

# Structural Determinants of Disaster Risk Management Expenditures in Selected Developed and Developing Countries Most Exposed to Disasters: A Comparative Panel Data Analysis<sup>12</sup>

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## Abstract

This study employs a comparative panel data approach to examine the macroeconomic, social-vulnerability, and demographic determinants of Disaster Risk Management Expenditures (DRME-aryth), considering the structural heterogeneity among selected developed and developing countries most exposed to disasters. Although the macroeconomic impacts of disasters are extensively discussed in the literature, studies analyzing the multi-dimensional determinants of DRME-aryth across different development levels remain limited. By presenting distinct expenditure models for different country groups using data spanning the 2014–2023 period, this research aims to bridge this gap. The main originality of the study lies in providing empirical evidence on how structural factors affecting disaster expenditures vary across development levels. The analysis results indicate that in the Developing Countries (EMDEs-GOÜ) model, post-disaster economic losses have a strong and significant negative impact on DRME-aryth. This finding suggests that these countries rely on external aid and international financial mechanisms instead of national capacity for post-disaster financing. Conversely, in the Developed Countries (DCs-GÜ) model, the elderly population share and fiscal capacity are found to be decisive factors, while the literacy rate is significant for both country groups. Furthermore, the structural break years (i.e., the years marking shifts in expenditure policy) also differ between the two country groups: 2016 for developed countries and 2021 for developing countries.

**Keywords:** Disaster Economics, Comparative Panel Data Analysis, Fiscal Asymmetry, Structural Heterogeneity, Disaster Risk Management Expenditures (DRME), Disaster Risk Management

## Afetlere En Çok Maruz Kalan Seçili Gelişmiş ve Gelişmekte Olan Ülkelerde Afet Risk Yönetimi Harcamalarının Yapısal Belirleyicileri: Karşılaştırmalı Bir Panel Veri Analizi<sup>1</sup>

### Öz

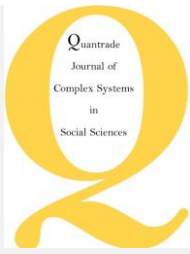
Bu çalışma, afet risk yönetimi harcamalarının (DRME-aryth) makroekonomik, sosyal-kırılganlık ve demografik belirleyicilerini, afetlere en çok maruz kalan gelişmiş ve gelişmekte olan ülkeler arasındaki yapısal heterojeniteyi dikkate alarak karşılaştırmalı bir panel veri yaklaşımıyla incelemektedir. Literatürde afetlerin makroekonomik etkileri yoğun biçimde tartışılrsa da, DRME-aryth'nin çok boyutlu belirleyicilerini ülkeler arası kalkınma düzeylerine göre analiz eden çalışmalar sınırlıdır. Çalışmanın temel özgünlüğü, afet harcamalarını etkileyen yapısal faktörlerin etkilerinin kalkınma düzeyine göre nasıl farklılaştığını ampirik olarak ortaya koymasındır. Araştırma, 2014–2023 dönemini kapsayan veriler

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üzerinden, farklı ülke grupları için ayrıışan harcama modellerini ortaya koyarak bu boşluğu gidermeyi amaçlamaktadır. Analiz sonuçlarına göre, Gelişmekte Olan Ülkeler (EMDEs-GOÜ) modelinde, afet sonrası ekonomik zararların DRME-aryth üzerinde güçlü ve anlamlı negatif bir etkisi olduğu tespit edilmiştir. Bu durum, EMDEs-GOÜ'lerin afet sonrası finansman için ulusal kapasite yerine dış yardımlara ve uluslararası finansal mekanizmalara bağımlı kaldığını göstermektedir. Gelişmiş Ülkeler (DCs-GÜ) modelinde ise harcamalar üzerinde yaşlı nüfus oranı ve mali kapasite belirleyici olurken, okuryazarlık oranı her iki ülke grubu için de anlamlı bulunmuştur. Ayrıca, harcama davranışlarında gözlenen yapısal kırılma yılları (yani harcama politikasındaki dönüşüm dönemleri) iki ülke grubu için farklı belirlenmiştir: gelişmiş ülkeler için 2016, gelişmekte olan ülkeler için ise 2021'dir.

**Anahtar Kelimeler:** Afet Ekonomisi, Karşılaştırmalı Panel Veri Analizi, Mali Asimetri, Yapısal Heterojenite, Afet Risk Yönetimi Harcamaları (aryth), Afet Risk Yönetimi

## Introduction

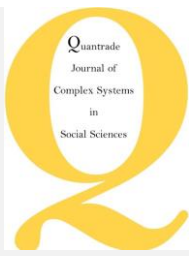
The fundamental objective of all national economic activities is to ensure sustainability. In this context, while developed countries (DCs-GÜ) aim to maximize the welfare of the state and its citizens, developing countries (EMDEs-GOÜ) prioritize sustainable development (UNDP, 2022). There is a general consensus that natural disasters pose a significant threat to sustainable development. According to World Bank reports, the estimated annual cost of natural disasters to the global economy is approximately USD 520 billion, pushing an additional 26 million people into poverty each year (World Bank, 2023). In a multi-country panel study covering 109 countries over the 1970–2003 period, Noy (2009) found that natural disasters reduced GDP growth by approximately 9% in EMDEs.

Disaster risk management has evolved from a purely engineering-based activity into a strategic, multidimensional public policy domain focused on coping with uncertainty (Tierney, 2012). The impact of natural disasters depends on various factors, including the size and structure of the economy, population density in high-risk areas, and the level of development of the financial system. Recent research has demonstrated that the economic costs of natural disasters can be minimized through higher skill levels, stronger institutions (local governments, healthcare services, the rule of law, etc.), greater trade openness, and efficient public spending (Cavallo & Noy, 2011). Advanced institutions and an educated population are essential for implementing effective measures to mitigate disaster impacts, allocating international aid rationally, and enforcing structural measures such as damage-reducing construction codes and zoning laws. Furthermore, countries with adequate foreign exchange reserves and those that impose restrictions on capital outflows cope better with post-disaster financial shocks. Although saving lives remains the foremost priority for states, factors such as social justice, economic rationality, and institutional sustainability also play a key role in shaping disaster policies under resource constraints (Boin & McConnell, 2007). In other words, efforts to reduce economic costs that may trigger new humanitarian and social problems are equally critical.

This study seeks to answer three primary questions: First, what are the economic, social, demographic, and disaster-based structural determinants of disaster risk management expenditures (DRME-aryth)? Second, how do the effects of these structural determinants on total DRME-aryth differ between EMDEs and DCs? Third, does there exist a structural determinant capable of generating a Schumpeterian effect, as discussed in the literature? Although all countries develop their own distinct disaster management strategies, this research empirically identifies the common determinants and quantifies their effect sizes.

The fundamental hypothesis of the study is as follows: "The structural break years of developed countries (DCs) and developing countries (EMDEs)—that is, the periods during which disaster policies underwent transformation—differ between the two groups; moreover, the structural determinants shaping disaster management expenditures diverge distinctly across these country groups."

The theoretical framework is defined as follows: "Disaster Risk Management (DRM) strategies exhibit significant variations in line with countries' levels of economic development, institutional structures, governance quality, and social resilience." This differentiation is observed empirically not only in disaster



response approaches but also in risk reduction, preparedness, and reconstruction strategies (Cutter et al., 2003; Skidmore & Toya, 2002; Hallegatte, 2014; Baltagi, 2008; Greene, 2018).

The World Bank classifies countries according to their Gross National Income (GNI) per capita—kgsh—levels, grouping middle- and low-income economies under the category of developing countries. The primary criterion in this classification is per capita income expressed in US dollars.

Developed countries have adopted proactive and comprehensive approaches to disaster risk management, owing to their economic prosperity, advanced technological capabilities, strong infrastructure, and well-established institutional frameworks. In these countries, DRM expenditures are not limited to post-disaster emergency response and recovery activities; they extend to all stages of the disaster cycle, including risk reduction, prevention, resilience building, and the development of early warning systems. In countries such as Japan, the USA, Italy, and Switzerland, multi-layered systems are reinforced by early warning technologies, compulsory insurance mechanisms, risk-based urban planning, and strong institutional coordination. This structure limits the macroeconomic effects of disasters by enhancing post-disaster response and economic recovery capacity (OECD, 2023; Coppola, 2020; Kellenberg & Mobarak, 2008). Nevertheless, due to their geographical locations and the intensifying effects of climate change, these countries remain exposed to severe risks from disaster types such as earthquakes, floods, and wildfires, which necessitates continuous investment and adaptation efforts.

In contrast, disaster management in developing countries (e.g., Bangladesh, the Philippines, Türkiye, and Mexico) is predominantly reactive, relying on post-event response and recovery processes. In these countries, the scarcity of financial resources, deficiencies in data and monitoring infrastructure, the inadequacy of insurance systems, and low levels of social awareness constitute the primary structural problems that intensify the macroeconomic impacts of disasters.

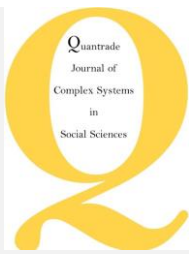
Furthermore, public perception of disaster risk and the level of public participation directly determine the effectiveness of disaster management strategies. While disaster education, media-based awareness campaigns, and drill exercises exhibit an institutionalized structure in developed countries, these processes often remain limited or cannot be sustained in developing countries (WHO, 2024).

