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Natural Disasters and Economic Growth in Indonesia

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Abstract

Natural disasters can have a profound impact on a country's economic growth, making it crucial for policymakers to understand the relationship between natural disasters and economic growth in order to develop effective strategies that mitigate adverse effects and promote sustainable development. The study utilizes secondary data spanning from 1990 to 2021 and employs the Fully-Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), Canonical Co-Integrating Regression (CCR), and Vector Error Correction Model (VECM) methods. The study's findings provide valuable insights into the substantial effects of natural disasters on economic growth, indicating a positive long-term impact. Furthermore, the analysis highlights a unidirectional causality, illustrating the notable influence of natural disasters on the country's economic performance. Policymakers should prioritize investments in upgrading and retrofitting infrastructure, focusing on key sectors like transportation, energy, water, and telecommunications, to mitigate the adverse effects of natural disasters and promote sustainable economic growth.

1. Introduction

Natural disasters such as hurricanes, earthquakes, floods, and wildfires can cause extensive damage to infrastructure, property, and industries. This can lead to a decline in economic output as businesses are interrupted, production facilities are damaged or destroyed, and transportation systems are disrupted [1–3]. A disaster refers to a sudden reduction in the availability of factors of production, such as capital and labor. In response, the economic system undergoes adjustments, which can involve either transitioning to a new equilibrium or reverting back to the equilibrium that existed before the disasters occurred [4].

The immediate consequences of natural disasters are apparent in the short term [5–9], and some of these effects can have lasting implications. For instance, financial crises triggered by disasters can impede long-term economic growth due to inflationary pressures. Moreover, natural disasters can have psychological impacts on affected individuals, potentially reducing their productivity. Additionally, the introduction of new technologies for disaster warning and detection can influence the returns on investments in physical capital, thus impacting the accumulation of such capital [10–15].

However, in rare cases, there can be instances where natural disasters lead to positive effects on economic growth [16], particularly in scenarios where this occurs through reconstruction and infrastructure development. After a major natural disaster, significant resources are often allocated to rebuild and develop infrastructure [17, 18]. This can involve constructing new buildings, roads, bridges, and utilities, among other things. The influx of investment and spending in these reconstruction efforts can stimulate economic activity, create jobs, and contribute to long-term economic growth [19, 20].

Indonesia is a country that is susceptible to a wide range of natural disasters due to its geographical location and geological characteristics [21]. Indonesia's susceptibility to frequent earthquakes and its highest number of active volcanoes worldwide are due to its location on the Pacific Ring of Fire. Moreover, heavy rainfall and tropical storms can cause substantial flooding, especially in low-lying regions. Lastly, Indonesia's mountainous topography and abundant rainfall increase the likelihood of landslides occurring. The impact of these natural disasters has the potential to disrupt national economic growth [22, 23].

The primary aim of this study is to address the research gap in the literature by examining the long-term relationship between natural disasters and economic growth in Indonesia. Previous research conducted in Indonesia includes studies such as analysis of the trend of disasters and the governance of disaster risk management [21], the influence of disaster events on the progress of tourism development [23], and identification of the potential engagement in natural disaster insurance through the utilization of a nationwide socio-economic survey [22].

This study aims to provide empirical evidence and support policymakers in anticipating potential disruptions from natural disasters in crucial sectors of the national economy, including agriculture, manufacturing, and infrastructure. By doing so, policymakers can develop effective contingency plans to minimize economic losses and ensure the stability of long-term economic growth.

This research is structured as follows: In section 2, the study provides an overview of the database utilized and offers explanations of various econometric techniques employed. Section 3 presents the empirical findings in detail and engages in a comprehensive discussion of the results. Lastly, section 4 presents the research's conclusions and recommendations.

2. Materials and Methods

This study uses annual time-series data from 1990 to 2021. Economic growth (GDP) is measured in constant 2015 US dollars, while the number of people affected quantifies natural disasters (ND). Capital (K), which stands for Gross Fixed Capital Formation, is measured in constant 2015 US dollars, and Labor (L) includes both the employed and unemployed individuals seeking work. The data on economic growth, capital, and labor were obtained from the World Development Indicators (WDI), while data on natural disasters were sourced from the OurWorldInData (OWID) website. To address potential heteroscedasticity, all data were transformed using natural logarithm. Figure 1 illustrates the GDP, ND, K, and L trends over time.

