

The Effect of Natural Disasters at the Rural Level on Economic Growth: Evidence from Indonesia

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Abstract

This study examines the effect of natural disasters on economic growth using annual village potential data (PODES) from 33 provinces in Indonesia. Several panel data models, namely Fixed Effect, Random Effect, Robust Fixed Effect, and Generalized Method of Moments (GMM), were tested to ensure robustness. The Robust fixed-effect model was ultimately selected as the most appropriate specification. The result finds that natural disasters, along with government spending on capital, labor, and technology, have a positive effect on economic growth. However, capital depreciation does not show a statistically significant impact. Among all provinces, East Nusa Tenggara consistently recorded the highest proportion of disaster-affected villages from 2011 to 2017. These findings suggest the importance of enhancing disaster mitigation policies to reduce the intensity and coverage of disaster impacts on rural development.

Keywords: Economic Growth, Fixed Effect Model, Natural Disaster.

JEL classification: O44, Q54

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1. INTRODUCTION

A natural disaster is an unexpected condition that reduces economic development and destroys a region's physical capital, infrastructure, and economic growth. Economic growth will decline for some time, and then it will adjust according to the conditions of a country. Some research shows the effect of natural disasters on economic growth in developed and developing countries (see Albuquerque & Rajhi, 2019; Onuma et al., 2020; Panwar & Sen, 2019; Seruyange & Klomp, 2021; Strobl, 2012). Some analysts argue natural disasters favour the economy (Albala-Bertrand, 1993; Skidmore & Toya, 2002). Others argue that natural

disaster harms the economy (Cavallo et al., 2013; Loayza et al., 2009; Noy, 2009; Raddatz, 2007), yet they do not provide a definitive conclusion on the association between natural disasters and economic growth (see Cavallo et al., 2013; Fisker, 2012).

Indonesia must deal with its natural conditions as a country prone to natural disasters. According to Gasparini, Manfredi, and Zschau (2007), Indonesia is located at the confluence of four tectonic plates, namely the Asian Continent plate, the Australian Continent plate, the Indian Ocean plate, and the Pacific Ocean plate, Indonesia is very potential and prone to natural disasters, such as volcanic eruptions, earthquakes, tsunamis, floods, and landslides. Also, the ring of the fire area stretches from the islands of Sumatra, Java, and Nusa Tenggara to Sulawesi, with a topography of old volcanic mountains and lowlands dominated by swamps, doubling the risk of disaster. These natural hazards often strike densely populated and economically active regions, particularly rural areas where livelihoods depend heavily on agriculture and natural resources.

In this context, natural disasters pose a significant challenge to economic development. They cause direct damage to infrastructure and assets, disrupt economic activity, displace populations, and increase the fiscal burden on governments. While Indonesia has made progress in disaster risk reduction and mitigation efforts, the economic impact of these disasters—especially at the subnational and rural levels—remains understudied. Most existing studies on the economic consequences of natural disasters tend to focus on national-level aggregates, specific catastrophic events, or use limited cross-sectional data. As a result, the spatial and temporal dynamics of disaster impacts on local economic growth are often overlooked.

Several researchers have studied the impact of natural disasters on the economy. Based on the study from Ahlerup (2013), natural disasters have a favorable relationship with future economic success on average. The experience of democratic emerging nations is driving this overall complementary connection. The general positive connection between natural disasters and economic performance appears to be caused by good acts in democratic developing countries that have received humanitarian help. Fischer (2021) also found a statistically significant positive association between the geographical lag of natural disasters and the change in the initial difference of the natural logarithm of GDP per capita. Post-disaster transfer payments are proven to increase the negative impact of disasters on China's economic growth. As a result, Xu and Mo (2013) proposed getting relief toward creating work incentives to prevent a lowering effect on economic development. According to Dzator et al. (2021), the impact of natural disasters on the economy depends on the type of natural disaster and the period of occurrence.

According to typical neoclassical development models, natural disasters are unlikely to impact the rate of technological progress. However, they may enhance short-run economic growth, partly because they pull countries away from their steady-state levels of macroeconomic objectives. Unlike neoclassical growth models, endogenous growth models advocate a radical perspective that natural disasters can stimulate economic growth by acting as catalysts for reinvestment and improving capital stock productivity (see Caballero & Hammour, 1994; Schumpeter, 1942). According to Barro and Jong-Wha Lee (1993), most

macroeconomic parameters are favourably associated with growth and adversely associated with catastrophe risks: disasters reduce investment and increase government spending. They also raise the black-market premium on foreign exchange and the frequency of revolutions.