In developed countries, disasters generally result in capital losses, while human losses remain relatively low. Conversely, the humanitarian cost in developing countries is substantially higher; indeed, approximately 90% of global disaster-related fatalities occur in developing countries (Kreimer & Arnold, 2000).

Research by Jones and Olken (2010) has shown that rising temperatures affect poor countries more severely than rich ones. According to their findings, a 1°C increase in annual temperature in a poor country reduces the export growth rate by 2% to 5.7%, whereas no comparable effect is observed in rich countries. Exports of agricultural products and light industrial goods are particularly affected, while the impact on heavy industry remains considerably more limited. In a subsequent study with Melissa Dell, Jones and Olken further demonstrated that temperature fluctuations not only destabilize poor economies but also increase political instability in these countries (Dell et al., 2012).

Consequently, while vulnerability to natural disasters and poverty mutually reinforce each other, post-disaster financing gaps emerge as an additional factor hindering the development of the poor. Together, these elements impose a significant constraint on the pace of human development.

At the same time, expenditures aimed at strengthening disaster resilience and advancing human development are complementary, offering mutual benefits. In this context, post-disaster support and interventions can be designed strategically to ensure a country's uninterrupted progress toward its sustainable development goals.



## 1. Literature Review

Studies in the economics literature have shown that natural disasters exert heterogeneous effects on economies, with these impacts varying according to countries' development levels, public policies, and institutional efficiency (Cavallo & Noy, 2011; Kousky, 2014; Hallegatte et al., 2019).

Economic losses, infrastructure damage, production disruptions, and social impacts caused by disasters exert significant fiscal pressure on countries' budgets. In the first year following a natural disaster, the economic growth rate of the affected country slows by an average of 0.7%, and when direct losses are excluded, the cumulative output loss three years after the disaster reaches approximately 1.5%. Real GDP per capita—kgsyh—declines by an average of 0.6%, with this rate rising to 1% in low-income countries (Cabezón et al., 2015). Another study on Caribbean countries found that an average hurricane causes an output loss of approximately 1%, while severe storms and floods produce an economic contraction of between 0.5% and 1% (Strobl, 2012; Acevedo, 2013).

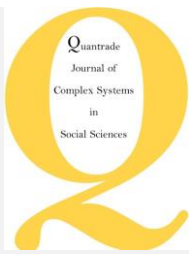
These economic shocks often trigger public borrowing. In the countries of the Eastern Caribbean Currency Union, the public debt-to-GDP ratio rises by an average of 5 percentage points following a disaster (Acevedo, 2013). One of the primary reasons for this increase is the urgent need for international aid and borrowing in the post-disaster period. Moreover, the literature has shown that disaster types with greater media coverage (e.g., hurricanes) facilitate access to foreign aid (Eisensee & Strömberg, 2007).

Despite these negative effects, some studies argue that disasters can lead to long-term structural transformations. Skidmore and Toya (2002) suggest that disasters pave the way for the adoption of more efficient infrastructure systems and modern technologies during the reconstruction process, enabling physical capital to be replaced by higher-quality human capital. This perspective aligns with Schumpeter's concept of "creative destruction." According to this view, societies exposed to high disaster risk can develop greater innovation and adaptation potential over the long run in order to cope with such risk.

However, these potential positive effects are mostly applicable to developed countries (DCs). In an empirical study covering the 1970–2003 period, Noy (2009) showed that developing countries (EMDEs) suffer substantially heavier macroeconomic damage from disasters of similar magnitude than developed countries. Countries with advanced financial systems—characterized by high banking penetration and widespread credit use—are less affected by the macroeconomic consequences of disasters. Although these countries generally experience larger post-disaster budget deficits, they incur smaller losses in production volume. Developed credit markets provide rapid access to domestic financing for restoration purposes, thereby minimizing the need for external borrowing, which can take longer to secure or even become unavailable. The most advantageous position is held by countries with broad financial systems and high insurance coverage; in such structures, risk is transferred to international markets through reinsurance mechanisms, and economic recovery therefore places almost no additional burden on the public budget. For instance, two severe earthquakes in New Zealand in 2010 and 2011 caused serious damage estimated at (Parker & Steenkamp, 2012), yet high insurance coverage shifted the bulk of the restoration costs to international reinsurance markets; consequently, no decline in business activity was observed, and economic growth even strengthened during the recovery (von Peter et al., 2012).

Similarly, Strobl and Kablan (2017), after examining the impact of tropical cyclones in developing small island states, found that the response of the real exchange rate depends on the country's macroeconomic policy regime. Under a floating exchange rate regime, the currency depreciates, which helps the economy recover from the shock.

Osberghaus (2019) found that temperature changes affect exports more strongly than imports. Natural disasters also adversely affect exports, while imports may decrease, increase, or show no response at all. These effects are more pronounced in countries with weak economies and institutions.



In a study prepared for the IMF's annual conference on the impact of climate risks on the economy, Hale (2024) analyzed whether climate risks actually affect real exchange rates (the relative prices of domestic and foreign goods) as predicted by theoretical models. The answer to this question helps clarify whether markets fully account for the risks associated with the increasing frequency and severity of climate-related natural disasters. Hale applied the model proposed by Farhi and Gabaix (2015) in their study "Rare Disasters and Exchange Rates," which is based on the hypothesis that the real exchange rate reflects the economy's future income expectations. This relationship, in turn, determines fluctuations in exchange rates, interest rates, currency options, and stock markets. Hale tested the Farhi–Gabaix model using data from 47 countries over more than 50 years (1964–2019). To measure the exchange rate response, both the disaster year and the subsequent year were considered. The main finding was that reality diverged from the model's predictions, suggesting that markets may be underestimating natural disaster risks. The model predicts a relatively small but steady decline in the real exchange rate of "risky" currencies (those more likely to depreciate) following disasters; however, robustness checks indicated that this effect is only transitory.

Businesses also fail to pay sufficient attention to climate risks when planning investments. Gu and Hale (2023) showed that multinational corporations do not adequately consider geophysical and climate risks when making decisions about their assets in different countries. However, international companies' focus on climate-related risks began to increase following the 2015 Paris Climate Agreement.

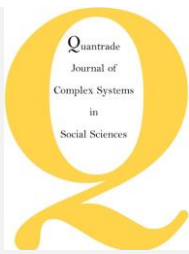
Avril et al. (2022) examine how the stringency of macroprudential regulations alters the impact of natural disasters on financial stress. In particular, natural disasters such as storms are shown to increase financial stress in countries with loose macroprudential regulations, while reducing it in countries with tight regulations. This finding suggests that strong financial regulations can facilitate the replacement of disaster-affected capital with more productive capital (creative destruction). However, for more predictable disasters such as floods, the effect of macroprudential regulations is less pronounced, as countries tend to be better prepared for such events.

Felbermayr and Gröschl (2014) examined the impacts of different types of natural disasters and found that poor countries suffer more from geophysical disasters, while rich countries are more adversely affected by meteorological disasters. The authors further argue that international openness and the effective functioning of democratic institutions mitigate the negative effects of natural disasters.

Burke et al. (2015) demonstrated the dependence of overall economic productivity on temperature levels. According to their analysis, economic productivity peaks at an annual average temperature of 13°C and declines sharply at temperatures above this threshold. This non-linear relationship, observed on a global scale, has remained unchanged since 1960 and is characteristic of both developed and developing countries. The authors also propose a revision of the traditional principles used to model the economic losses associated with climate change. They emphasize that if societies continue to operate as they currently do, global economic growth will decelerate and existing socioeconomic inequalities will deepen further.

## 2. Data and Methodology

The primary objective of this research is to analyze the economic, social, demographic, and disaster-based structural determinants of disaster risk management expenditures (DRME-aryth) within a comparative framework. This study draws upon the empirical framework developed in a broader doctoral investigation (Ibis, 2026), which examines integrated disaster risk management expenditures through decision-theoretic and advanced econometric approaches. Specifically, the study seeks to identify how these determinants differ between developed countries (DCs) and developing countries (EMDEs), while investigating whether post-disaster reconstruction processes trigger a technological and institutional transformation through the "creative destruction" effect conceptualized by Schumpeter (1942). In line with these objectives, the study employs annual panel datasets covering the 2014–2023 period. Due to the limited availability of disaster management data, the variables were compiled from multiple sources through an extensive screening process and harmonized on a country-by-country basis. The comprehensive dataset was constructed by integrating



statistical databases from the World Bank, the International Monetary Fund (IMF), EM-DAT (the International Disaster Database), the United Nations Office for Disaster Risk Reduction (UNDRR, 2023), and the OECD. The sample comprises 14 countries selected on the basis of high disaster exposure and consistent data availability, including 7 DCs (USA, Australia, South Korea, Spain, Italy, Japan, and Greece) and 7 EMDEs (Bangladesh, Indonesia, the Philippines, India, Mexico, Pakistan, and Türkiye). Following the theoretical relevance and model selection strategies proposed by Baltagi (2008) and Greene (2018), one dependent and eleven independent variables were specified.

The choice of a comparative panel data approach is motivated by both the nature of the research question and the structure of the available data. Panel data econometrics allows for the simultaneous control of unobserved country-specific heterogeneity and time-varying common shocks, both of which are particularly relevant when studying disaster-related expenditure behavior across structurally heterogeneous economies (Baltagi, 2008; Greene, 2018). In the presence of limited annual observations per country, panel estimation also enhances statistical efficiency by pooling cross-sectional and time-series variation. Moreover, the comparative framework—rather than a single-group analysis—is essential for testing the central hypothesis of this study, namely that the structural determinants of DRME-aryth differ systematically between DCs and EMDEs. The Supremum F test is employed to detect structural breaks of unknown timing, while bootstrap standard errors are used to ensure inferential robustness under non-normal error distributions. Together, these methodological choices provide a coherent framework for capturing both the heterogeneity and the temporal dynamics of disaster risk management expenditures.

