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Research article

Do natural disasters affect economic growth? The role of human capital, foreign direct investment, and infrastructure dynamics

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A R T I C L E I N F O

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A B S T R A C T

Natural disasters do occur and have become a global problem due to increasing intensity. Developing countries are mostly affected due to natural disasters owing to a poor environment, feeble adaptation, impoverished socioeconomic conditions, poor infrastructure, limited resources, and unstable institutions. The SDG 11.5 target which highlights the mitigation of loss due to natural disasters—remains crucial to achieving sustainable cities and human settlements—but the literature is limited on this scope. Thus, this research contributes to the literature by incorporating an infrastructure index, foreign direct investment (FDI), human capital index, globalization, and capital formation into the disaster-growth debate across four-income groups in 98 countries from 1995 to 2019. We developed infrastructure and human capital indices using a standard procedure across all income groups. The two-step generalized method of moments employed herein confirmed the income reduction effect of natural disasters. While the economic cost of natural disasters is relatively high in low-income countries and mild in high- and upper-middle-income countries. Besides, infrastructural development, FDI, human capital, globalization, and gross fixed capital formation also affect economic growth across income groups. Thus, the enhancement of socio-economic policies could decline economic losses, especially in vulnerable and poor settlements in developing countries.

1. Introduction

Natural disasters do occur [1] and have become a global problem due to increasing intensity [2,3]. The occurrence of natural disasters including floods, landslides, extreme temperatures, wildfires, earthquakes, epidemics, insect infection, droughts, mass movement (dry), storms, and volcanic activities have increased globally [4,5]. A disaster is a sudden loss in factors of production such as capital and labor, to which the economic system adjusts, either shifting towards a new equilibrium or returning to the pre-disaster equilibrium [6]. There are 13,386 reported global natural disasters that account for 3.6 million human lives, 7.7 billion affected persons, and $3.3 trillion in economic loss [4,7]. These are accountable for direct (i.e., human deaths, property loss, and injuries) and indirect damages (fall in potential wages and capital) [5], and also hamper health, education, nutrition, and several income-earning activities [8]. The reconstruction of damaged infrastructures (e.g., buildings, roads, and bridges) is accountable for budget

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adjustments, economic contraction, and higher government expenditures [9]. The cost of disasters is relatively higher in the developing world [10]. For example, about 90% of disaster-related fatalities are recorded in developing economies [11]. Natural disasters have become a serious issue in developing economies owing to poor environments, indigent socioeconomic conditions, feeble adaptation [12], poor infrastructure, unstable institutions, and limited resources [13]. Further, developing economies do not have suitable disaster mitigation and restructuring plans, and up-gradation of the public physical infrastructure [14,15].

Natural disasters occur when hazards interact with economic, social, environmental, and physical vulnerabilities. The level of development and economic structure typically determines country-specific vulnerability to natural disasters [16]. Further, climate change accounts for the intensity and occurrence of extreme weather events (i.e., heat waves, droughts, cold spells, and floods) [17]. While climate change is not the cause of all disasters, it remains responsible for the intensity and frequency of most natural disasters [18]. It is forecasted that damage due to disasters will increase in the presence of vulnerable modern societies and climatic changes [5]. A skyrocketed increase in the frequency and intensity of natural disasters indicates the need for sustainable cities and human settlements [4,5]. The awareness of socio-economic consequences of natural disasters has increased demand from private and public sectors to reduce disaster losses [19]. The consequences of natural disasters on global economies depend on the size of the economy and the geographical location [20]. The cost of natural disasters depends on exposure, risk, vulnerability, intensity, duration, frequency, and magnitude [21].

The Sustainable Development Goal (SDG)-13 named "Climate Action" highlights the importance of climate change mitigation. Its first target (SDG-13.1) entails increasing resilience and adaptive capacity to cope with natural disasters and climate-related hazards [22]. SDG-13 implies the promotion of climate action, particularly against extreme weather and natural disasters [23]. Also, the SDG 11.5 target implies the need of reducing disaster-related human and economic losses [24]. The SDG 11.5 target remains crucial to achieving sustainable cities and human settlements but the literature is limited on this research area. Thus, investigating the impact of climate change-induced natural disasters on global economies is an emerging research area [25]. The severity of natural disasters prompted the United Nations (UN) to conceptualize the 2015–2030 Sendai Framework for disaster risk reduction (DRR). The framework seeks to minimize the risk of ongoing disasters and avoid future disasters via the integrated execution of social, economic, political, environmental, structural, educational, institutional, cultural, health, technological, and legal measures [26]. The four established priorities in the framework include (1) realizing the risk of disasters, (2) good governance to cope with disaster risk, (3) investing in DRR, and (4) enhancing readiness for a quick response, and "building back better" in rehabilitation, reconstruction, and recovery [27].