Skidmore and Toya (2002) discovered that climatic disasters benefit economic growth, whereas geological occurrences do not affect them. They found a partially direct association between the frequency of climatic disasters and total factor productivity growth in 89 developed and developing countries. The findings for geological disasters show no substantial impact on total factor productivity growth. Skidmore and Toya (2002) made the most significant contribution to the literature on the economics of natural disasters by directly assessing the relationship between foreign technology absorption and catastrophic events. According to their research, natural disasters update capital stock and drive new technologies, leading to higher TFP and GDP growth. After controlling for essential drivers, the frequency of climatic disasters has a positive relationship with TFP growth, human capital accumulation, and GDP per capita growth. One of the explanations for this correlation could be the adoption of new technology when natural disasters damage a country's capital stock, and the economic incentives replace it with more advanced technology. In other words, natural calamities may present opportunities to improve capital stock, leading to better rates of TFP and GDP per capita growth. Such explanations are an excellent illustration of Schumpeterian creative destruction (see Schumpeter, 1942). To our knowledge, Skidmore and Toya (2002) provided the most extensive empirical research on evaluating the direct long-run impacts of natural catastrophes on economies.

Others argue that disaster harms the economy (Cavallo et al., 2013; Loayza et al., 2009; Noy, 2009; Raddatz, 2007). Meanwhile, according to An and Park (2019), developing countries face significant challenges in paying post-disaster recovery expenses compared to industrialized countries. Foreign aid from the international community enhances accessibility and may accelerate post-disaster rehabilitation in recipient nations. According to McDermott et al. (2014), natural disasters have long-term detrimental consequences on economic growth in nations with low levels of financial sector development. The government may encourage policymakers to investigate the efficacy of feasible ex-ante catastrophe risk funding methods, particularly in developing countries. Cavallo et al. (2013), Noy (2009), Panwar and Sen (2019), and Raddatz (2007) also make arguments for the negative consequences of natural disasters on economic growth.

However, Noy (2009) discovered adverse effects only for low-income or developing countries and lasted for only a short time. Cavallo et al. (2010) and Raddatz (2007) found that only climatic and humanitarian disasters harm economic growth. Furthermore, the empirical growth studies do not provide a definitive conclusion on the association between natural disasters and economic growth (see Cavallo et al., 2013; Fisker, 2012). Guo et al. (2015) discovered that natural disasters do not significantly influence economic development. Thus, in managing recoveries, human capital reinvestment should be the goal, which is used to restore the local economy based on long-term sustainable growth.

This paper investigates the economic consequences of natural disasters at the subnational level in Indonesia by addressing two core questions: (1) to what extent do natural

disasters influence economic growth, and (2) which provinces are most frequently affected by natural disasters, including the proportion of disaster-affected villages within each province. These questions are explored using the Village Potential Statistics (Potensi Desa/PODES) from 33 Indonesian provinces, which provide a uniquely granular dataset. Unlike most national-level disaster data, PODES offers information at the **village level**, allowing for provincial aggregation while preserving local-level variation. This feature has rarely been utilized in economic analyses of disaster impacts. PODES 2014 covered natural disasters from 2011 to 2013, and PODES 2018 covered natural disasters from 2015 to 2017. The data are presented at a provincial level and aggregated from the data at the village level, which is the uniqueness of PODES data. Despite the richness of this dataset, previous literature has not leveraged PODES to examine the relationship between natural disasters and economic outcomes, particularly in the rural context. This highlights a notable gap in disaster economics and regional development literature, where the impacts of disasters are often studied using national macroeconomic indicators or case studies rather than structured panel data with local disaggregation.

This study assumes that natural disasters tend to positively influence economic growth through the destruction of infrastructure, reduction in labor productivity, and disruptions in capital formation in the long run. To empirically test this hypothesis, we employ static and dynamic panel data models, including the Generalized Method of Moments (GMM) estimator, to account for potential endogeneity and omitted variable bias. In addition, we perform a series of robustness checks to validate the consistency and reliability of our findings. In doing so, this study contributes methodologically and fills an empirical gap in understanding how natural shocks shape regional growth trajectories in a disaster-prone country like Indonesia.