A comprehensive list of all variables, their definitions, transformations, and data sources is presented in Table 15 at the end of the article.

Total disaster risk management expenditures (DRME-aryth), defined as the dependent variable, capture government spending related to disaster risk reduction, preparedness, emergency response, and recovery activities. To ensure consistency in the econometric analyses and to enhance the interpretability of the coefficients, the natural logarithm of this variable (LDRME-laryth) was used. The independent variables were categorized into three functional groups in order to capture the multidimensional nature of disaster management. The first group, comprising disaster-related indicators, measures the physical and human severity of disasters through the logarithmic forms of total damage (*lasutz*), the total number of people affected (*laetks*), and the frequency of occurrences (*ldasvs*).

The second group includes socioeconomic indicators that reflect the social and economic vulnerabilities of the countries. Within this scope, the adult literacy rate (*ynoyo*) and the share of the population aged 65 and over (*yun*) are incorporated into the analysis in their original forms. In contrast, the natural logarithmic transformations of total population (*lutn*), social security contributions (*lsqkp*), current health expenditures (*lucsh*), and premium-insurance indemnity indicators (*luptsg*) are employed to ensure model stability.

Finally, the third group focuses on macroeconomic indicators representing the macro-fiscal capacities and economic development levels of the countries, employing the logarithmic forms of gross domestic product (*lgsyh*) and GDP per capita (*lkgsyh*).

The econometric estimation procedures and diagnostic tests closely follow the methodological frameworks established by Tatoğlu (2021, 2024). Specifically, Tatoğlu (2023) was consulted for model selection strategies and unit root tests, while Tatoğlu et al. (2020) provided the basis for analytical methods accounting for structural breaks. This study also builds upon the multidimensional panel data approaches successfully applied in related fields (Tatoğlu & İçen, 2019). Traditional econometric diagnostic tests were conducted using Stata 18, complemented by a hybrid approach through OmegaMetrixAI (v1.0), developed by Omega Research Labs (2025). This AI-based verification system reinforces the methodological rigor of the study by providing critical

diagnostics for coefficient stability, outlier effects, and overall model robustness across alternative specifications.

### 3. Findings from the Panel Data Analysis

#### 3.1. Panel Data Analysis of Developing Countries (EMDEs-GOÜ)

In analyzing the data for developing countries (EMDEs) using the panel data method, information criteria such as the Adjusted R<sup>2</sup>, Mallows Cp, the Akaike Information Criterion (AIC), the corrected AIC for small samples (AICC), and the Bayesian Information Criterion (BIC) (Schwarz, 1978) were employed for model selection. For these criteria, lower values indicate a better model fit. The results show that Model 4 yielded the lowest values for Mallows Cp, BIC, and AICC. Model 4 was therefore selected as the most appropriate specification, as it was also among the models with the highest Adjusted R<sup>2</sup>.

Table 1. Model Selection Based on Basic Panel Data Results (EMDEs)

Model No	Number of Variables	Adjusted R <sup>2</sup>	Mallow's C <sub>p</sub>	AIC Akaike Information Criterion	AICC Akaike-Corrected	BIC Bayesian Information Criterion	Explanatory Variables	Selection
1	1	0.9976	99.0836	-135.6640	-135.3010	-131.167	lasutz	✗
2	2	0.9988	16.2344	-184.1690	-183.5540	-177.424	lasutz, yun	✗
3	3	0.999	4.5970	-195.2100	-194.2720	-186.216	lasutz, luptsg, lsgkp	✗
4	4	<u>0.999</u>	<u>2.3752</u>	<u>-197.7940</u>	<u>-196.4610</u>	-186.552	lasutz, luptsg, lsgkp, ynoyo	✓
5	5	0.999	3.7308	-196.5210	-194.7150	-183.0300	lasutz, luptsg, lsgkp, ynoyo, lucsh	✗
6	6	<u>0.9991</u>	2.7137	<u>-198.0290</u>	-195.6680	-182.2890	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn	✗
7	7	0.9991	4.0760	-196.7930	-193.7930	-178.8050	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn, lucsh	✗
8	8	0.999	6.0287	-194.8500	-191.1210	-174.6140	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn, lucsh, yun	✗
9	9	0.999	8.0006	-192.8840	-188.3320	-170.3990	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn, lucsh, yun, ldasvs	✗
10	10	0.999	10.0006	-190.8840	-185.4110	-166.1510	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn, lucsh, yun, ldasvs, lkgsyh	✗
11	11	0.999	12.0000	-188.8850	-182.3850	-161.9030	lasutz, luptsg, lsgkp, lgsyh, ynoyo, lutn, lucsh, yun, ldasvs, laetks, lkgsyh	✗

Within the framework of Model 4, selected as the appropriate model for developing countries (EMDEs) on the basis of the information criteria, the mathematical structure of the model is expressed in Equation 1 below:

The panel data model equation for the EMDEs is as follows:

$$laryth_{it} = \beta_0 + \beta_1 lasutz_{it} + \beta_2 luptsg_{it} + \beta_3 lsgkp_{it} + \beta_4 ynoyo_{it} + u_{it} \quad (1)$$

In the constructed model, the subscript  $i$  denotes the countries (cross-sectional dimension), while  $t$  represents the time dimension (2014–2023).

In this model, the dependent variable is used in its logarithmic form (LDRME-laryth) to render total disaster risk management expenditures suitable for econometric analysis. The set of independent variables consists of the logarithmic forms of total damage caused by disasters (lasutz), premium-insurance indemnity indicators (luptsg), and social security contributions (lsgkp).

In addition, the adult literacy rate (ynoyo) variable is included in the model in its original form, without any transformation in the econometric analyses. The correlation graphs illustrating the relationships among the variables in the developing countries (EMDEs) model are presented in Figure 1.

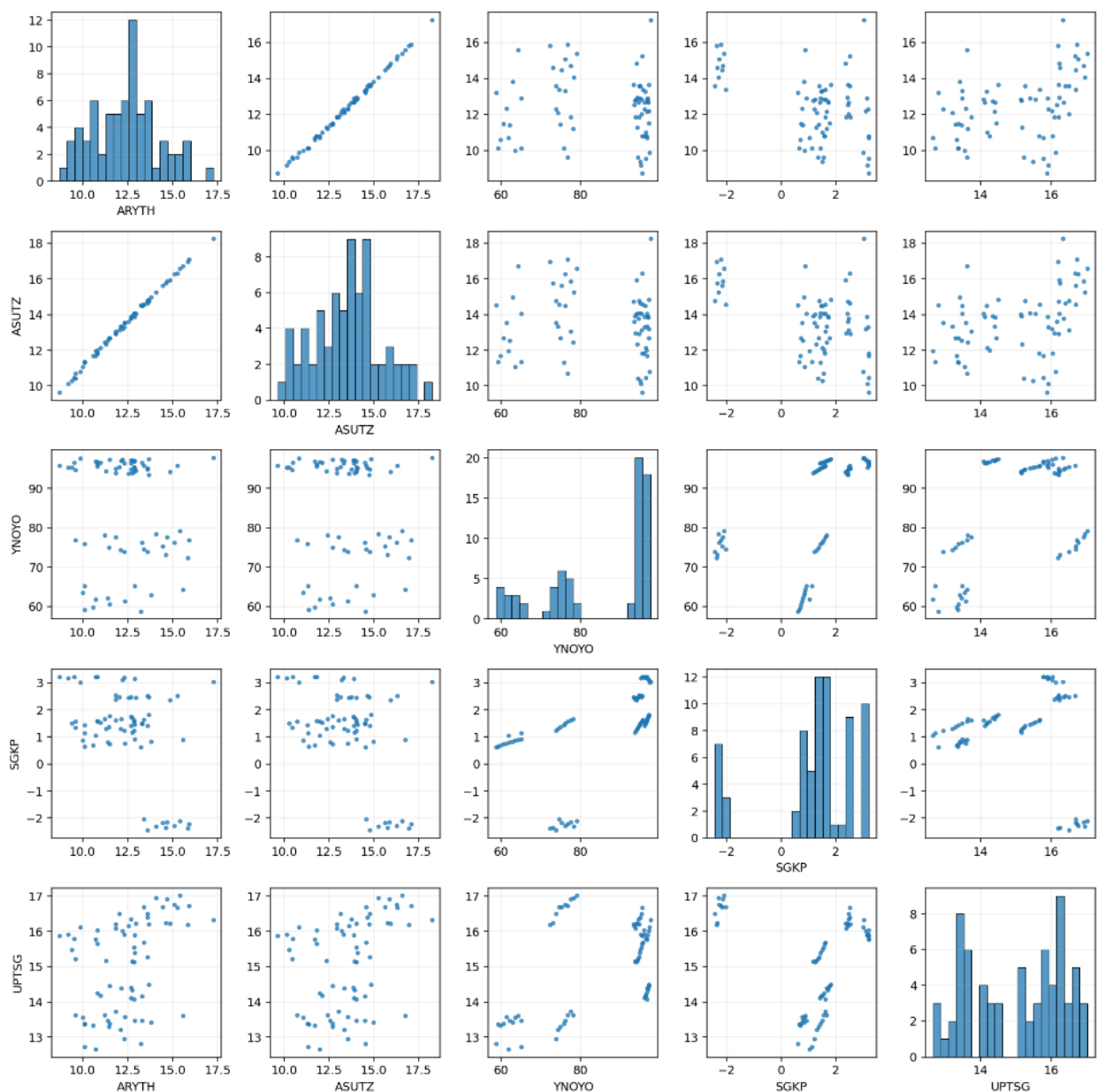


Figure 1. Correlation Matrix and Histograms of Variables (EMDEs)

These graphs reveal a notably high and positive correlation between the dependent variable, disaster risk management expenditures (DRME-aryth), and total post-disaster economic damage (asutz). This finding confirms that disaster-related costs strongly influence the level of public spending. Relatively moderate relationships are observed among the other independent variables in the model.

