage both economically, socially and financially which has disrupted the stability of national development. The Secretary General of the United Nations stated that the Gross National Product (GDP) of developing countries suffered a loss of 5% each year which was caused by natural disasters. Losses caused by natural disasters in macro-economic terms are grouped into two, namely real losses and intangible losses. Of the total damage that occurred after the disaster, McKenzie, Prasad, and Kaloumaira (2005) states that the real impact occurred because goods and services that are usually sold and can be purchased in the market cannot be found. While intangible impacts occur because goods and services have no market value.[1]

As one of the countries that has a high potential risk of natural disasters, Indonesia has experienced various disaster events. Disaster events that occur and are recorded according to date, location, type, number of victims and/or losses are referred to as disaster events. If a disaster occurs in more than one area and on the same date, it is counted as one incident (https://bnpb.go.id/definition-bencana). Data released by Katadata.co.id states that in 2021 there were 3,058 natural disasters in Indonesia. Types of disasters include floods, extreme weather, forest fires, earthquakes, tidal wave landslides and abrasion, drought and volcanic eruptions. Meanwhile, according to *https://dibi.bnpb.go.id/* the highest number of disaster events in the

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period 2001 - 2021 occurred in the provinces of West Java, DKI Jakarta and the Special Region of Yogyakarta.

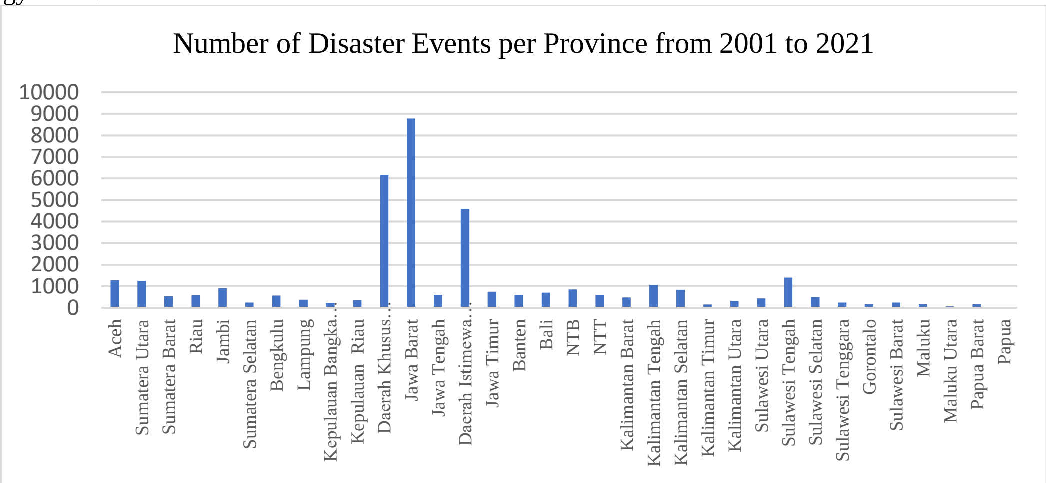

Figure 1. Number of Disaster Events in Indonesia from 2001 to 2021

Disaster events cause the emergence of several potential losses which are grouped into tangible and intangible losses. The impact of a natural disaster on economic growth, inflation and employment is a macroeconomic impact. Even though it is said to be a secondary impact, the impact of a disaster is always bad, especially in the short term, namely decreased production. Research conducted Noy (2009) revealed that after a disaster, developing countries experienced a higher decline in output than developed countries.[2] The results of his research also show that preparedness and the ability to prevent macroeconomic impacts in countries that have higher education and per capita income, better institutions, higher openness, and more government spending. That is, the ability to mobilize resources must be higher.

Research related to disaster risk in Indonesia has found that most of the natural disasters in Indonesia are hydrometeorological and geological disasters. The most frequent disasters are floods followed by earthquakes. The results of Fitriani et.al's research, 2021 revealed that between 1815 and 2019 natural disasters often occurred in the form of landslides, floods, tornadoes, and fires. Research on natural disasters that has been carried out has emphasized more on the characteristics of the probability of occurrence of disasters, but not many studies have discussed the economic impact of disasters, especially macroeconomics, which are still very limited.