A comprehensive policy is beneficial across the world to achieve sustainable development. Sustainable development ensures the institution of strategies and policies to fulfill the demands of present generations without disturbing the demands of future generations [28]. Thus, researchers and decision-makers are concerned about the consequences of natural disasters on humanity and the economy (local and global economies) [29], and plans (comprehensive policy) to execute recovery/relief [30]. Thus, the outcomes of the present research will help policymakers to make a comprehensive policy to diminish the socio-economic consequences of disasters.

Yet, literature that discusses the long-run consequences of disasters and socioeconomic drivers on sustainable development is limited and lacks consensus across income groups. Considering the Sendai Framework for DRR and the lack of extensive literature, we address the following research questions: first, what is the impact of natural disasters on economic development? Second, are there heterogeneous effects of disaster-growth relationships across income groups? And third, what is the role of human capital, FDI, and infrastructure in the disaster-growth relationship?

In response to these research questions, the main objectives of this study are.

1. To reveal the effect of natural disasters on economic growth.
2. To investigate the heterogeneity of disaster-growth relationships across income groups.
3. To explore the impact of human capital, FDI, and infrastructure on economic growth.

The effects of natural disasters on economic indicators remain unclear due to inconsistent results (i.e., negative, positive, and neutral effects on the economy) reported in the extant literature [5]. Thus, economists make a significant effort to explain the determinants of economic growth [31]. In recent years, the productivity effects of natural disasters have gained responsiveness from economists [32]. The economics of natural disasters reveals two major strands. First, a handful of studies have discussed the impact of natural disasters on macroeconomic indicators. Second, other studies have investigated the relationship between individuals and their coping capacity to face natural disasters [25]. Dacy and Kunreuther [33] initiated the research on socio-economic effects of disasters. The debate between natural disasters and economic development is still alive due to the potential risks of climate change. Theoretical and qualitative analysis of development-led-disaster risks and disaster risk-led-development constraints is widely accepted. However, the empirical analysis of this complex relationship remains contested [34]. The empirical question remains on the economic impact of natural disasters [35]. Yet, the available studies fail to consider disaster risk in the socio-economic framework [36].

Natural disasters generally have adverse impacts on economic activities, hence, some studies highlight the need for comprehensive policies to mitigate the consequences of natural disasters [25]. In Vietnam, Noy and Vu [37] confirmed the lower output growth in fatal disasters but the economy showed a short-run boost for disasters that destroyed more capital and property. They confirmed the 'investment-producing destruction' hypothesis. However, the macroeconomic effect of a natural disaster may vary across countries. Later, Fomby et al. [38] examined the impact of natural disasters (i.e., earthquakes, floods, storms, and droughts) on two components of GDP growth (i.e., agricultural and non-agricultural) in 84 countries. Natural disasters showed heterogeneous effects across countries, however, the effects were mild in developed countries than in developing countries. Unlike others, some disasters showed a favorable influence on economic growth. Moderate floods showed a favorable impact on economic growth through an increase in agricultural productivity. But severe disasters were accountable for the worse impact on economic activities. Similarly, Loayza et al. [15] reported that developing economies experienced more loss during disasters. The adverse impacts may show heterogeneous effects, depending on the type and intensity of natural disasters. Later, Shabnam [39] reported an adverse impact of floods on economic growth and found 0.005% reduction in per capita GDP growth for 1000 out of 1 million population affected by floods. However, the study found the possibility of a favorable impact on long-run economic growth due to other characteristics namely proper rebuilding and innovation. Using a large panel, Sodhi [40] showed the consequences of natural disasters on income and economic growth in 179 economies. The vulnerability of society increased due to natural disasters. Pakistan is located in an extreme risk zone in terms of natural disasters. Due to this, Baig et al. [41] explained the causality between economic growth and natural disasters in Pakistan. The results confirmed an inverse link between economic growth and natural disaster loss. The causality analysis established a one-way

Table 1
Literature on the relationship between natural disasters and socio-economic indicators.