2.1 Fully-Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS) and Canonical Co-Integrating Regression (CCR) methods

The subsequent step involves estimating the long-run parameters. Although co-integration tests ascertain the existence of a long-term relationship, they do not facilitate the exploration of long-run elasticity estimates. Therefore, it becomes imperative to examine the long-run equilibrium relationship between the variables using FMOLS (Fully Modified Ordinary Least Squares), DOLS (Dynamic Ordinary Least Squares), and Canonical Co-Integrating Regression (CCR) analyses, along with Ordinary Least Square (OLS) and Robust Least Square (RLS) methods. These advanced methods effectively address issues such as the serial correlation of long-term execution and endogeneity problems, thereby ensuring consistent and reliable estimates based on the selected samples.

To measure the relationship between GDP and the main explanatory variables, this paper describes GDP as a function of capital, labor, and natural disaster. Therefore, the GDP function can be presented as:

$$\mathrm{GDP_t} = f(\mathrm{K_t}, \mathrm{L_t}, \mathrm{ND_t}) \quad (1)$$

where GDP is the gross domestic product, K is the capital, L is the labor, and ND is the natural disaster.

Furthermore, the econometric model representing the relationship is given in equations 2.

$$\mathrm{LnGDP_t} = \beta_0 + \beta_1 \mathrm{LnK_t} + \beta_2 \mathrm{LnL_t} + \beta_3 \mathrm{LnND_t} + \varepsilon_t \quad (2)$$

Where β_0 is an intercept, β_1, β_2, β_3 are the coefficients, ε represents the error term.

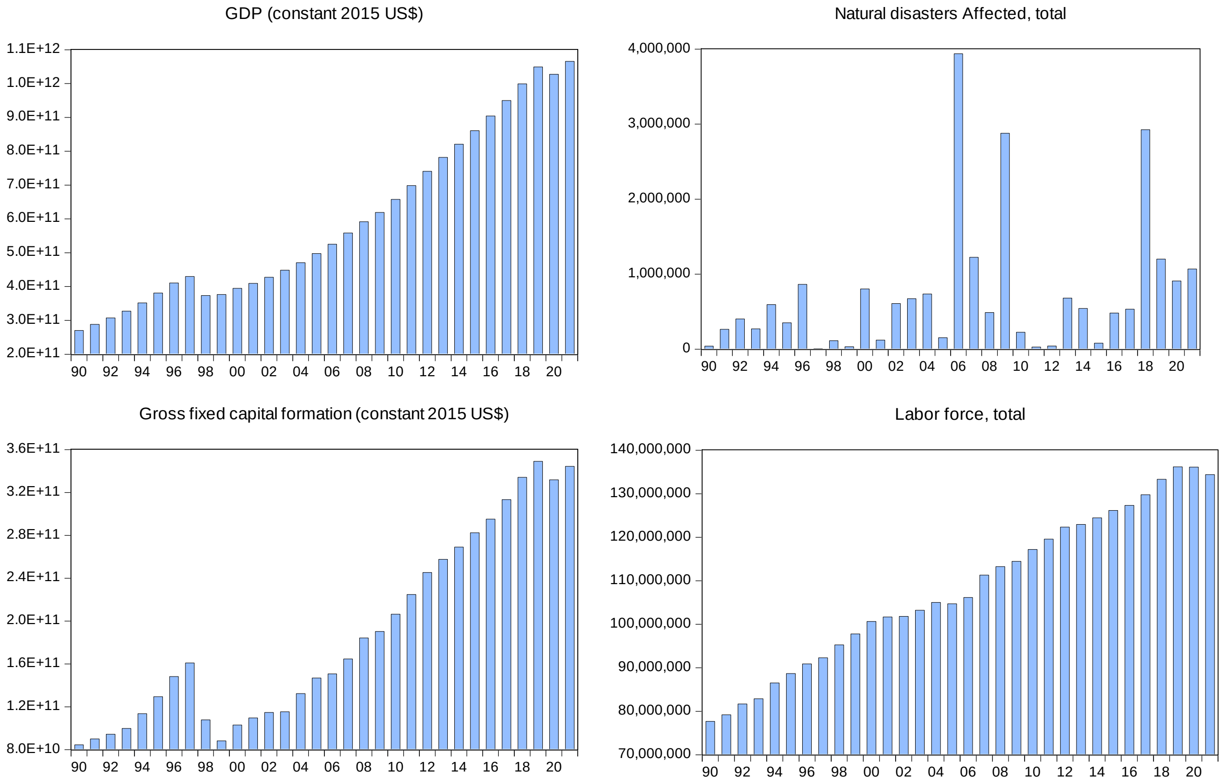

Figure 1. Data variables.