In Law no. 24 of 2007, a natural disaster is defined as an event/series of events that threatens and disrupts community life. Natural disasters are one of the events that can disrupt the economy in a region, especially if the intensity and coverage area is quite large. Natural disasters cause direct economic losses in the form of stock losses and indirectly in the form of disruption to business and a decrease in gross domestic product.[3] To assess the impact of disasters economically ECLAC which stands for the European Commission for Latin America and Caribbean designed a method for assessing the effects of disasters economically (Zapata-Marti, 1997) in Artiani (2011).[4] Disaster impacts are grouped into three groups, namely direct damage, indirect damage and secondary effects. Macroeconomic impacts occur due to changes in the main economic variables that arise as a direct or indirect impact of a disaster. These economic variables represent changes in economic activity [2]. Several macroeconomic indicators are economic growth, inflation and employment opportunities. GRDP is a measure for observing economic growth in a region by observing the factors that cause economic change.[5]

The economic impact caused by the disaster occurred on GRDP, balance of payments, investment, and public finances. The level of loss depends on the type and size of the disaster that occurs, therefore Noy (2009) states that the estimation of the impact of disasters on inflation and employment is quite relevant.[2] Quantitative assessment of economic impact is generally carried out for the national economy on a macro basis, but it is possible to do it on a micro basis if sufficient information is available. Research to obtain a model of economic growth has been carried out by Almuhayar (2017) (Safitri and Satrianto A 2019) by examining the effects of disasters and the effects of spatial dependence that affect economic growth in several provinces in Sumatra in the period 2010 – 2015.[6] [7] Other research has also been conducted by Noy (2009) with regression using panel data, namely the use of times series data and combined cross section data.[2]

Several possibilities in the use of panel data according to (Greene 2003) are related to the intersection points and fixed coefficients between time and between individuals.[8] These possibilities are, first: The coefficient values are fixed but have different intersection points between individuals; second: the coefficient is fixed but the cutoff points are different between time and between individuals; third, all coefficients are not the same between individuals, but the intersection points and coefficients are different between individuals and over time. Therefore, to estimate panel data, 3 (three) possibilities can be used, namely first, the Common Effect Model or CEM which is called a simple linear regression approach (OLS). The model is:

$$y_{it} = \alpha + X'_{it}\beta + \varepsilon_{it} \qquad (1)$$

Second, the Fixed Effect Model (FEM) is a way of estimating panel data parameters using shadow variables to identify differences in intersection points. According to (Greene 2003) the FEM model is:[8]

$$y_{it} = \alpha_i + X'_{it}\beta + \varepsilon_{it} \qquad (2)$$

The index i at the point of intersection αi describes the point of intersection of each individual that is not the same, but the point of intersection for each cross section does not change or is constant (constant). Third, the Random Effect Model (REM) is used to solve the uncertainty problem in FEM. According to (Greene 2003) the REM model is:[8]

$$y_{it} = \alpha + X'_{it}\beta + \mu_i + \varepsilon_{it} \qquad (3)$$

In order to choose the right model, several tests were carried out before determining the estimated model, namely the Chow Test to determine the CEM or FEM model and the Hausman Test to determine the choice of the best estimation model, FEM or REM model. If the conditions in both tests are not met, then the Lagrange Multiplier Test is performed. This test is used to identify the existence of heteroscedasticity of the FEM model. The next step is to determine the criteria for the Goodness of the Model by using the determination (R^2). The greater the value of the coefficient of determination, the better the obtained model will be. Regression parameter testing can be done by simultaneous test and partial test.

2. Research Methodology

This study uses a quantitative method with a descriptive verification approach using secondary data to answer research problems in the form of provincial macroeconomic losses in Indonesia, namely the GRDP indicator (Y_1it). The data used is panel data, namely time series data for 21 years and cross section data from 34 provinces in Indonesia. Data on the number of disasters and the amount of damage to facilities were obtained from BNPB, while the GRDP and number of workers were obtained from BPS.

Data analysis included descriptive analysis for each variable, classical assumption test and panel data regression estimation with 3 (three) approaches, namely the fixed effect model, the common effect model (CEM), and the random effect model (REM). Basuki and Prawoto (2017) provide guidance that selecting an estimation model can be done by means of the Chou Test and Hausman Test. After the estimation model is selected, panel data estimation is performed using OLS. The basic equation used in this study is:

Y_{1it} $= f\,(X_1, X_2, X_3)$

Macroeconomic loss $= \beta 0 + \beta 1 JTKit + \beta 2 KBit + \varepsilon it$

where:

PDRB (Y_{1it})	: Macroeconomic loss
JTK (X_{1it})	: Labor
KB (X_{2it})	: Event of Disaster
KFU (X_{3it})	: Public Facilities
β0	: Constant
β1, β2	: Regression Coefficient
i	: Province
t	: year
ε	: error term