Author(s)	Variables	Location	Technique(s)	Time	Findings
Baig et al. [41]	GDP, natural disasters	Pakistan	ARDL bound test	1977–2015	1) An inverse link exists between natural disasters and economic performance. 2) One-way causality exists from natural disasters to economic growth.
Benali et al. [16]	The budget deficit, public debt, GDP, natural disasters	9 MICs	DH causality, FMOLS, DOLS	2000–2014	1)One-way causality from natural disasters to the budget deficit. There exists a two-way causality between public and budget deficit.
Mohan et al. [42]	Export, investment, import, private & government consumption, hurricane index	21 Caribbean countries	Bias-corrected least squares	1970–2011	1)The impact of natural disasters has a diversified impact on each component of GDP. 2)Natural disasters affect import, export, investment, and private & public consumption.
Mukherjee and Hastak [46]	Economic growth, natural disasters, population, trade, investment share of PPP	189 countries	Random parameter modeling	1970–2010	1)Regions or countries show variations in terms of risk factors like disaster intensity (fatalities, homelessness) and economic indicators.
Lee and Tang [43]	GDP, poverty, natural disasters, financial development	Philippines	Toda and Yamamoto (TY) causality test	1974–2014	1)Two-way causal links exist among poverty, growth, and financial development. 2)One-way causality exists from disasters to financial development and economic growth.
Panwar and Sen [5]	Natural disasters, GDP, financial burden, agricultural and non-agricultural growth, education, trade, financial depth, and inflation,	102 countries	GMM	1981–2015	1)The relationship between natural disasters and economic sectors showed variation subject to intensity and type of disasters. 2)Developing world faced more economic damage due to natural disasters.
Khan et al. [25]	Economic growth, natural disasters, fiscal balance, and FDI	B&RIC	GMM, Driscoll & Kraay	1990–2018	1)Severe natural disasters show adverse impacts on economic growth, FDI, fiscal balance. 2)Trade, FDI, and economic activities show a favorable impact on fiscal balance.
Batala et al. [20]	Industrial growth, natural disasters, FDI, and export performance	South Asian Countries	AMG estimator	1990–2016	1)Natural disasters show an adverse impact on FDI. 2)Results show a partially positive impact of natural disasters on exports. 3) Natural disasters reveal a positive association with industrial growth.
Wang et al. [47]	GDP, natural disasters, FDI	HICs, UMICs, LMICs, LICs	Fixed effect regression	1980–2019	1)Natural disasters hurt growth in LICs and MICs. 2)The economy shows comparatively faster convergence towards the pre-disaster level in HICs due to greater domestic economic capacity.

Abbreviations: AMG: Augmented mean group; ARDL: Autoregressive Distributed Lag; B&RIC: Belt and Road initiative countries; DH: Dumitrescu and Hurlin; DOLS: Dynamic Ordinary Least Square; FMOLS: Fully Modified Ordinary Least Square; GMM: Generalized Method of Moments; PPP: Purchasing Power Parity; MICs: Middle-Income Countries.

causality from natural disasters to economic growth. In 21 Caribbean countries, Mohan et al. [42] extended the literature in terms of four components of national income accounting. The study revealed diversified effects of disasters on various parts of GDP (i.e., consumption, investment, government expenditures, export, and import). Due to diversified effects across different sectors, it was difficult to estimate the clear and cumulative effect of natural disasters and hurricanes on GDP. In the Philippines, Lee and Tang [43] established one-way causality from natural disasters to economic growth and financial development and a two-way causal relationship between economic growth, poverty, and financial strengthening. Oliveira [44] reported that natural disasters were accountable for the reduction in GDP growth in Brazil. Climate change mostly deteriorated the agricultural and services sectors while the industrial sector was less sensitive to environmental issues. The economy showed sensitivity subject to large natural disasters, which further led to the situation of emergency. Panwar and Sen [5] revealed disaster-related human and economic impacts in 73 developing and 29 developed economies. The loss was higher in developing nations, subject to the intensity and type of natural disasters.