These research findings indicate that the fixed effect model best fits the data. Based on robust estimation techniques, the analysis reveals that the disaster variable also demonstrates a positive association with economic growth. Additionally, government expenditures on capital, labor, and technology, which are proxied by household cellular phone ownership, significantly impact economic growth. Our study makes two contributions. The first contribution in terms of policy implications, namely, the importance of increasing the policy of government spending on capital expenditure, for the first point, and the second point is that human resource investment is essential in driving economic improvement. Third is increasing the mitigation policy on disasters to reduce the impact of a disaster in terms of the number and area coverage. The province whose villages are affected by the disaster yearly is East Nusa Tenggara. This information is essential to increase the mitigation policy on disasters and reduce the impact of disasters in terms of the number and area coverage.

The second contribution of our study is to the Indonesia-specific literature on disasters and economics. This paper contributes to the literature by investigating the disaster's effect on economic growth in Indonesia using the PODES database. The original data are represented at the village level to meet another variable: the aggregated provincial data. To our knowledge, no previous study in Indonesia has utilized the PODES database to construct the disaster data. It brings new findings to the context of Indonesia.

For further research, it should cover (i) the data that represent the district level and employ comprehensive series data, and (ii) the data that employ spatial econometrics to capture the spillover effect of disasters both at the district level and at the province level. This paper will continue with Section II discussing data and econometric models, Section III discussing results, and Section IV discussing the conclusion and implications.

2. METHODS

This paper used a labor augmenting technological progress model (Barro & Sala-I-Martin, 1995) to explain economic growth, and Okuyama (2003) as a theory-based approach for economic growth, and with a disaster, as follows:

$$Y = F[K, L.A(t)] \quad (1)$$

where $L.A(t)$ denotes the amount of effective labor (defined to be $\hat{L}$), a measure that reflects the productivity of each worker. The capital per effective worker, $\hat{k}$, can be written as:

$$\hat{k} = \frac{K}{L.A(t)} = \frac{k}{A(t)} \quad (2)$$

Moreover, the output per effective worker can be written as:

$$\hat{y} = \frac{Y}{\hat{L}} = f(\hat{k}) \quad (3)$$

which can be further to:

$$\Delta \hat{k} = s.f(\hat{k}) - (x + n + \delta)\hat{k} \quad (4)$$

Dividing both sides of (4) by $\hat{k}$, the growth rate of capital per effective worker is:

$$\gamma_{\hat{k}} = \frac{s.f(\hat{k})}{\hat{k}} - (x + n + \delta) \quad (5)$$

Since there is no change in capital per effective worker at the steady state, the following condition should apply:

$$\frac{s.f(\hat{k}^*)}{\hat{k}^*} = (x + n + \delta) \quad (6)$$

From Equation 6, as Okuyama (2003) notes, when a disaster occurs, the capital stock per effective worker decreases from the steady state level to $\hat{k}_d$. Okuyama (2003) explains that “a higher rate of technological progress leads to a faster growth of the effective labor” to justify this effect further. Compared to the period of the regular technological growth rate, x more resources are spent on making each worker more productive during the higher

technological growth rate, x_r . During the reconstruction process, the technology-replacing economy directs more resources towards human capital rather than physical capital than the economy with no technology replacement. This model suggests that climatic disasters can induce human capital investment for an economy that experiences creative destruction during recovery.

From a theoretical perspective, natural disasters create significant and intense damage to capital stocks and, sometimes, labor. The recovery activities change replace the older facilities with newer ones, which may be built upon and use newer technologies. We assume that the level of technology in an economy is the aggregated technological level consisting of a mixture of old and new capital stocks. The recovery activities increase the rate of technological progress to some extent by updating the technological level of the damaged older capital. We added natural disaster as an independent variable and modified the model's natural disaster relation with growth from Dell et al. (2012), Felbermayr and Gröschl (2014), Loayza et al. (2012), and Lee et al. (2018).

From the explanation above, to capture the impact of natural disasters on economic growth, the data analysis technique carries out the econometrics model through panel data statistics as follows:

$$\text{Economic Growth}_{it} = \beta_1 + \beta_2 \text{Disaster}_{it} + \beta_3 \text{Labor}_{it} + \beta_4 \text{Capital}_{it} + \beta_5 \text{Technology}_{it} + \beta_6 \text{Depreciation}_{it} + \varepsilon_{it} \quad (7)$$

This study hypothesizes that natural disasters positively impact economic growth, capital, labor, and technology, which positively affect economic growth, reflecting their role in enhancing productivity and recovery. In contrast, capital depreciation is expected to have a negative effect, as it diminishes the productive asset base. Therefore, β_2 , β_3 , β_4 , and β_5 are expected to be positive result, while β_6 is expected to be negative. Lastly, the subscript ($t=1, 2, \dots, t$) denotes the period.