3. Result And Discussion

3.1 Descriptive Analysis

The research found the highest average GRDP values during the period 2001 to 2021 respectively for DKI Jakarta, East Java, West Java and Central Java. The province with the highest average GRDP on the island of Sumatra is Riau, on the island of Kalimantan it is East Kalimantan and South Sulawesi on the island of Sulawesi. In more detail, the average provincial PDRP value in the period 2001 – 2021 is shown in Figure 1 below:

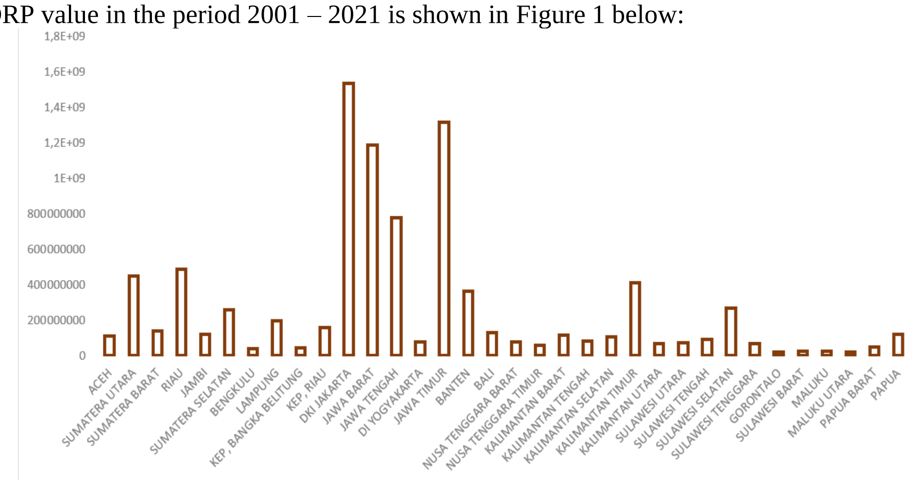

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Figure 1. Provincial GRDP (average) in 2001 - 2021

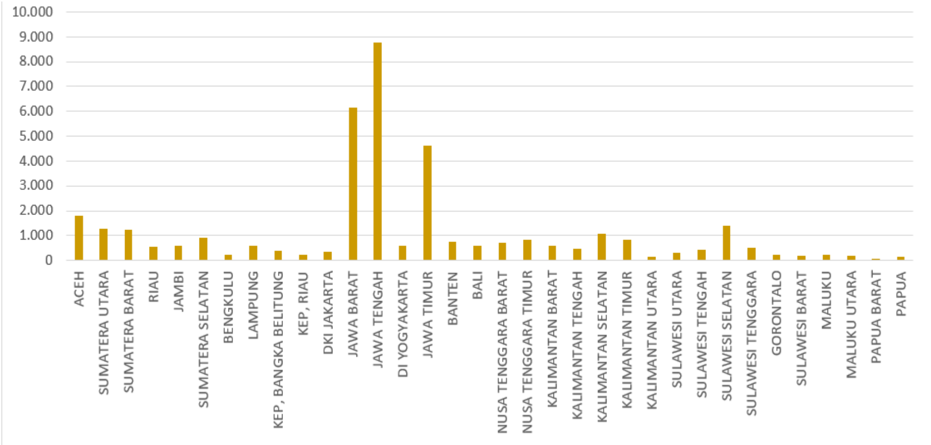

Figure 2. Number of Disaster Events in 2001 - 2022

Figure 2. above shows disaster events in each province during the period 2001 – 2021. The highest number of disaster events occurred in Central Java, followed by West Java and East Java. The highest number of disasters on the island of Sumatra occurred in Aceh and on the island of Sulawesi was South Sulawesi.

3.2 Relations between Variables

The resulting calculation of the correlation value of the independent variable and the dependent variable can be seen in the following table.

Table 1. Correlation between variables

	GRDP	Number of workers	Number of workers
Total workforce	0.355		
Disaster incident	0.284	0.019*	
Public facilities	0.162	0.026*	0.103*

**Signifikan pada α =1%*

The table above shows that all variables have a positive and significant correlation with GRDP at α = 1%.

3.3 Classic assumption test

Multicollinearity testing is carried out to detect the presence or absence of multicollinearity cases or a linear relationship between independent variables, namely, the number of disasters, the number of workers and the number of damaged facilities. The test results are shown in the following table.

Table 2. Multicollinearity Test

	PDRB
Total workforce	1.010
Disaster incident	1.106
Public facilities	1.096

The table above shows that the VIF value in the GRDP model (Y_1it) is not greater than 5, so that it can be said that there is no multicollinearity in the model studied. The next classic assumption test is the normality test. The data normality test in this study used the Kolmogorov Smirnov test. The test results are shown in the following table.