Table 2. Tests for the Presence of Unit and Time Effects

Test	H <sub>0</sub> : No unit and time effect.	H <sub>0</sub> : No unit effect.	H <sub>0</sub> : No time effect.
F	1.601	2.459**	0.812
LM	1.615	1.377	0.238
LR	2.11	2.11*	0.27

**Note:** \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The F, LM, and LR tests conducted to assess the joint presence of unit and time effects in the developing countries (EMDEs) model indicate that no unit or time effects are present. The results of these F, LM, and LR tests are consistent with the classical panel tests reported in the literature. Although the general conclusion points to the absence of unit and time effects, a closer examination reveals a low-level unit effect at the 5% and 10% significance levels according to the F and LR tests, respectively. However, when the overall evaluation is considered together with the LM test result, these marginal significance levels are deemed negligible. This indicates that the classical panel data model is compatible with, and stable in relation to, the underlying data structure.

For these reasons, the analysis proceeds with the classical model. Within this framework, the variance inflation factor (VIF) criterion was first applied to test for multicollinearity. The results, presented in Table 3, confirm that the relationships among the independent variables in the model are consistent with the underlying econometric assumptions.

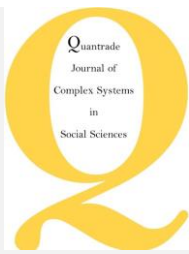
Table 3. Multicollinearity – VIF Criterion

Variables	VIF	Tolerance Coefficient
lasutz	1.4492	0.6900
ynoyo	2.9641	0.3374
lsgkp	2.5183	0.3971
luptsg	2.1933	0.4559

For the developing countries model, all Variance Inflation Factor (VIF) values were found to be below 5, indicating that no multicollinearity problem is present in the model. This finding confirms that the selected variable set is sufficiently stable for estimation and econometrically reliable.

Table 4. Structural Break – Supremum F Test (EMDEs)

Test Statistic	Estimated Break Year	Supremum F Value
F	<u>2021</u>	<u>3.0813**</u>
	2022	2.9206**
	2019	2.6902**
	2020	2.6600**



2018

2.2746 \*

**Note:** \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The presence of a structural break in the developing countries (EMDEs) model was investigated using the Supremum F test, which is employed to identify an unknown break date within the classical model. The test results are presented in Table 4 above.

According to the Supremum F test results, the year 2021 was identified as the date most strongly supporting a structural break, and the null hypothesis ( $H_0$ ) of no structural break for this year was rejected. This finding confirms 2021 as a break point and indicates that the regime analyses reflect a distinct structural change in disaster risk management expenditures (DRME-aryth). The 2021 structural break should be interpreted primarily as a consequence of the systemic shocks induced by the COVID-19 pandemic on the global economy and public finances.

In the post-pandemic period, the fiscal pressure on EMDEs has been significantly heavier compared to developed countries (DCs). Public budgets worldwide have come under great stress due to efforts to manage emergency health expenditures, social support packages, and supply chain disruptions.

Consequently, the 2021 break indicates that DRME-aryth is now determined within a new economic and political framework characterized by increased indebtedness, weak fiscal buffers, and shifting priorities.

The emergence of the structural break in 2021 is associated not only with economic shocks but also with mandatory policy adaptations in disaster financing mechanisms. The pandemic starkly exposed the weak social protection networks and low insurance penetration in EMDEs. Within the framework of disaster risk management, harder policy decisions—such as restricting public spending or turning toward external aid—became necessary from 2021 onwards.

The post-break period confirms that while the responsiveness of EMDEs to DRME-aryth accelerated, expenditure volumes declined due to resource insufficiency, in some cases turning negative—meaning that expenditures decreased as damages increased. This pattern forms the theoretical basis for the negative coefficient of lasutz, which will be examined in the later stages of the analysis.

The current break is a clear indicator of the sensitivity of EMDEs' disaster risk management policies to global crises and external shocks.

To model the impact of the structural break identified in 2021 for developing countries (EMDEs), the base model defined in Equation 1 was extended by adding a break dummy variable ( $D_t$ ) and interaction terms between this variable and the independent variables. This approach captures potential changes in both the intercept and the slope coefficients between the pre-break and post-break regimes.

The mathematical structure of this extended model is expressed in Equations 2 and 3 below:

The structural break-adjusted model equation for the EMDEs is as follows:

$$\text{laryth}_{it} = \beta_0 + \beta_1 \text{lasutz}_{it} + \beta_2 \text{luptsg}_{it} + \beta_3 \text{lsgkp}_{it} + \beta_4 \text{ynoyo}_{it} + \beta_5 D_t + \beta_6 D_t \text{lasutz}_{it} + \beta_7 D_t \text{luptsg}_{it} + \beta_8 D_t \text{lsgkp}_{it} + \beta_9 D_t \text{ynoyo}_{it} + u_{it} \quad (2)$$

The structural break dummy variable for the EMDEs is defined as follows:

$$D_t = 1, \text{ if } t \geq 2021$$

$$D_t = 0, \text{ if } t < 2021 \text{ (otherwise)} \quad (3)$$

The validity of the assumptions regarding the error terms for this extended model will be re-examined in the subsequent stages.

The compliance of the error terms of the extended model established for developing countries (EMDEs) with the normality assumption was examined using the Jarque–Bera, D'Agostino, Shapiro–Wilk, and Anderson–Darling tests. The results of these normality tests are presented in Table 5.

Table 5. Normality Tests

Test Methods	Test Results	p-value/critical values
Jarque-Bera	18.935***	0.000077
D'Agostino	14.960***	0.000564
Shapiro-Wilk	0.949***	0.006104
		%10: 0.624
Anderson-Darling	0.677	%5: 0.748
		%1: 1.038
Skewness (S)		0.9153
Kurtosis (K)		4.7725

**Note:** \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

According to the test results, the null hypothesis ( $H_0$ ) that the error terms are normally distributed is rejected. This finding econometrically demonstrates that the model suffers from a non-normal distribution of the error terms.

To visually examine the deviation of the error terms from the normality assumption in the developing countries (EMDEs) model, the QQ (quantile–quantile) plot and the histogram are presented below.

Visual inspection reveals that the distribution of the error terms exhibits a negatively skewed pattern and a more peaked (leptokurtic) structure than the normal distribution.

The QQ plot in Figure 2 confirms the left-skewed distribution of the error terms and the peaked structure that deviates from normality.

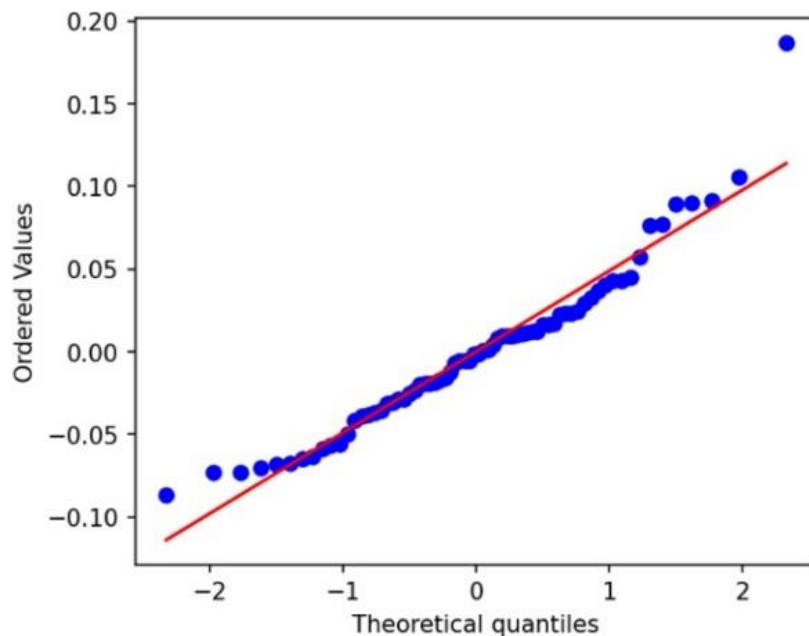


Figure 2. Frequency Distribution of Error Terms (QQ Plot)

Similarly, the histogram presented in Figure 3 shows that the distribution of the error terms is negatively skewed and more peaked than a normal distribution.