2.2 Vector Error Correction Model (VECM) Causality

In order to examine the lasting balance and dynamic interactions between economic growth, natural disasters, capital, and labor in Indonesia, this research employs the vector error correction model (VECM). Since most of the time series data are non-stationary, a direct regression approach would result in a "pseudo-regression." The concept of cointegration is introduced to address this problem, indicating the presence of a stable, long-term relationship between economic variables [24]. The analysis of multivariate models was further extended to include unit root tests, leading to the formal proposition of the VECM model. The VECM model is widely used to investigate the long-term and short-term equilibrium connections involving cointegrated variables [25]. If the variables are found to be cointegrated in this study, the equations for the VECM model is shown in equations 3-6.

$$\Delta lnGDP_t = \beta_0 + \sum_{i=1}^{k}(\beta_{1i}\Delta lnGDP_{t-i} + \beta_{2i}\Delta lnK_{t-i} + \beta_{3i}\Delta lnL_{t-i} + \beta_{4i}\Delta lnND_{t-i}) + \lambda_1 ECT_{t-1} + \upsilon_t \quad (3)$$

$$\Delta lnK_t = \alpha_0 + \sum_{i=1}^{k}(\alpha_{1i}\Delta lnK_{t-i} + \alpha_{2i}\Delta lnGDP_{t-i} + \alpha_{3i}\Delta lnL_{t-i} + \alpha_{4i}\Delta lnND_{t-i}) + \lambda_2 ECT_{t-1} + \upsilon_{2t} \quad (4)$$

$$\Delta lnL_t = \delta_0 + \sum_{i=1}^{k}(\delta_{1i}\Delta lnL_{t-i} + \delta_{2i}\Delta lnGDP_{t-i} + \delta_{3i}\Delta lnK_{t-i} + \delta_{4i}\Delta lnND_{t-i}) + \lambda_3 ECT_{t-1} + \upsilon_{3t} \quad (5)$$

$$\Delta lnND_t = \theta_0 + \sum_{i=1}^{k}(\theta_{1i}\Delta lnND_{t-i} + \theta_{2i}\Delta lnGDP_{t-i} + \theta_{3i}\Delta lnK_{t-i} + \theta_{4i}\Delta lnL_{t-i}) + \lambda_4 ECT_{t-1} + \upsilon_{4t} \quad (6)$$

In this context, β, α, δ, and θ represent coefficients in each model, Δ represents the first difference, and k is the ideal lag length determined by the Akaike Information Criteria (AIC). We examine short-run and long-run causality using equations (3-6). Uncertainty variables are combined to assess their overall association in both the short and long run using the vector error correction model ECT_{t-1}.

3. Results and Discussion

Before delving into the regression results, several tests need to be conducted, including the unit root test, lag optimum test, and cointegration test. First, we present the outcomes of the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests in Table 1, which indicate that the variables are non-stationary at levels but become stationary in the first difference.

Table 1. Results of ADF and PP unit root test

Variable	ADF Statistical Value		PP Statistical Value	
	Level	1st Difference	Level	1st Difference
lnGDP	0.8741	0.0032	0.8741	0.0037
lnK	0.9127	0.0009	0.8662	0.0072
lnL	0.1008	0.0300	0.0103	0.0163
lnND	0.0009	0.0000	0.0010	0.0001

Table 2. VAR Lag Order Selection Criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	39.28686	NA	1.12e-06	-2.352457	-2.165631	-2.292690
1	159.3394	200.0875	1.10e-09	-9.289291	-8.355159*	-8.990454
2	183.5312	33.86861*	6.79e-10*	-9.835415*	-8.153978	-9.297509*

Note: * indicates lag order selected by the criterion

Table 3. Results of the Johansen cointegration test.

Null Hypothesis	Trace Statistic	5% Critical Value	Prob.**	Max-Eigen Statistic	5% Critical Value	Prob.**
R = 0	48.43324	47.85613	0.0441*	30.15738	27.58434	0.0228*
R ≤ 1	18.27586	29.79707	0.5457	11.06085	21.13162	0.6413
R ≤ 2	7.215017	15.49471	0.5528	6.585779	14.26460	0.5392
R ≤ 3	0.629238	3.841466	0.4276	0.629238	3.841466	0.4276

Consequently, proceeding with the cointegration test is feasible.