Kukułka [45] included FDI in the disaster-growth framework in the case of East Asian economies. Results confirmed a reduction in FDI due to the occurrence of natural disasters, which negatively affects the economic growth in Malaysia and Thailand. Further, Khan et al. [25] studied the effect of natural disasters on per capita economic growth, FDI, and fiscal balance in Belt and Road initiative countries (B&RIC). Results confirmed an adverse long-run economic impact of natural disasters, which in turn showed negative impacts on FDI and fiscal balance. However, economic activities, FDI, and trade have the potential to improve the fiscal balance. Further, FDI showed more sensitivity subject to natural disasters. Extending the literature, Batala et al. [20] considered the effect of natural disasters on FDI, industrial growth, and exports in South Asia. Results showed a negative impact of severe natural disasters on FDI while the impact was partially positive on exports. Moreover, trade openness and income level were identified as positive determinants of industrial growth, FDI, and export performance. Only Guo et al. [2] considered human capital in this debate in China from 1985 to 1998. Results confirmed a non-significant effect of natural disasters on economic growth. Results confirmed an increase in economic growth through human capital after the occurrence of meteorological disasters.

Reviewing the existing literature (Table 1) on natural disasters and their socio-economic consequences, there are still research gaps. First, previous studies failed to assess the impact of infrastructure in the disaster-growth debate. Second, no study investigated the role of human capital in the disaster-growth framework, which in turn reduces disaster risks (i.e., as in the Sendai Framework for disaster risks). Third, the impact of globalization on the disaster-growth nexus remains unclear. Fourth, the literature is limited to the heterogeneous disaster-growth relationship across World Bank income groups. Therefore, our research contributes to the literature based on three main facts. (1) Previous literature on the disaster-growth nexus suffers from omitted-variable bias, hence, we develop an infrastructure index that captures sanitation conditions, clean fuels, drinking water, and electricity. Quality infrastructure enables a community to cope with natural disasters and also decreases the probability of a shock. Therefore, this research reveals the role of infrastructure in the disaster-growth framework. (2) We develop a human capital index to examine its impact on the disaster-growth framework. Disaster resilience is linked to human capital, hence, is an important tool to develop a comprehensive policy. (3) We extend the literature by studying the disaster-growth empirical relationship across all income groups (i.e., 98 countries). Income group analysis is helpful for countries to find possible strategies to follow DRR plans. Given this, we mainly ascertain the effect of natural disasters on economic growth and identify factors that can minimize disaster loss and achieve sustainable development.

2. Materials and methods

Growth theories cannot provide robust inferences on the link between natural disasters and economic growth. Neoclassical theories assume natural disasters do not affect technological progress. However, short-run growth is possible by moving economies from a normal growth path. The endogenous growth theory reports the economic consequences of disasters. However, Schumpeter's creative destruction theory supports a positive link between economic growth and natural disasters because physical destruction may induce investment for the reconstruction of existing capital [5,48]. Therefore, Fabian et al. [49] suggested addressing this issue in future research.

The Solow-Swan model is suitable to reveal the economic effect of natural disasters. It is widely used due to its conceptual strength and clarity in explaining the shift to a long-run steady state. Suppose a Cobb-Douglas production model is [50]:

$$Y = AK^{\alpha}L^{\beta}M^{1-\alpha-\beta} \tag{1}$$

$$0 < \alpha < 1;\ 0 < \beta < 1;\ 0 < (1 - \alpha - \beta) < 1$$

where Y is output, K is capital, L is labor, M is materials and other intermediate inputs, A is general productivity parameter or technology, α, β, and $1 - \alpha - \beta$ are factors shared by each input. Natural disasters affect economic productivity via three channels, [50]:

(a) Natural disasters affect total productivity (A)
(b) Natural disasters affect the supply of materials and intermediate inputs (m)
(c) Natural disasters affect the relative endowment of capital (k) and labor (l)