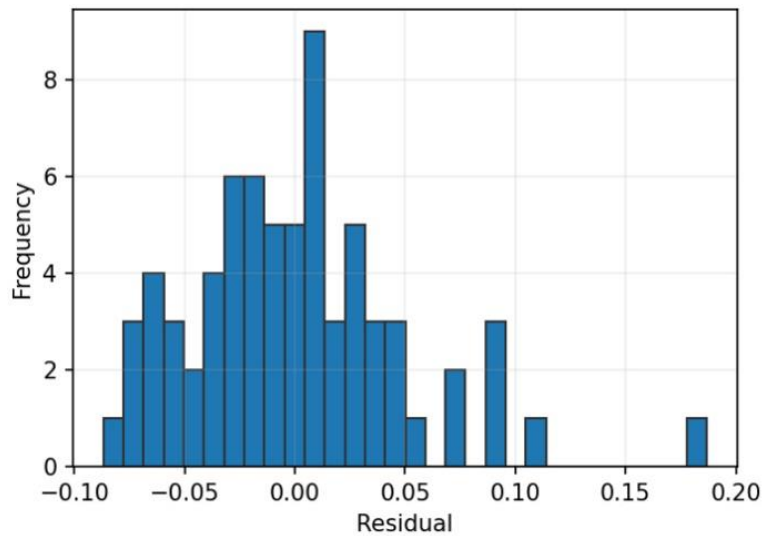


Figure 3. Histogram of Residuals

These visual findings confirm the presence of a non-normal distribution problem in the error terms of the extended model with the dummy variable.

The results of the autocorrelation, heteroskedasticity, and specification error tests performed for the developing countries (EMDEs) model are presented in Table 6.

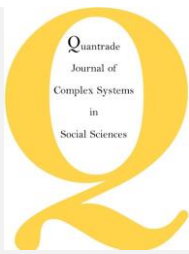
Table 6. Tests for Autocorrelation, Heteroskedasticity, and Specification Error

	Test	Coefficient / Test Statistic
Autocorrelation Test	Durbin-Watson	1.8270
	Breusch-Godfrey (LM)	0.9710
	Breusch-Godfrey (F)	0.1026
Heteroskedasticity Test	Breusch-Pagan (LM)	11.6674
	Breusch-Pagan (F)	1.7716
	White (LM)	19.8410
	White (F)	0.9691
Specification Error Test	Reset (F)	5.9411***
	Reset (Chi-Square)	17.8234***

**Note:** \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The findings obtained from the examinations reveal the level of compliance of the model with econometric assumptions.

The Durbin–Watson and Breusch–Godfrey tests applied to examine the presence of autocorrelation did not reject the null hypothesis of no autocorrelation; accordingly, it was determined that the model exhibits no autocorrelation problem. Similarly, the Breusch–Pagan and White tests conducted within the scope of the heteroskedasticity analysis did not reject the null hypothesis of homoskedasticity, indicating that no heteroskedasticity problem is present in the model. However, the RESET tests (F and Chi-Square) applied to identify specification errors rejected the null hypothesis, revealing the presence of a specification error. This suggests that there may be omitted variables in the model for developing countries (EMDEs).



Ultimately, while the model with structural breaks does not suffer from autocorrelation, heteroskedasticity, or multicollinearity, the specification error and the non-normal distribution problem (as identified in Section 3) persist.

To obtain robust estimates against the non-normal distribution and specification error detected in the developing countries (EMDEs) model, the model was re-estimated using bootstrap standard errors for the periods before the structural break (Regime 1: 2014–2020) and after the break (Regime 2: 2021–2023). This method allows for reliable inferences, particularly in cases where the error terms are not normally distributed. The final estimation results are presented in Table 7.

Table 7. Final Estimation Results (EMDEs)

Variables	Regime 1 (Pre-Break: 2014–2020)	Regime 2 (Post-Break: 2021–2023)
cons	+0.0588***	+0.0675***
lasutz	-1.4918***	-1.5920***
luptsg	+0.0144*	+0.0563***
lsgkp	-0.0005	-0.0052***
ynoyo	+0.9634***	+0.9867***

**Note:** \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

According to the econometric results, post-disaster total economic damage (asutz) exerts the strongest and most statistically significant negative impact on total disaster risk management expenditures (DRME-aryth), with coefficients of  $-1.4918$  before the 2021 break year and  $-1.5920$  after the break. Holding other variables constant, a 1% increase in damage leads to a decrease in expenditures of approximately 1.49% to 1.59%, depending on the regime.

This negative relationship indicates that EMDEs do not tend to meet the fiscal burden arising after a disaster through domestic capacities.

It can be interpreted as these countries choosing to restrict their own budgetary expenditure items by remaining dependent on international funds, loans, or external aid rather than financing disaster losses domestically.

This pattern reflects chronic fiscal vulnerability to external shocks rather than a lack of fiscal discipline in disaster financing.

Examination of the adult literacy rate (ynoyo), one of the demographic indicators, reveals that it exerts an increasing effect on expenditures, with strong, positive, and statistically significant values of 0.9634 in Regime 1 and 0.9867 in Regime 2. The rise in human capital, together with greater risk awareness and organizational capacity, increases public demand for disaster risk management and, consequently, the level of expenditure.

The social security contributions (lsgkp) variable, while statistically insignificant before the 2021 break year, becomes negatively significant in the post-break regime with a coefficient of  $-0.0052$ . Holding other variables constant, a 1% increase in social security contributions leads to a decrease in DRME-aryth of approximately 0.005%.

This slight reducing effect of social security systems on expenditures in the post-break period can be associated with the direct or indirect use of social funds for disaster financing under the intense fiscal burden created by the pandemic.

The positive effect observed for the premium-insurance indemnity indicators (luptsg), which serves as a measure of financial inclusion, strengthened from 0.0144 in Regime 1 to 0.0563 in Regime 2, while remaining statistically significant in both regimes.

Specifically, a 1% increase in the premium-insurance indemnity ratio (luptsg) raised expenditures by approximately 0.01% before the break and by approximately 0.05% after the break.

This positive relationship is interpreted as evidence that the developing insurance sector creates fiscal space for public authorities in the areas of risk reduction and preparedness expenditures, and generates potential for sharing risk reduction costs through private sector participation.

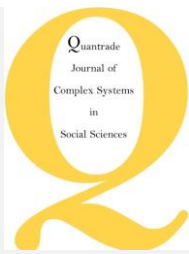
### 3.2. Panel Data Analysis of Developed Countries (DCs-GÜ)

For model selection, information criteria such as the Adjusted  $R^2$ , Mallow's  $C_p$ , the Akaike Information Criterion (AIC), the small-sample corrected AIC (AICC), and the Bayesian Information Criterion (BIC) (Schwarz, 1978) were employed.

For these criteria, lower values indicate a better model fit. Model 6 yielded the lowest values for Mallow's  $C_p$ , BIC, and AICC, and it was also among the models with the highest Adjusted  $R^2$ . Although Model 8 produced the lowest AIC, Model 6 was selected as the appropriate model, since all criteria except AIC pointed to this specification.

Table 8. Model Selection Based on Basic Panel Data Results (DCs)

Model No	Number of Variables	(Adjusted) $R^2$	Mallow's $C_p$	AIC Akaike Information Criterion	AICC Akaike-Corrected	BIC Bayesian Information Criterion	Explanatory Variables	Selection
1	1	0.99015	580.8748	+8.7523	+9.11594	+13.2493	lasutz	✗
2	2	0.99790	71.83733	-98.4963	-97.88094	-91.75084	lasutz, ynoyo	✗
3	3	0.99859	27.68408	-125.5579	-124.6204	-116.5639	lasutz, ynoyo, luptsg	✗
4	4	<u>0.99883</u>	<u>13.17536</u>	<u>-137.7983</u>	<u>-136.4649</u>	-126.5558	lasutz, ynoyo, laetks, luptsg	✗
5	5	0.99891	9.59310	-141.3530	-139.5465	-127.8620	lasutz, ynoyo, laetks, lutn, yun	✗
6	6	<u>0.99896</u>	7.34414	<u>-143.8976</u>	-141.537	-128.158	lasutz, ynoyo, laetks, lutn, lgsyh, yun	✓
7	7	0.99898	7.17111	-144.3411	-141.3411	-126.3532	lasutz, ynoyo, laetks, lutn, lgsyh, lsgkp, yun	✗
8	8	0.99899	7.34954	-144.4573	-140.7285	-124.2208	lasutz, ynoyo, laetks, lutn, lgsyh, lsgkp, yun, lucsh	✗
9	9	0.99898	9.01947	-142.8477	-138.2959	-120.3627	lasutz, ynoyo, laetks, lutn, lgsyh, lsgkp, yun, lucsh, ldasvs	✗



10	10	0.99896	11.0000	-140.8708	-135.3971	-116.1373	lasutz, ynoyo, laetks, lutn, lgsyh, lsgkp, yun, lucsh, ldasvs, luptsg	✘
11	11	0.99895	11.5400	-140.8819	-134.6365	-114.4781	lasutz, ynoyo, laetks, lutn, lgsyh, lsgkp, yun, lucsh, ldasvs, luptsg, lkgsyh	✘

Within the framework of Model 6, selected as the appropriate model for developed countries (DCs) on the basis of the information criteria, the mathematical structure of the model is expressed in Equation 4 below:

The panel data model equation for the DCs is as follows:

$$\text{laryth}_{it} = \beta_0 + \beta_1 \text{lasutz}_{it} + \beta_2 \text{laetks}_{it} + \beta_3 \text{lutn}_{it} + \beta_4 \text{yun}_{it} + \beta_5 \text{ynoyo}_{it} + \beta_6 \text{lgsyh}_{it} + u_{it} \quad (4)$$

In this model, the dependent variable is used in its logarithmic form (LDRME-laryth) to render total disaster risk management expenditures suitable for econometric analysis. The set of independent variables consists of the logarithmic forms of total damage caused by disasters (lasutz), the total number of people affected by disasters (laetks), the total population of the countries (lutn), and gross domestic product (lgsyh). Additionally, the share of the population aged 65 and over (yun) and the adult literacy rate (ynoyo) are included in the model in their original forms, without any transformation in the econometric analyses.