Selecting the appropriate lag length for the Vector Autoregressive Model (VAR) is a complex undertaking, demanding precision, as the inclusion of lags in time series models directly influences the estimation process. In this case, the Akaike Information Criterion (AIC) method recommends using lag 2 (refer to Table 2).

The cointegration test suggests that the variables move together in the long run. Table 3 presents the results of the Johansen cointegration test, indicating a significant long-term relationship among the studied variables as all null hypotheses are rejected. Additionally, both the Trace test and the Max-eigenvalue test suggest the presence of 1 cointegrating equation at the 0.05 significance level (* denotes rejection of the hypothesis at the 0.05 level).

3.1 Results of FMOLS, DOLS, and CCR Estimation

Table 4 presents the results of the dynamic approach using FMOLS, DOLS, and CCR methods alongside a comparison with the static approach of OLS and RLS outcomes for the GDP model. The findings reveal that natural disasters have a significant long-term impact on GDP.

The OLS and RLS results in Table 4 demonstrate similar findings regarding the impact of capital and labor on economic growth, with both variables showing a significant influence. In the OLS estimation, a 1% increase in capital and labor leads to a GDP increase of approximately 0.4818% and 1.1809%, respectively. Similarly, in the RLS estimation, a 1% increase in capital and labor leads to a GDP increase of around 0.4922% and 1.1532%, respectively. However, natural disasters do not show significance in the OLS estimation, whereas in the RLS estimation, they have a positive impact at a 10% significance level. Specifically, a 1% increase in natural disasters results in a GDP increase of approximately 0.0059%.

Based on the FMOLS, DOLS, and CCR approaches presented in Table 4, it is evident that capital has a positive and significant impact on GDP. A 1% increase in capital leads to an approximate increase in GDP by 0.5097%, 0.5541%, and 0.5101% according to the FMOLS, DOLS, and CCR methods, respectively. Similarly, labor also demonstrates a positive and significant effect on GDP. A 1% increase in labor contributes to an increase in GDP by approximately 1.1166%, 0.9538%, and 1.1157% according to the respective approaches.

Furthermore, this study surprisingly finds a positive impact of natural disasters on GDP. A 1% increase in natural disasters leads to an approximate increase in GDP by 0.0062%, 0.0124%, and 0.0079% according to the FMOLS, DOLS, and CCR methods, respectively. It is worth noting that previous research has also found that droughts, floods, and storms have a positive long-term

Table 4. Results of OLS, RLS, FMOLS, DOLS, and CCR estimation.

Variable	Dependent Variable : GDP				
	OLS	**RLS**	**FMOLS**	**DOLS**	**CCR**
lnK	0.4818 (19.5561)*	0.4922 (19.3318)*	0.5097 (20.5129)*	0.5541 (27.7922)*	0.5101 (20.8290)*
lnL	1.1809 (17.1840)*	1.1532 (16.2387)*	1.1166 (15.8124)*	0.9538 (15.1953)*	1.1157 (16.4865)*
lnND	0.0050 (1.5586)	0.0059 (1.7914)***	0.0062 (1.9140)***	0.0124 (3.2173)*	0.0079 (1.7791)***
C	-7.3265 (-10.0829)*	-7.0948 (-9.4488)*	-6.8716 (-9.0200)*	-5.0566 (-7.2583)*	-6.8854 (-9.6875)*
R-squared	0.9967	0.8920	0.9962	0.9993	0.9961
Adjusted R-squared	0.9963	0.9971	0.9958	0.9989	0.9957

Note: *, ** and *** represent 1%, 5% and 10% level of significance.

Table 5. Results of multivariate 'VECM' causality.

Dependent Variable	Independent Variable (Lag Length Criteria=2)				
	(F-statistics)				**[t-statistics]**
	ΔGDP	ΔK	ΔL	ΔND	ECT_{t-1}
ΔGDP	-	76.7714*	1.3800	2.7193***	0.38877**
		(0.0000)	(0.2828)	(0.0769)	[2.4523]
ΔK	84.6173*	-	2.0967	1.7241	0.5182**
	(0.0000)		(0.1386)	(0.1999)	[2.8025]
ΔL	5.4974*	6.5692*	-	0.1285	0.37357*
	(0.0080)	(0.0038)		(0.9418)	[2.9133]
ΔND	0.9436	1.4087	0.6393	-	0.9076*
	(0.4415)	(0.2746)	(0.6000)		[3.8782]

Note: *, ** and *** represent 1%, 5% and 10% level of significance.