Table 3. Normality Test Using Kolmogorov Smirnov

Model	**D**	***P-value***	**Decision**
$In\ (Y_{1it})$ or GRDP elasticity	0,181	0,058	Accept H_o/fail to reject H_0

The table above shows a D value of 0.181 (18.1 percent) describing GRDP elasticity (In 〖(Y〗 _1it) has a probability value (p-value) of 0.058 > 0.05. This value means that the residual GRDP elasticity model in Indonesia has meets the normal distribution assumption. The next classical assumption test is the heteroscedasticity test with the Glejser Test and obtains the following results.

Table 4. Heteroscedasticity Test (Glejser)

Model	F_{hitung}	F_{tabel}	$P\text{-}value$	Decision
$In\ (Y_{1it})$ or GRDP elasticity	0,840	3,179	0,437	Accept H_o/fail to reject H_0

In the table above it can be seen that the F_count residual value of the GRDP elasticity model is smaller than F_table and this means that there is not enough evidence to reject Ho. This condition means that the residual model in Indonesia has fulfilled identical assumptions. Durbin Watson's autocorrelation test obtained the following results.

Table 5. Autocorrelation Test (Durbin Watson)

No	**Province**	**d**	D_L	D_U	**Decision**
1	Aceh	0,0033	0,6102	1,4002	Reject H_0
2	Bali	0,5786	0,6102	1,4002	Reject H_0
3	Banten	0,1514	0,6102	1,4002	Reject H_0
4	Bengkulu	0,1514	0,6102	1,4002	Reject H_0
5	Special Region of Yogyakarta	0,6657	0,6102	1,4002	Reject H_0
6	Jakarta Capital Special Region	0,0186	0,6102	1,4002	Reject H_0
7	Gorontalo	1,0223	0,6102	1,4002	Reject H_0
8	Jambi	0,6657	0,6102	1,4002	Reject H_0
9	West Java	0,0409	0,6102	1,4002	Reject H_0
10	Central Java	1,0223	0,6102	1,4002	Reject H_0
11	East Java	0,6336	0,6102	1,4002	Reject H_0
12	West Kalimantan	0,0409	0,6102	1,4002	Reject H_0
13	South Kalimantan	0,6657	0,6102	1,4002	Reject H_0
14	Central Kalimantan	1,0223	0,6102	1,4002	Reject H_0
15	East Kalimantan	0,6336	0,6102	1,4002	Reject H_0
16	North Kalimantan	0,0033	0,6102	1,4002	Reject H_0
17	Bangka Belitung Islands	0,0429	0,6102	1,4002	Reject H_0
18	Riau islands	0,0033	0,6102	1,4002	Reject H_0
19	Lampung	0,5786	0,6102	1,4002	Reject H_0
20	Maluku	0,6336	0,6102	1,4002	Reject H_0
21	North Maluku	0,1514	0,6102	1,4002	Reject H_0

No	Province	d	D_L	D_U	Decision
22	West Nusa Tenggara	0,0033	0,6102	1,4002	Reject H_0
23	East Nusa Tenggara	0,0186	0,6102	1,4002	Reject H_0
24	Papuan	0,0429	0,6102	1,4002	Reject H_0
25	West Papua	0,5786	0,6102	1,4002	Reject H_0
26	Riau	1,0223	0,6102	1,4002	Reject H_0
27	West Sulawesi	0,6657	0,6102	1,4002	Reject H_0
28	South Sulawesi	0,0186	0,6102	1,4002	Reject H_0
29	Central Sulawesi	0,0033	0,6102	1,4002	Reject H_0
30	Southeast Sulawesi	0,0409	0,6102	1,4002	Reject H_0
31	North Sulawesi	0,0186	0,6102	1,4002	Reject H_0
32	West Sumatra	0,0409	0,6102	1,4002	Reject H_0
33	South Sumatra	0,6336	0,6102	1,4002	Reject H_0
34	North Sumatra	0,0186	0,6102	1,4002	Reject H_0

3.4 Panel Data Regression Model Estimation Test

Determination of the model for panel regression to analyze economic losses caused by natural disasters using the Chow test, Hausman test and Lagrange Multiplier test. The estimated panel regression model is GRDP (Y_1it) and GRDP elasticity (In(Y_1it) Table 6. The following describes the results of the Chow test and Table 7 explains the results of the Hausman test.