A fixed proportion of output is saved and transformed into capital formation. It is also supposed that the growth rate of the labor force is fixed and exogenous. However, intermediate inputs and productivity can change arbitrarily. Therefore [50]:

$$\Delta K = sY - \delta K \tag{2}$$

$$\Delta L = nL \tag{3}$$

where s is the rate of saving, n is the population growth rate, δ is the rate of depreciation, and Δ is the change in the variable. The dynamic behavior of an economy is shown by the neoclassical production function (Eq. (1)) and accumulation equations (Eqs. (2) and (3)). A Steady-state has constant growth rates, which implies that output and capital per worker remain constant. The growth rate of capital/worker (Eq. (4)) and output/worker (Eq. (5)) is [50]:

$$Gr(k) = \frac{\Delta(k)}{k} = s\frac{y}{k} - (\delta + n) \tag{4}$$

$$Gr(y) = \frac{\Delta(y)}{k} = \alpha Gr(k) \tag{5}$$

Fig. 1 shows the economic impact of natural disasters, considering the Solow-Swan model. The economy is supposed to operate at a steady-state (point **A**). Supposing that a natural disaster adversely affects the capital stock but labor remains unchanged. Due to this, capital/capita decreases and reaches k_d. The output also drops from the steady-state output (y^*) to post-disaster output (y_d). The economy reaches point B after a natural disaster. The distance between points **B** and **C** shows available space for recovery (growth). The economy converges towards steady-state capital (k^*). The capital increase is linked to a higher saving rate (s_r) than the pre-disaster saving rate (s). The recovery saving rate (s_r) accelerates the capital accumulation, and the economy moves to point **D**. The economy gradually recovers (point **D** to **A**), and the capital stock becomes equal to steady-state capital (k^*). The saving rate also moves back to the pre-disaster saving rate [51].

Chhibber and Laajaj [52] reviewed the literature on natural disasters and economic growth and reported four possible scenarios—Fig. 2(A–D). Scenario **A** (Fig. 2A) and Scenario **B** (Fig. 2B) show that natural disasters are accountable for a momentary effect on the economy. In scenarios **A** and **B**, the human and physical capital-labor ratio declines in the short run. A post-disaster higher return on capital may be due to savings and FDI inflow. The post-disaster reconstruction investments further increase the capital-labor ratio [35]. In scenario **B**, there exist some post-disaster over-investment in the intermediate run. But the economy returns to its long-term growth path because (a) long-run capital depreciation is more than the replacement investments [53], and (b) the end of foreign aid because it is temporary assistance [35]. According to scenario **C** (Fig. 2C), there exists a permanent reduction in the capital-to-labor ratio due to financial issues, which in turn staggers the capital reinvestment. As a result, the economy moves to a lower long-run growth path [54] According to scenario **D** (Fig. 2D), the natural disaster creates a favorable long-run effect on income due to the replacement of destroyed or depreciated capital with technically advanced capital [55].

2.1. Model

This study explores the effect of natural disasters on economic growth in 98 countries from 1995 to 2019. The selection of countries involved several steps. First, a list of countries (all income groups) was obtained from World Bank [56]. Second, disaster statistics were obtained from (a) the Emergency Events Database (EM-DAT) [57] — an international database having disaster statistics for nearly 200 countries, and (b) the Disaster Information Management System [58]. Third, we selected countries that had higher frequency of natural disasters, thus, eliminating countries whose frequency of natural disasters was comparatively less. Fourth, some countries were also deleted whose data on explanatory variables were not available from 1995 to 2019. Thus, selected countries were categorized into 24

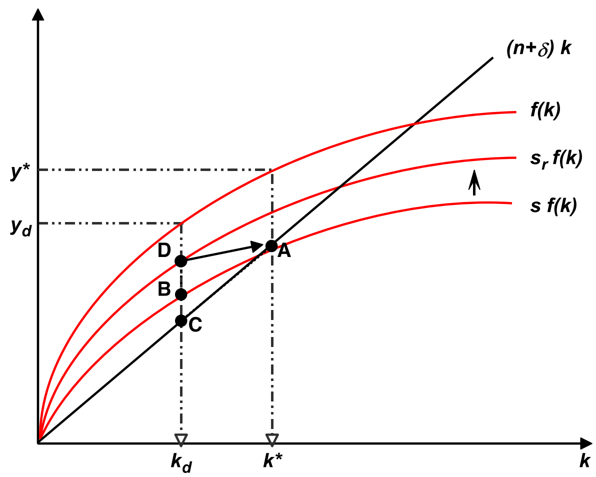

Fig. 1. Effect of natural disaster on the economy. *Source:* Authors' reconstruction from Ref. [51].