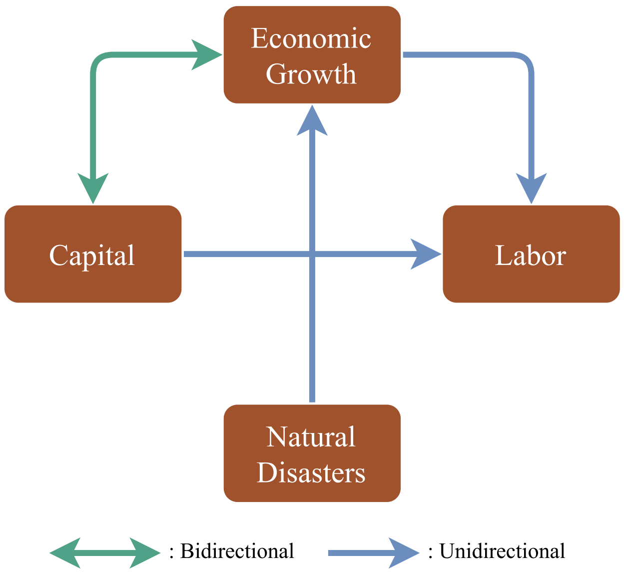

Figure 2. Overview of the results from Multivariate VECM causality.

contribution to economic growth [20]. Specifically, a previous study shows that floods, as a natural disaster, have positive effects on long-term economic growth [19].

Economic models suggest that growth can potentially accelerate in disaster-affected areas following a negative shock. This is primarily attributed to post-disaster reconstruction efforts, which lead to increased investments and long-term productivity effects on the economy [17, 18, 26].

3.2 Results of Multivariate 'VECM' Causality

Afterwards, we conducted the Granger causality test to examine the causal relationships among the variables using the VECM approach. The test categorizes the causality direction into unidirectional and bidirectional causality, and the results are presented in Table 5. The outcomes indicate that the coefficients of the Error Correction Term (ECT) in the equations for GDP, K, L, and ND are statistically significant, suggesting that these variables have a significant impact on the long-run equilibrium.

Figure 2 demonstrates bidirectional causality between economic growth and capital, indicates that higher economic growth leads to increased capital, and conversely, higher capital results in higher economic growth [27–30]. Additionally, unidirectional causality was found from capital to labor, from economic growth to labor, and from natural disasters to economic growth.

The presence of unidirectional causality running from natural disasters to economic growth in this study is supported by similar findings in other countries prone to natural disasters, such as Pakistan [31], Philippines [32], and India [33]. Furthermore, previous studies conducted in developing countries have found unidirectional causality from natural disasters to GDP per capita, while this relationship is not observed in developed countries [34].

4. Conclusions and Recommendations

Based on the findings obtained from the dynamic approach, the empirical analysis provides compelling evidence of the relationship between natural disasters and economic growth, including a unidirectional causality from natural disasters to economic growth. While natural disasters are commonly associated with negative impacts on economic growth, this study reveals that they can also have positive effects, particularly in the long term. This is attributed to the significant resources allocated for infrastructure rebuilding and development following major natural disasters.

Our suggestions involve prioritizing investments in disaster risk reduction measures by governments to minimize the adverse effects of natural disasters on economic growth. This includes upgrading infrastructure to enhance resilience against natural disasters by implementing measures such as reinforcing structures, improving early warning systems, and enhancing emergency response capabilities. Moreover, it is recommended that individuals and businesses be encouraged to obtain comprehensive insurance coverage against natural disasters. This can provide long-term financial protection and help alleviate the economic impact on affected individuals, communities, and businesses.

In summary, the study highlights the complex relationship between natural disasters and economic growth. While natural disasters are commonly associated with negative effects, their aftermath presents opportunities for economic recovery and long-term growth. By prioritizing investments in disaster risk reduction, upgrading infrastructure resilience, and promoting comprehensive insurance coverage, governments can effectively minimize the negative impact of natural disasters and foster sustainable economic growth.

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