The correlation graphs illustrating the relationships among the variables in the developed countries (DCs) model are presented in Figure 4.

These graphs reveal a notably high and positive correlation between the dependent variable, disaster risk management expenditures (DRME-aryth), and total post-disaster economic damage (asutz). This finding indicates that, as in the developing countries (EMDEs) model, disaster-related costs exert strong pressure on the budgets of developed countries as well. Relatively moderate relationships are observed among the other variables in the model.

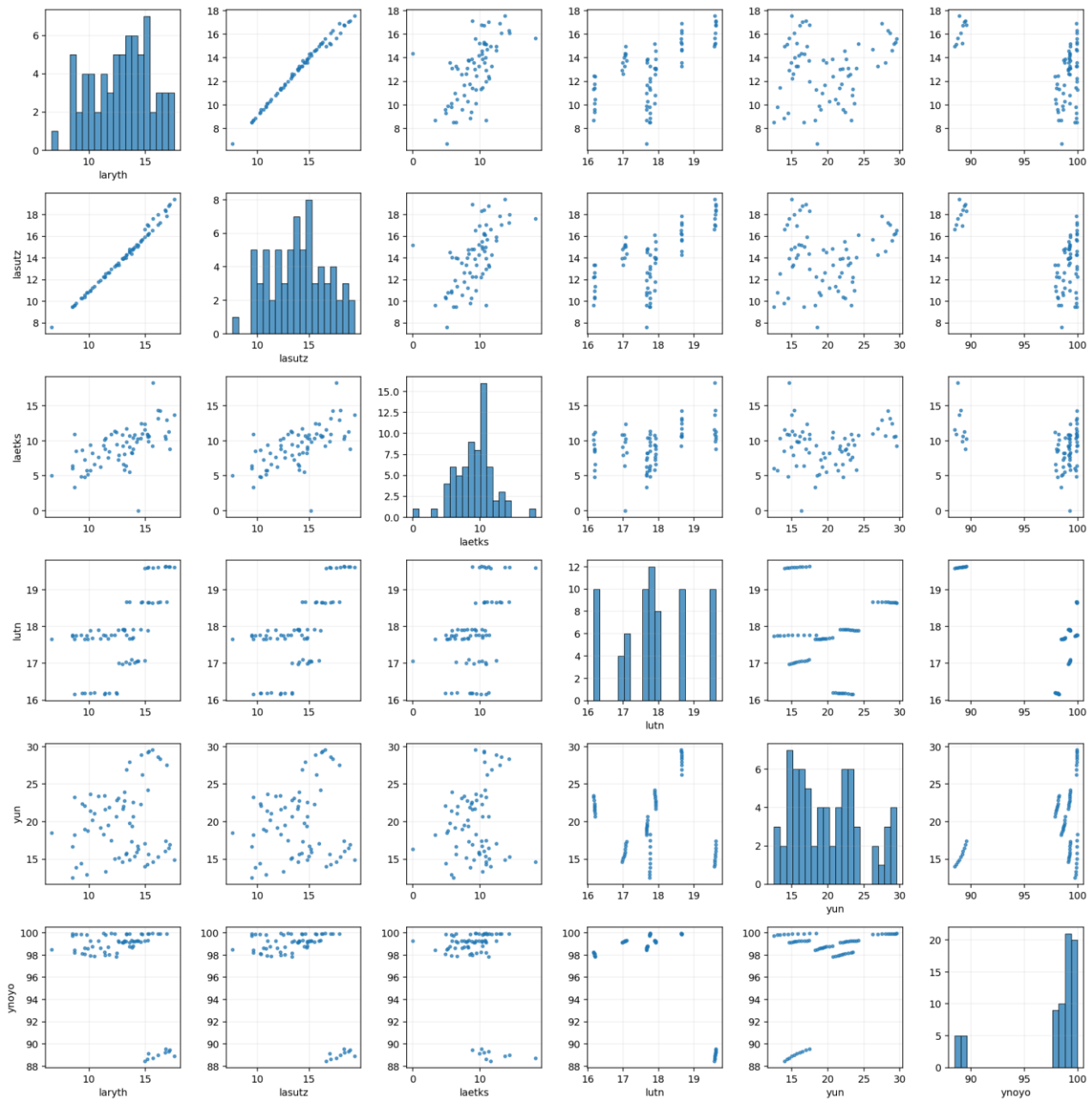


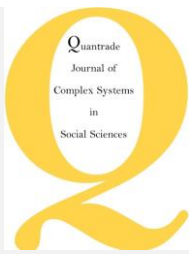
Figure 4. Correlation Matrix and Histograms of Variables (DCs)

To examine the presence of unit and time effects in the developed countries (DCs) panel data model, the F, LM, and LR tests were first applied.

The test results presented in Table 9 reveal the findings regarding the joint presence of unit and time effects.

Table 9. Tests for the Presence of Unit and Time Effects

Test	H0: No unit and time effect.	H0: No unit effect.	H0: No time effect.
F	2.246**	2.459**	1.494



LM	2.496	1.840	0.657
LR	0.62	0.00	0.62

**Note:** \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively

The tests for the joint presence of unit and time effects, when evaluated alongside results other than the F-test, indicate that no unit or time effects are present in the model. Although it is theoretically unnecessary to test for the existence of individual unit or time effects in this case, a closer examination reveals a low-level unit effect with marginal significance according to the F-test.

The obtained test results are consistent with the classical panel data methodology in the literature (Baltagi, 2008; Greene, 2018). For these reasons, the analysis proceeds with the classical model. First, the presence of multicollinearity was examined within the classical model established for developed countries (DCs), and the variance inflation factor (VIF) criterion results are presented in Table 10.

Table 10. Multicollinearity – VIF Criterion

Variables	VIF	Tolerance Coefficient
lasutz	4.5674	0.2189
ynoyo	2.5851	0.3868
lgsyh	4.5854	0.2224
lutn	6.8236	0.2271
yun	2.4359	0.4105
laetks	1.6727	0.5979

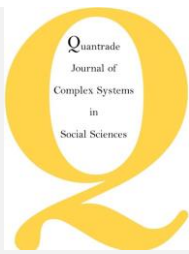
When the table results are examined, the VIF values of all variables are below 5, with the exception of the total population (lutn) variable. Although the VIF value of lutn is higher than the others, it remains below the generally accepted threshold of 10 in the literature. Based on these results, it is concluded that no multicollinearity is present in the model. This finding confirms that the selected variable set is sufficiently stable for estimation and provides an econometrically reliable foundation.

The presence of a structural break in the developed countries (DCs) model was investigated using the Supremum F test, which is employed to identify an unknown break date within the classical model. The test results are presented in Table 11.

Table 11. Structural Break – Supremum F Test (DCs)

Test Statistic	Estimated Break Year	Supremum F Value
F	2016	2.9134**
	2020	1.3840
	2021	1.3381
	2018	1.0197
	2017	1.0062

**Note:** \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively



According to the Supremum F test results, the structural break for the model was identified as the year 2016. This finding indicates a distinct structural change in disaster risk management expenditures (DRME-aryth).

The fact that the structural break in the developed countries model emerged earlier than in the developing countries (the year 2021) indicates that these countries underwent a proactive policy shift in their disaster risk management dynamics.

Global agreements such as the 2015 Paris Climate Agreement and the Sendai Framework for Disaster Risk Reduction (2015–2030) triggered a rapid adaptation in the fiscal and institutional structures of developed countries.

Developed countries, owing to their generally stronger governance and fiscal capacity, rapidly integrated these global commitments into their national budgets. During this period, expenditures shifted away from reactive post-disaster recovery costs toward proactive risk reduction and preparedness activities.

The break year of 2016 coincides with the onset of efforts by many developed countries to enhance disaster resilience and to integrate complex risks, such as climate change, into public finance.

This break is also associated with the official recognition of the impact of demographic pressure on costs in developed countries. An aging population structure increases the costs of specialized protection and long-term care during disasters.

Throughout the 2015–2017 period, the rise in health and social security expenditures in developed countries influenced the planning of risk financing.

Thanks to their high fiscal capacity, these countries were able to incorporate the additional expenditure burden into their budgets at an earlier stage. Consistent with the findings, this policy adaptation emerged not as a result of a sudden external shock, as in the case of developing countries, but as an internal necessity driven by long-term structural risks.

This situation reflects the fiscal flexibility of developed countries and their capacity to initiate policy changes early, independently of macroeconomic shocks.