Table 6. Chow Test

Model	F_{count}	F_{tabel}	*P-value*	Decision
GRDP(Y_1it) between individuals	86,993	2,157	0,0000	Reject H_0
GRDP 〖(Y〗_1it) over time	0,117	2,413	0,9880	Accept H_0
GRDP elasticity or In(Y_1it) between individuals	241,837	2,163	0,0000	Reject H_0
GRDP elasticity or In(Y_1it) over time	0,475	2,417	0,7931	Accept H_0

The table above shows that F_count has a greater value than F_table. Thus there is not enough evidence to accept the H_0 hypothesis for the model Y_(1it) and In(Y_1it) or H_0 is rejected. That is, the individual component of the selected estimation model is FEM. For the intertemporal component, the test results show that the calculated F_value is smaller than that of F_table so that H_0 in the intertemporal GRDP model and the GRDP elasticity model fail to be rejected or H_0 is accepted. These results indicate that the correct estimation model for the time component is CEM.

Table 7. Hausman Test

Model	Coefficient	X^2_{tabel}	*P-value*	Decision
GRDP (Y_1it) between individuals	0,705	3,8415	0,4010	Accept H_o/fail to reject H_0
GRDP elasticity or In(Y_1it) over time	2,024	5,9915	0,3634	Accept H_o/fail to reject H_0

The p value is in Table 7. In the inter-individual GRDP model (Y_1it between individuals) and the inter-time GRDP elasticity model (In(Y_1it) between time) is greater than 0.05 as a result H_0 fails to be rejected or H_0 is accepted, so that the estimation model is correct is REM. The results of this test also mean that the Lagrange Multiplier test is not necessary.

Determination of the appropriate model for each region is done by comparing the value of the coefficient of determination (R^2) below.

Table 8. Comparison of the value of the coefficient of determination (R^2)

Model	R^2
GRDP(Y_1it) between individuals	21,68%**
GRDP 〖(Y〗_1it) over time	2,20%*
GRDP elasticity or In(Y_1it) between individuals	68,61%**
GRDP elasticity or In(Y_1it) over time	10,20%*

The table above shows the coefficient of determination (R^2) in the inter-individual GRDP model and the inter-individual GRDP elasticity model has a larger percentage than the coefficient of determination of GRDP and GDP elasticity over time.

Based on several tests that have been carried out, the estimated panel regression obtained is:

$$\text{PDRB} = \alpha\, 0i + 0{,}0056 \text{ workforce} + 0{,}0078 \text{ Disaster Event}$$

The In(Y_1it) model in the GRDP equation with a coefficient of determination of 68.61 percent is shown in Table 8. This value means that the ability of the number of workers and the number of disaster events to explain changes in the GRDP value is 68.38% and the rest (31, 38%) is the contribution of other variables.

The next step is to test the significance of the regression model parameters. Test the significance of the regression model parameters include simultaneous tests and partial tests. Table 9, is the result of the simultaneous test, where the F_count obtained is 55.7452. This value is greater than F_table=F (0.05:(1.52))=4.027. This means that the GRDP elasticity model is acceptable.

Table 9. Estimation of Model Test

Fitness of Model	$GRDP\ Elasticity$
The coefficient of determination	0,6861
Adjusted coefficient of determination	0,6738
F count	55,7452
Probability value	0,0000

The partial test results for the GRDP elasticity model or In y_{1it} are as follows:

Table 10. GRDP Elasticity Model Estimation ($In\ (y_{1it})$)

Variable	coefficient	Standard Error	t_{count}	*P-value*
C (GRDP)	7,6876	0,2864	26,8393	0,0000
X_1	0,0056	0,0006	8,78087	0,0000
X_2	0,0078	0,0025	3,08106	0,0033

Based on the table above, the value t_table=t_(0.025:52)=2.007 is obtained. The GRDP variables, the number of workers and the number of disaster events have t_count no less than t_table, as well as a p-value that is less than 0.05, meaning that the number of workers and the number of disaster events significantly affect GRDP. This means that if the number of disaster events and the number of workers in a province increases, the total GRDP of that province will increase, in other words, the GRDP of a province will increase as there is an increase in the number of workers and disasters.

4. Conclusions And Recommendations

The number of disaster events, the number of workers and the amount of damage to public facilities are significantly related to the GRDP Value (Y_it) in 34 Provinces in Indonesia. The selected panel regression model for provincial GRDP in Indonesia is REM. Labor and disaster events have a significant influence on increasing GRDP. This study has limitations because it only uses one macroeconomic indicator, namely GRDP, so for future research it is suggested to add other macroeconomic indicators such as inflation and employment opportunities.

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