In order to find the best regression panel model, this study applied a simple Chow test with Restricted Residual Sums of Squares (RRSS), which was a simple test of OLS on the pooled model, and the unrestricted residual sums of squares (URSS), which was a simple test of the fixed effect/Least Square Dummy Variable/LSDV regression (Baltagi, 2005). The Breusch and Pagan Lagrange multiplier test was also applied in this study to decide on the best model between pooled and random models (Hill et al., 2011).

This study uses disaster occurrences in Potensi Desa (PODES) data issued by Statistics Indonesia (Badan Pusat Statistik/BPS). Lee et al. (2018) used the same method and measurement on disaster occurrence to construct the disaster variable. In the research, Lee et al. (2018) used Pacific Islands' disaster data to construct severe natural disasters by specifying a threshold on the distribution of the economic and human costs of disasters. The intensity measure is based on the distribution of economic damage or population affected, and identifying severe natural disasters based on this intensity is the key innovation.

Furthermore, this research divides the disaster variable into two forms: the number of disaster occurrences in the log natural form and the percentage of villages that have

disasters. The original data were stated at the village level and then aggregated at the province level. The aggregation of disaster data at the province level to meet the other variables is only available at the province level. Detailed information related to variables is presented in Table 1 below:

Table 1. Proxy and Sources of Variables

Variable	Proxy	Source
Economic Growth (<i>GRDP_real</i>)	Gross Regional Domestic Product (GRDP) at Constant Price. The data is in billion rupiahs.	Statistics Indonesia (BPS)
Natural Disaster (<i>disaster</i>)	We use two kinds of data to represent the natural disaster: firstly, total disaster occurrences, and secondly, the percentage of villages hit by disaster.	Potential Village Data (<i>Potensi Data/PODES</i>), BPS
Government Capital Spending (<i>bmreal</i>)	The data uses total local government spending on capital in province and district administrations across Indonesia, which is in billion rupiahs with deflators.	Ministry of Finance, Statistics Indonesia (BPS)
Labor (<i>labor</i>)	The data uses the labor force.	Statistics Indonesia (BPS)
Technology (<i>cell</i>)	The household has access to a cell phone. The data are in percentages.	Statistics Indonesia (BPS)
Depreciation (<i>dep</i>)	The effective rate of capital depreciation is approximately calculated by adding the population growth rate to 0.05, as recommended by Mankiw et al. (1992)	Statistics Indonesia (BPS)

3. RESULTS AND DISCUSSIONS

3.1 Results

The descriptive statistics of the variables (in logarithms) are summarized in Table 2. The real Gross Regional Domestic Product (GRDP) is the proxy of economic growth measured in constant 2010 rupiahs. The highest value of economic growth is 14.32%, while the lowest is 9.68%. Meanwhile, the variability of economic growth is 1.17%, and the average value is 11.67%. Disasters, proxied by two indicators- the total number of disasters and the percentage of villages hit by disaster- were obtained from the statistics of Indonesia and aggregated from the village level to the province level. The highest value for total disaster occurrence is 8.21%, and the lowest is 3.71%; similarly, the average value is 6.32%. On the other hand, the highest value of the percentage of villages hit by disaster is 8.21%, and the lowest is 3.71%. The variability for the percentage of villages hit by disaster is 0.92%.

Table 2. Descriptive Statistics

Variable	Source	Unit of measurement	Obs	Mean	Std. Dev.	Min	Max
Economic Growth (<i>lnGRDP_real</i>)	BPS	Constant 2010 (Rp billion)	231	11.76	1.17	9.68	14.31
Natural Disaster (<i>lndisaster</i>)	BPS	Total number of disaster occurrences	231	6.32	0.92	3.71	8.21
Government Capital Spending (<i>lnbmreal</i>)	Ministry of Finance	Real + deflator (Rp billion)	231	6.52	1.00	3.57	10.20
Labor (<i>lnlabor</i>)	BPS	Total labor force	231	14.48	1.00	12.71	16.84
Technology (<i>cell</i>)	BPS	Percentage (Household access to cellular/total household)	231	84.84	10.52	35.12	98.04
Depreciation (<i>dep</i>)	BPS	Population growth + 0.05 or 5% (Mankiw, 1992) in percent	231	1.45	0.64	0.40	4.30

Note: This table presents the statistical descriptive summary for dependent and independent variables. It shows the variable's names, sources, units of measurement, number of observations, mean, standard deviation, and the minimum/lowest and maximum/highest number of each variable.