The structural break-adjusted model equation for the DCs is as follows:

$$\text{laryth}_{it} = \beta_0 + \beta_1 \text{lasutz}_{it} + \beta_2 \text{laetks}_{it} + \beta_3 \text{lutn}_{it} + \beta_4 \text{yun}_{it} + \beta_5 \text{synoyo}_{it} + \beta_6 \text{lgsyh}_{it} + \beta_7 D_t + \beta_8 D_t \text{lasutz}_{it} + \beta_9 D_t \text{laetks}_{it} + \beta_{10} D_t \text{lutn}_{it} + \beta_{11} D_t \text{yun}_{it} + \beta_{12} D_t \text{synoyo}_{it} + \beta_{13} D_t \text{lgsyh}_{it} + u_{it} \quad (5)$$

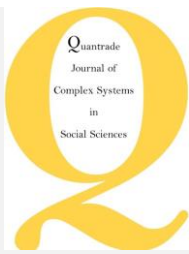
The structural break dummy variable for the DCs is defined as follows:

$$\begin{aligned} D_t &= 1, \text{ if } t \geq 2016 \\ D_t &= 0, \text{ if } t < 2016 \text{ (otherwise)} \end{aligned} \quad (6)$$

Based on this extended model, the fundamental econometric assumptions regarding the error terms will be re-examined in the subsequent stages.

The compliance of the error terms with the normality assumption for the extended model designed for developed countries (DCs) was examined using the Jarque–Bera, D'Agostino, Shapiro–Wilk, and Anderson–Darling tests. The results of these normality tests are presented in Table 12.

According to the results of all applied tests, the null hypothesis ( $H_0$ ) that the error terms are normally distributed is rejected.



This finding econometrically demonstrates that the model exhibits a non-normality problem with respect to the error terms.

Table 12. Normality Tests

Test Methods	Test Results	p-value/critical values
Jarque-Bera	93.4565***	0.000077
D'Agostino	22.8359***	0.000564
Shapiro-Wilk	0.9015***	0.006104
Anderson-Darling	1.2809	%10: 0.624 %5: 0.748 %1: 1.038
Skewness (S)		-0.7328
Kurtosis (K)		8.4676

Note: \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively

The QQ (quantile–quantile) plot and the histogram, prepared to visually examine the deviation of the error terms from the normality assumption in the developed countries (DCs) model, are presented below.

The visual inspection conducted supports the non-normality problem identified in Section 3.2.

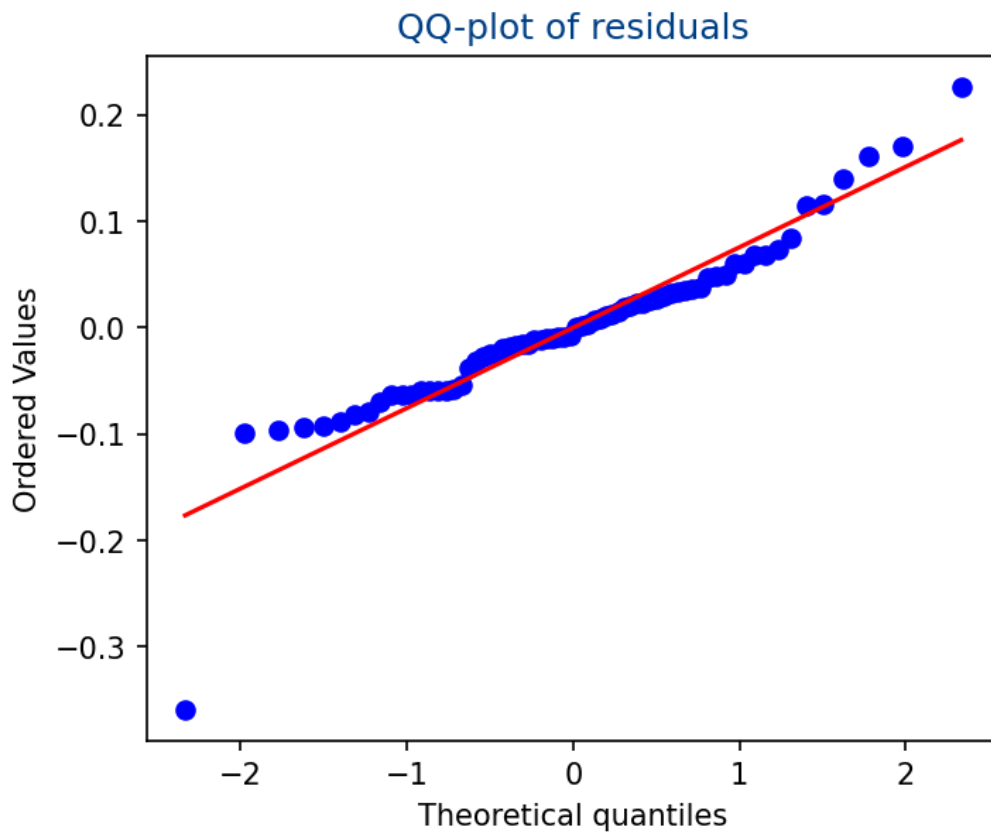


Figure 5. Frequency Distribution Plots of Error Terms (QQ Plot)

Examination of the QQ plot presented in Figure 5 reveals that the distribution of the residuals exhibits positive skewness and a higher level of kurtosis than the standard normal distribution.

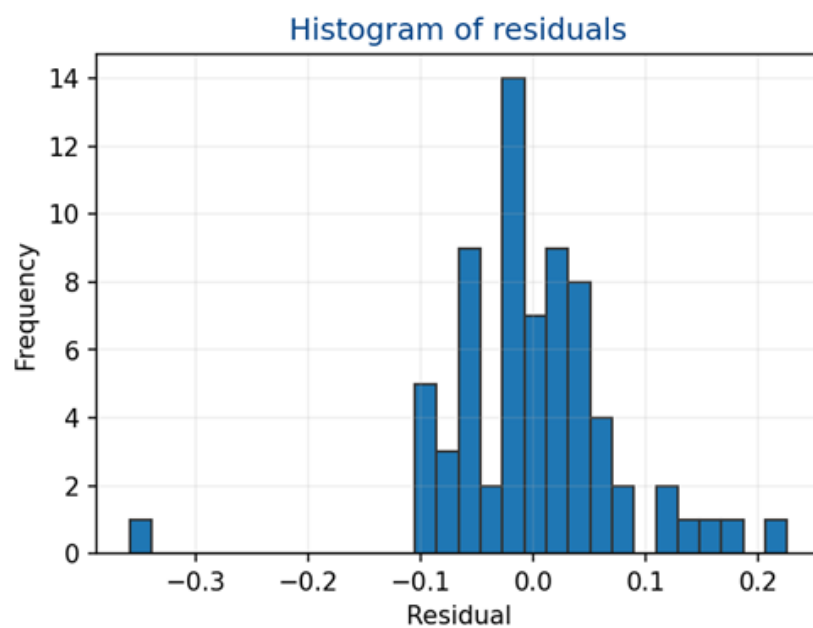


Figure 6. Histogram of Residuals

Similarly, examination of the histogram in Figure 6 reveals that the distribution of the error terms is positively skewed and exhibits a more peaked (leptokurtic) structure than the normal distribution. These visual findings further confirm that the assumption of normal distribution for the error terms of the model is not satisfied.

Table 13. Tests for Autocorrelation, Heteroskedasticity, and Specification Error

	Test	Coefficient / Test Statistic
Autocorrelation Test	Durbin-Watson	2.4951
	Breusch-Godfrey (LM)	18.9427***
	Breusch-Godfrey (F)	8.3425***
Heteroskedasticity Test	Breusch-Pagan (LM)	19.2464***
	Breusch-Pagan (F)	3.9817***
	White (LM)	30.7262***
	White (F)	1.2170
Specification Error Test	Reset (F)	1.2316
	Reset (Chi-Square)	3.6948

**Note:** \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively

The results reveal the extent to which the model complies with the fundamental econometric assumptions.

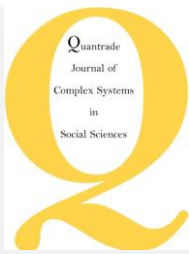
According to the Durbin–Watson and Breusch–Godfrey test results applied to examine the presence of autocorrelation, the model exhibits an autocorrelation problem. Similarly, all test results within the scope of the heteroskedasticity analysis, except for the White F test, indicate the presence of a heteroskedasticity (non-constant variance) problem in the model. The RESET tests (F and Chi-Square) conducted to identify specification errors did not reject the null hypothesis, leading to the conclusion that the model exhibits no specification error.

Ultimately, while the developed countries model with structural breaks does not suffer from specification error or multicollinearity, autocorrelation, heteroskedasticity, and non-normal distribution problems persist.

To obtain robust estimates against the problems identified in the extended model for developed countries (DCs), bootstrap robust standard errors were employed. Using this robust method, the model was re-estimated for the periods before the structural break (Regime 1: 2014–2015) and after the break (Regime 2: 2016–2023), and the final estimation results are presented in Table 14.

Table 14. Final Estimation Results (DCs)

Variables	Regime 1 (Pre-Break: 2014–2015)	Regime 2 (Post-Break: 2016–2023)
cons	-4.4035***	-4.9214***
lasutz	+0.9749***	+0.9978***



laetks	-0.0003	-0.0164***
lutn	+0.0192	-0.2779***
yun	+0.0157**	+0.0115***
ynoyo	+0.0460***	+0.0570***
lgsyh	-0.0690	+0.1502***

**Note:** \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively

According to the econometric results, post-disaster total economic damage (lasutz) exerts the strongest, positive, and statistically significant impact on total disaster risk management expenditures (DRME-aryth), with coefficients of 0.9749 before the break year and 0.9978 after the break. Holding other variables constant, a 1% increase in disaster damages raises expenditures by approximately 0.97% to 1.00%, depending on the regime.

This indicates that, owing to their high fiscal capacity and advanced insurance systems, developed countries are able to rapidly mobilize their own economic resources against disaster losses without remaining dependent on external aid. This positive relationship suggests that disaster losses directly trigger expenditure budgets toward both proactive prevention and reactive recovery.

The fact that certain variables became statistically significant after the break year, despite being insignificant before 2016, indicates that developed countries underwent a structural and financial transformation in their disaster risk management policies starting from 2016.

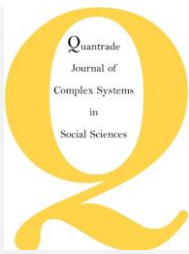
This pattern reflects the permanent integration into developed country budgets brought about by the 2015–2016 global policy adaptations (the Paris Climate Agreement and the Sendai Framework for Disaster Risk Reduction) discussed in the previous section.

The finding that the share of the population aged 65 and over (yun), one of the demographic indicators, is positive and highly statistically significant demonstrates that the demographic structure has transformed the way disaster impacts are managed, and that demographic-based protection needs have gained priority in expenditures.

The increasing vulnerability and special needs of the elderly population impose additional and mandatory costs on the disaster budgets of developed countries through items such as hospital capacity, specialized evacuation procedures, and home care protocols. This confirms the integrated nature of disaster management with social services in developed economies.

#### 4. Conclusion

In this study, the determinants of disaster risk management expenditures (DRME-aryth) were examined using a comparative panel data model for developed countries (DCs) and developing countries (EMDEs). The results demonstrate that the fiscal and social impacts of disasters vary significantly according to the structural characteristics of the countries.



In the developing countries (EMDEs) model, post-disaster economic damage ( $\lambda_{\text{asutz}}$ ) exerts a strong and statistically significant negative impact on total disaster risk management expenditures ( $\text{LDRME-}\lambda_{\text{aryth}}$ ). This negative relationship indicates that increasing damages lead to a contraction rather than an expansion of  $\text{DRME-}\lambda_{\text{aryth}}$ .

This finding highlights the inadequacy of national capacity and the over-reliance on external aid in the face of external shocks among EMDEs (Kousky, 2014). Rather than allocating funds from their own budgets at the time of a disaster, EMDEs tend to freeze or reduce existing expenditure budgets and turn instead to international financial mechanisms. This pattern is consistent with the findings of Noy (2009) and Cabezon et al. (2015), who similarly report that EMDEs suffer disproportionately heavier macroeconomic damage from disasters and exhibit weaker fiscal responsiveness compared to developed countries.

While this finding is expected given the structural constraints of developing economies, the critical issue is how this financial dependency can be transformed into resilience.

A fundamental question arises: How can EMDEs channel the external aid and international financial support they receive—aimed at compensating for economic losses and capacity inadequacies—into productive areas that can trigger a structural transformation in disaster risk management policies? Transforming such aid from mere "wound-healing" mechanisms into integrated infrastructure investments and risk reduction strategies that enhance long-term resilience constitutes the most important dimension of disaster finance debates in the literature.

Another significant finding in the EMDEs-GOÜ group is the strong positive effect of the adult literacy rate ( $\lambda_{\text{noyo}}$ ) on expenditures. This demonstrates that as education levels and human capital increase, societal awareness of disaster risks rises, generating demand for higher-quality disaster management from public authorities and thereby driving up expenditures.

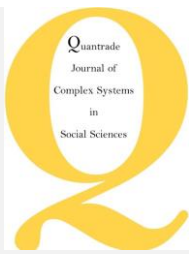
In this context, the adult literacy rate ( $\lambda_{\text{noyo}}$ ), which is statistically significant for both country groups, plays a key role in the success of such policy transformation. Policymakers should prioritize channeling external aid and national budget resources not only toward physical infrastructure but also toward education programs that enhance societal risk awareness and human capital capacity.

A society with a high level of education will act as the most important social engine of a Schumpeterian transformation by demanding more transparent and results-oriented management of disaster risk expenditures. Furthermore, factors such as social security contributions ( $\lambda_{\text{sgkp}}$ ) and premium-insurance indemnity indicators ( $\lambda_{\text{uptsg}}$ ) play significant roles in expenditure dynamics.

In the developed countries (DCs) model, the post-disaster economic damage coefficient exerts a significant and positive effect on total expenditures, confirming that these countries rapidly mobilize their own fiscal resources against disaster losses without remaining dependent on external aid.

Expenditure dynamics in DCs are shaped by demographic structure, such as the share of the population aged 65 and over, and by fiscal capacity indicators such as gross domestic product.

These findings are consistent with the literature, particularly with Skidmore and Toya (2002) and Felbermayr and Gröschl (2014), who emphasize that developed economies—owing to their stronger institutions and fiscal capacity—are better able to absorb disaster shocks and convert reconstruction into long-term productivity gains.



This demonstrates that developed countries proactively plan their disaster management policies to cover long-term demographic risks and integrate the specialized protection costs of the elderly population into their budget discipline. In developed countries, where literacy rates have reached saturation, expenditure flexibility shifts toward demographic needs such as the aging population.

In contrast, in developing countries, where literacy levels are still rising, education-based awareness continues to play a key role in expanding disaster budgets.

Based on the analyses, this study reaches two fundamental conclusions.

First, the economic and social impacts of disasters differ according to the development level of the countries. While social vulnerability and economic loss are the dominant determinants in the EMDEs-GOÜ group, demographic structure and fiscal capacity come to the fore in the DCs-GÜ group.

Second, disaster risk management expenditures exhibit a multi-dimensional determinant structure, in which both disaster severity and socioeconomic indicators simultaneously play effective roles in the process.

**Policy Implications:** The findings of this study offer several actionable policy implications for both country groups. For EMDEs, the strong negative relationship between disaster damages and DRME-aryth underscores the urgency of redirecting external aid and concessional financing away from short-term relief and toward long-term resilience investments—such as risk-reducing infrastructure, early warning systems, and disaster insurance penetration.

Strengthening adult literacy and risk-awareness programs would further amplify the multiplier effect of disaster expenditures on economic recovery and human development.

For DCs, where fiscal capacity is robust, the priority lies in adapting public budgets to the rising costs imposed by demographic aging, by integrating specialized protection mechanisms for the elderly into mainstream disaster financing frameworks.

From a broader macroeconomic perspective, channeling disaster expenditures into productive resilience investments rather than reactive recovery can generate positive externalities—reducing future output losses, stabilizing public debt trajectories, and supporting sustainable growth.

These policy directions align with the Sendai Framework for Disaster Risk Reduction (2015–2030) and contribute directly to the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

Table 15. Variables, Definitions, and Data Sources

Variable	Code	Type	Definition	Transformation	Source
Total disaster risk management expenditures	DRME-aryth	Dependent	Government spending on disaster risk reduction, preparedness, emergency response, and recovery	Logarithm (LDRME-laryth)	UNDRR, OECD
Total damage from disasters	asutz	Disaster-related	Monetary value of total economic damage caused by disasters	Logarithm (lasutz)	EM-DAT

Total people affected by disasters	aetks	Disaster-related	Number of people affected by disasters	Logarithm (laetks)	EM-DAT
Frequency of disaster occurrences	dasvs	Disaster-related	Annual count of disaster events	Logarithm (ldasvs)	EM-DAT
Adult literacy rate	ynoyo	Socioeconomic	% of population aged 15+ who can read and write	Original form	World Bank, UNESCO
Population aged 65 and over	yun	Socioeconomic	% of total population aged 65+	Original form	World Bank
Total population	utn	Socioeconomic	Total population of the country	Logarithm (lutn)	World Bank
Social security contributions	sgkp	Socioeconomic	Government revenue from social security contributions	Logarithm (lsgkp)	IMF, OECD
Current health expenditures	ucsh	Socioeconomic	Total current health expenditures (% of GDP)	Logarithm (lucsh)	WHO, World Bank
Premium-insurance indemnity indicators	uptsg	Socioeconomic	Insurance premium and indemnity volumes	Logarithm (luptsg)	OECD, national sources
Gross domestic product	gsyh	Macroeconomic	Total economic output of the country	Logarithm (lgsyh)	World Bank, IMF
GDP per capita	kgsyh	Macroeconomic	GDP per capita expressed in US dollars	Logarithm (lkgsyh)	World Bank, IMF

### Ethical Considerations of the Study

It is declared that the study was designed to realistically and ethically meet the needs, and that integrity was maintaining in obtaining data, concluding the study, and publishing the results. Ethical committee approval was not required for this research. No research requiring ethics committee approval was conducted in this study.

### Informed Consent

There was no need to obtain informed consent from individuals, as the study did not involve any procedure or interventions on human participants.

### Author Contributions

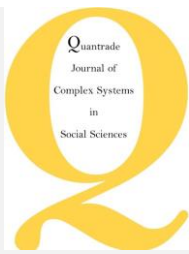
Idea/Concept: T.I., H.T.; Design: T.I., H.T.; Supervision/Consultancy: T.I., H.T.; Resources: T.I., H.T.; Data Collection and/or Processing: T.I., H.T.; Analysis and/or Interpretation: T.I., H.T.; Literature Review: T.I., H.T.; Writing: T.I., H.T.; Critical Review: T.I., H.T.

### Conflict of Interest Statement

The author declares no conflict of interest.

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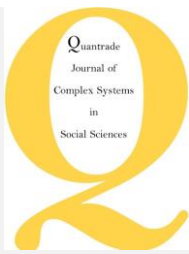


## Declarations

This study has not been presented at any congress. This article is derived from the empirical chapter of the first author's doctoral dissertation (Ibis, 2026).

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