The Eastern Indonesia region became the region with many disaster phenomena (Figure 1). The provinces of Gorontalo, East Nusa Tenggara, and West Nusa Tenggara were the top three regions with the highest disaster occurrences in the expected years. Besides, the western regions of Indonesia, such as Riau, Jakarta, and Yogyakarta Provinces, in 2011, 2012, and 2017, also became regions with high disaster occurrence. In 2011, 36.14 per cent of villages in Gorontalo were affected by the disaster; 33.09 per cent in East Nusa Tenggara; and 31.99 per cent of villages in Riau. In the following year, 2012, 37.09 per cent of villages in East Nusa Tenggara were affected by the disaster; 35.60 per cent of villages in Gorontalo and 34.08 per cent of subdistrict areas in DKI Jakarta. Furthermore, in 2017, 60.05 per cent of the villages in Yogyakarta were affected by the disaster; 44.17 per cent in East Nusa Tenggara; and 43.83 per cent in West Nusa Tenggara.

Figure 1 shows the percentage of villages hit by natural disasters from 2011 to 2017. The data comes from PODES (Potensi Desa) Statistics. Furthermore, the trend of natural disasters in Indonesia increased during 2011-2017. The islands with the highest disaster incidence in Indonesia were Sumatra (29 per cent), followed by Java (27 per cent). There were five provinces in Indonesia, with a total of disaster events reaching above 1,000 incidents yearly. Aceh, West Java, Central Java, East Java, and East Nusa Tenggara are five provinces. In addition, there are provinces with several disaster events reaching above 1,000 disasters in the same period, namely North Sumatra, North Sulawesi, Central Kalimantan, East Sulawesi, and Papua. The province where a minor disaster occurred is Bangka Belitung

Island. The number of disasters in 2011 was only 41, and increased to 156 in 2017. In contrast, only three provinces experienced a decrease in natural disaster events, namely Riau, DKI Jakarta, and South Kalimantan, with an average reduction in disasters of 22 per cent. Detailed information about the number of disasters from PODES data aggregation can be seen in Table 3 below.

Table 3. Total Natural Disaster Occurrence

Island	Province	Total Natural Disaster Occurrence						Total
		2011	2012	2013	2015	2016	2017	
Sumatra	Aceh	1,905	2,169	2,94	2,764	3,045	2,681	43,923
	North Sumatra	897	1,010	1,512	1,701	1,737	1,805	
	West Sumatra	419	415	544	722	816	795	
	Riau	791	810	906	915	732	627	
	Jambi	445	458	492	731	638	555	
	South Sumatra	628	634	721	920	762	701	
	Bengkulu	208	265	282	297	316	343	
	Lampung	406	395	483	703	628	761	
	Bangka Belitung Island	41	49	81	129	153	156	
	Riau Island	86	86	126	164	162	200	
	Jakarta	79	91	84	62	53	56	41,851
	West Java	2,171	2,116	2,509	3,014	2,955	3,663	
	Central Java	1,481	1,583	2,197	2,245	2,467	2,98	
Java	Yogyakarta	123	136	169	162	188	372	
	East Java	1,301	1,297	1,589	1,767	1,802	2,182	
	Banten	528	609	560	703	677	860	
Bali & Nusa Tenggara	Bali	125	146	213	120	161	397	16,028
	West Nusa Tenggara	318	334	382	536	617	708	
	East Nusa Tenggara	1,513	1,692	1,685	2,366	2,389	2,326	

Table 3. (continued)

Island	Province	Total Natural Disaster Occurrence						Total
		2011	2011	2011	2011	2011	2011	
Kalimantan	West Kalimantan	634	599	842	1,042	903	796	15,570
	Central Kalimantan	454	453	485	1,043	646	549	
	South Kalimantan	730	720	751	798	631	623	
	East Kalimantan	368	357	464	591	560	531	
	Kalimantan							
Sulawesi	North Sulawesi	650	594	706	1,134	909	866	24,055
	Central Sulawesi	655	696	772	900	907	1,052	
	South Sulawesi	886	1,082	1,134	1,191	1,133	1,213	
	Southeast Sulawesi	498	386	838	754	691	669	
	Sulawesi							
	Gorontalo	326	320	358	396	363	338	
	West Sulawesi	223	255	296	291	292	281	
	Sulawesi							
Maluku & Papua	Maluku	363	372	396	497	461	446	11,322
	North Maluku	444	462	425	622	567	564	
	West Papua	135	155	148	316	230	225	
	Papua	411	480	632	1,042	994	935	

Table 4 shows statistical tests of model estimation, which present a fixed-effect model. It also compares the results of the first difference in the general moment of the method (FD-GMM). The research conducts statistical tests regarding the BLUE requirement of the model to determine the best model stated by Gujarati & Porter (2008). The study employs robustness checks to find the goodness of fit in panel data, both static and dynamic (first-difference general method of moments/FD-GMM). In the FD-GMM model, the specification test uses the Arellano-Bond (consistency) and Sargan (instrument validity) tests. The Arellano-Bond test is used to test the consistency of the estimation obtained from the GMM process. The Sargan test determines the validity of instrument variables that exceed the estimated parameters (conditions of overidentifying restriction). The results of the Arellano-Bond test show that the use of the dynamic panel data method with the Arellano-Bond generalized method of moment analysis approach did not meet the statistical criteria of the best model. The instrument variables used in this model are valid. The Arellano-Bond (AB) results in AR (1) show a p-value of 0.073 and AR (2) of 0.200. Furthermore, the Sargan test results in Table 4 show that the probability value is 0.000, respectively. The output shows that there is autocorrelation in the first difference order error. The FD-GMM employs the

robust option in the STATA model to get the optimal model. Table 5 shows the final estimation result of robust estimation and non-robust estimation.

Table 4. Summary of Estimation's Robustness

Description	FEM		FD-GMM	
	Stat	Prob	Stat	Prob
Model F-statistic	71.82	0.00		
Pesaran	14.25	0.00		
Hausman test (Prob. Chi ²)	44.27	0.00		
Wooldridge test (Autocorrelation)	80.25	0.00		
Modified Wald test (Heteroskedasticity)	814.73	0.00		
Sargan			55.48	0.00
AR (1)			-1.7909	0.073
AR (2)			1.2813	0.2

Note: This table presents statistical tests of the classical assumption check, instrument validity test (Sargan test), and consistency test (Arellano-Bond test). The Arellano-Bond test tests the consistency of estimates obtained from the GMM process. The Sargan test determines the validity of instrument variables that exceed the estimated parameters (conditions of overidentifying restriction).

Table 5. Estimation Results

	(1)	(2)	(3)	(4)	(5)
Variables	PLS	REM	FEM	FEM (Robust)	FD-GMM (Robust)
lnGDRP (lag1)					0.953*** (0.0166)
Indisaster	-0.233*** (0.0384)	0.0696*** (0.0229)	0.0793*** (0.0222)	0.0793** (0.0316)	-0.00798 (0.00672)
lnbmreal	0.384*** (0.0342)	0.0422*** (0.00872)	0.0362*** (0.00801)	0.0362*** (0.0126)	-0.00301 (0.00480)
lnlabor	1.003*** (0.0423)	0.952*** (0.0708)	1.004*** (0.112)	1.004*** (0.135)	0.0588** (0.0266)

Table 5. (continued)

	(1)	(2)	(3)	(4)	(5)
Variables	PLS	REM	FEM	FEM (Robust)	FD-GMM (Robust)
cell	-0.00189 (0.00303)	0.00531*** (0.00101)	0.00469*** (0.000971)	0.00469** (0.00192)	-0.000272 (0.000434)
dep	0.370*** (0.0488)	-0.0967** (0.0391)	-0.126*** (0.0383)	-0.126 (0.118)	-0.0106*** (0.00322)
Constant	-4.168*** (0.489)	-3.046*** (0.990)	-3.732** (1.554)	-3.732* (1.926)	-0.131 (0.328)
Obs.	231	231	231	231	165
R-squared	0.862		0.778	0.778	
Number of regions	33	33	33	33	33

Note: This table presents the regression result for the robustness estimates for the static and dynamic pooled model. The dependent variable is "The Real Gross Regional Domestic Product" in the natural logarithm unit. The standard error is reported in parentheses, and significance levels are denoted with an asterisk: *p < 10%, **p < 5%, and ***p < 1%.

Referring to Table 4, the Fixed Effects Model (FEM) with robust standard errors (Robust FEM) was selected as the best model. Therefore, the discussion focuses on the results of the Robust FEM. *lnDisaster* (Natural Disaster), with a coefficient of 0.0793 (significantly positive), indicates that, after controlling for region-specific characteristics that do not change over time, natural disasters have a small but statistically significant positive impact on real Gross Regional Domestic Product, in which can be interpreted as a "build back better" effect, or increased economic activity associated with post-disaster reconstruction and assistance, as suggested by Okuyama (2003) regarding technological updates and accelerated recovery.

The coefficient appearing close to zero and insignificant in the FD-GMM may indicate that, after controlling for long-term GRDP dynamics (via *lnGRDP*(lag1)) and addressing endogeneity issues, the net impact of disasters on long-term economic growth is neutral or minimal. This could mean that the recovery process fully offset the initial negative effects, or that the "build back better" stimulus was not strong enough to generate statistically significant long-term growth. Therefore, although the FD-GMM is theoretically a robust method, the insignificant and even negative results for *lnDisaster* in the FD-GMM are unreliable due to instrument validity issues detected by the Sargan test.

Disaster-positive economic growth aligns with Okuyama (2003), who notes that natural disasters, although destructive, can trigger a reconstruction process involving new investment, the replacement of better Technology, and possibly an increase in human capital, which overall generates a measurable economic stimulus in the short to medium term.

The *lnbmreal* (Government Capital Spending) variable, with a coefficient of 0.0362 (significantly positive), indicates that Government Capital Spending has a positive and significant impact on real GRDP. This result is consistent with the notion that public investment drives economic growth. Meanwhile, labour (*Labour*), with a coefficient of 1.004 (positive and significant), indicates that labour has a positive and substantial impact on real GDP. A 1% increase in the labour force is associated with an increase of approximately 1% in GRDP, indicating a strong and vital relationship. The cell as a proxy for Technology shows a coefficient value of 0.00469 (significantly positive), so it can be concluded that Technology access (proxied by mobile phone access) has a positive and significant impact on real GRDP, indicating that increased communication technology penetration can contribute to regional economic growth. The last variable, *dep* (Depreciation), with a coefficient value of -0.126 (negative and insignificant), is the only coefficient that is not statistically significant in the Robust FEM. Still, the coefficient is negative and theoretically consistent (capital depreciation inhibits growth).

3.2 Discussions

The estimation results reveal important insights into the dynamics of economic growth in the context of natural disasters and key production inputs at the regional level in Indonesia. Using the fixed effect model, which proves to be the most robust and statistically appropriate specification, the study finds that government capital spending, labor, technology, and natural disasters have positive and statistically significant effects on economic growth. In contrast, depreciation of capital negatively impacts it. One of the most notable findings is the positive association between disaster exposure and regional economic growth, which challenges conventional assumptions that disasters uniformly hinder development. This aligns with the theoretical propositions of Okuyama (2003), who highlights how disaster-induced destruction can trigger technological replacement and investment in human capital, thereby enhancing long-term growth. The finding is further supported by Ahlerup (2013) and Fischer (2021), who argue that in democratically developing countries, disasters may lead to growth through reconstruction efforts, foreign aid, and improved governance responses. The model's results suggest that reconstruction and stimulus following disasters in the Indonesian context may lead to technological upgrading and more effective capital allocation, particularly when supported by humanitarian assistance.

In addition to the disaster variable, government capital expenditure is found to be a significant driver of economic growth, reinforcing the argument that public investment plays a vital role in stimulating regional economies. This result is in line with the findings of Putri (2014), Astria (2014), Mirza (2011), and Rizky et al. (2016), who highlight the critical role of capital spending in infrastructure development and service delivery across Indonesian

regions. Labor is also confirmed as a core contributor to regional output, with a coefficient close to one, indicating that gross regional domestic product increases closely mirror increases in the labor force. This supports the findings of Sari (2018), Eigbiremolen and Anaduaka (2014), Norlita (2018), and others, who emphasize the dual importance of labor quantity and quality in driving economic performance. Furthermore, technology, proxied by household access to cell phones, exhibits a significant positive relationship with growth. This supports Okuyama's (2003) argument that disaster-related reconstruction can accelerate technological diffusion, and it also highlights the broader role of digital infrastructure in enhancing economic resilience and productivity.

These findings also align with the results of Khan et al. (2023), who examined the role of human capital, foreign direct investment (FDI), and infrastructure development in moderating the effects of natural disasters on economic growth. Their study, which covers 98 countries over the period 1995–2019, shows that the negative impact of disasters on growth tends to be more severe in low-income countries, while middle- and high-income countries are more resilient, mainly when supported by strong infrastructure, investment flows, and capital formation. While our study focuses specifically on the Indonesian context using subnational panel data, the shared conclusion is that the economic consequences of natural disasters are not uniform—they depend on broader structural conditions and policy responsiveness. Our findings reinforce this by showing that disaster events can coincide with positive economic outcomes in Indonesia, particularly when supported by government capital spending and technological access. The study by Khan et al. thus strengthens the argument that the post-disaster economic trajectory is highly path-dependent, shaped by enabling factors like investment, governance, and institutional capacity, which are implicitly reflected in our findings through variables like labor, technology, and fiscal support.

The results of this study also find resonance in the work of Joseph (2022), who analyzed the causal impact of the 2010 Haiti earthquake on regional economic growth using a difference-in-differences approach with nighttime light intensity as a proxy for subnational economic activity. His findings reveal a significant and persistent decline in economic growth, lasting nearly a decade after the disaster. This contrasts with our study, which finds a positive association between disaster incidence and economic growth in Indonesia, likely due to differing contexts in governance, institutional resilience, and recovery mechanisms. While Haiti's case illustrates the long-term negative impact of a single, high-intensity disaster in a vulnerable institutional setting, the Indonesian context reflects how frequent but relatively lower-scale disasters, coupled with effective capital spending and technological infrastructure, may enable a more adaptive and even stimulative post-disaster economic response. The comparison underscores the importance of contextual and institutional factors in determining the economic trajectory after a disaster, supporting Joseph's (2022) conclusion that disaster economics must account for local heterogeneity in vulnerability, intensity, and policy response.

Conversely, the study confirms that capital depreciation erodes economic performance, consistent with theoretical expectations from the Solow model and findings by Mankiw et al. (1992). A 1 percent increase in depreciation leads to a substantial reduction in per capita

GRDP, underlining the importance of maintaining and renewing capital stock as part of growth policy.

This study's findings also resonate with Wariyanti and Rahmayani (2025), who applied the Solow-Swan growth framework to assess the impact of natural disasters on provincial economic growth in Indonesia. Using panel data regression for 31 provinces from 2011 to 2023, they found that while Gross Fixed Capital Formation (GFCF) and the Human Development Index (HDI) positively and significantly influence GRDP, natural disasters do not exhibit a statistically significant effect. This contrasts with our study, which identifies a positive and significant association between disaster occurrence and economic growth, particularly when mediated through public capital expenditure and technological access. The divergence in findings may stem from differences in variable construction and analytical scope; while Wariyanti and Rahmayani (2025) employ broader macro indicators and treat disasters as an exogenous shock, our study emphasizes disaggregated village-level disaster exposure and integrates it with regionally specific development dynamics. Nonetheless, both studies agree on the critical role of capital investment in driving growth, reinforcing that disaster resilience and recovery are closely tied to infrastructure capacity and long-term development inputs.

What distinguishes this study from existing literature is its use of disaggregated disaster exposure data from the PODES (Village Potential Statistics), which captures village-level disaster incidence and aggregates it to the provincial level. This approach enables a more localized and nuanced understanding of disaster impacts—something that is often overlooked in macro-level analyses. This granularity provides new empirical evidence on how disasters and economic policy interact at the subnational level in a disaster-prone developing country. However, several limitations must be acknowledged. The disaster variable is treated in aggregate form, without differentiating types or severity of disasters. The technology variable is limited to mobile phone ownership, which may not fully capture digital infrastructure or innovation capacity. Moreover, the current model does not explore potential interaction effects, such as the relationship between disaster exposure and governance quality or infrastructure resilience. Future research may address these gaps by incorporating additional dimensions such as disaster type, institutional factors, and spatial spillovers to understand better the heterogeneity of disaster effects and the role of adaptive capacity in shaping post-disaster recovery trajectories.

4. CONCLUSIONS

This paper develops a framework for analyzing the economic impact of a disaster. Our findings imply that disasters have pulled the economic growth. The remaining variable representing the growth economy theory shows the expected result in various coefficients and their significance level. The research has contributed to the policy implications and literature study in Indonesia.

From the policy perspective, firstly, it is important to increase the policy of government spending on capital expenditure. Secondly, human resource investment is essential in driving economic improvement. Thirdly, there is a need to increase the mitigation policy on disasters

to reduce the impact of disasters in terms of the number and area coverage. The province whose villages are affected by the disaster yearly is East Nusa Tenggara. This information is vital to increase the mitigation policy on disasters and reduce the impact of disasters in terms of the number and area coverage.

This paper uses the PODES database to investigate the effect of the disaster on economic growth in Indonesia. The original data are represented at the village level. The data analyses employ the aggregated data at the provincial level to control for other variables. To our knowledge, no previous study in Indonesia has utilized the PODES database to construct the disaster data. It brings new findings to the context of Indonesia. The study limits the range of time series data to 2011-2017. Further research would (i) cover the data that represents the district level and employ the long time-series data, and (ii) employ spatial econometrics to capture the spillover effect of disaster both at the district level and the province level.

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6. APPENDIX