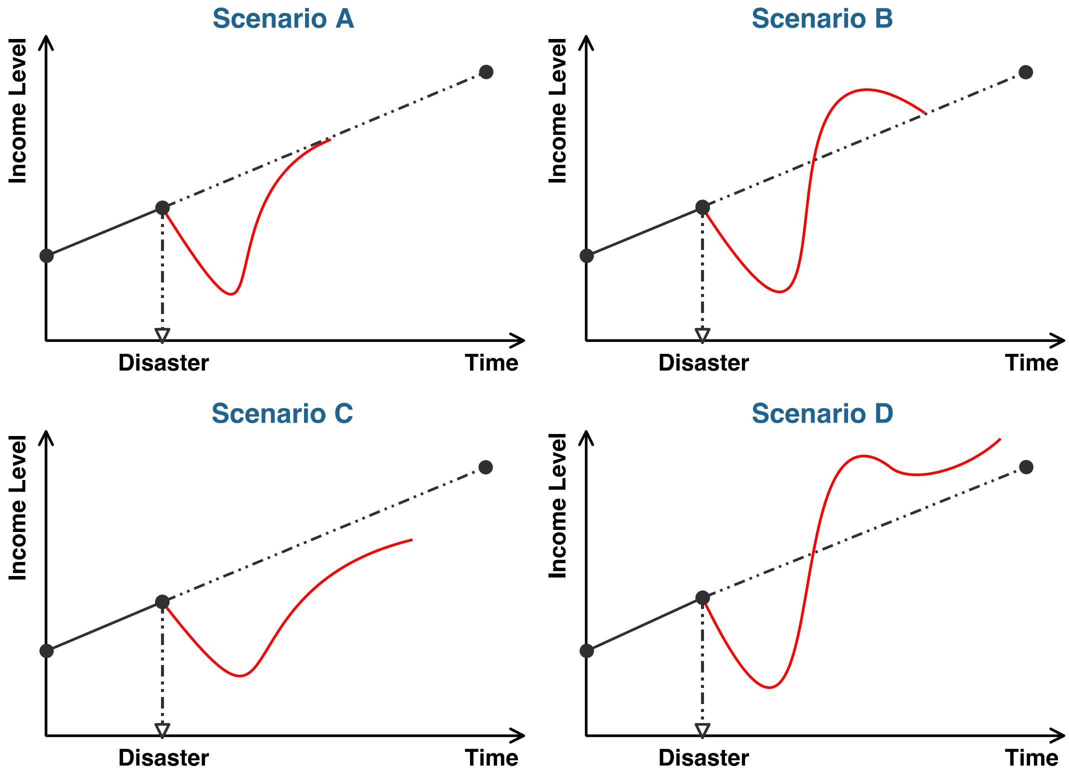

Fig. 2. (A–D) Economic growth and natural disaster linkages. Source: Authors' reconstruction from Ref. [52].

high (HICs), 26 upper-middle (UMICs), 32 lower-middle (LMICs), and 16 low (LICs) income countries. Wang and Zhang [59] reported that income group analysis shows practical significance for many countries. This classification is useful for analytical and operational purposes. So, researchers used this classification for data analysis [60]. Although, the economic costs of natural disasters are found across the world [61,62]. Yet, physical damage and deaths are less in developed countries [11]. Developing countries are more vulnerable to natural disasters [13], thus, analysis of countries using income group classification of countries is relevant in the growth-disaster framework.

The CRED collected this data from UN agencies, press agencies, insurance companies, research organizations, and non-governmental organizations. The EM-DAT counted a disaster considering criteria i.e. (a) 10 or more deaths, (b) 100 affected people, (3) emergency declaration, and (d) call for world help. The disasters include hydro-meteorological (storms, droughts, wave surges, floods, landslides, and avalanches), geophysical (earthquakes, volcanic eruptions, and tsunamis), and biological (epidemics and insect infestations).

Variable selection implies the inclusion of suitable variables in a specific model, thus, it is appropriate to drop redundant or irrelevant variables. The selection of appropriate variables is required to estimate a best-fit model. The principle of parsimony states that simple models with fewer variables are more suitable as compared to complicated models with several variables. Moreover, simple models are comparatively easier to interpret, generalize, and have implications. However, important variables should not be excluded from the specified model [63]. Similarly, economic growth is influenced by several socioeconomic variables in developed and developing countries—but it is difficult to include all variables in a single regression model due to several econometric issues. Thus, the given model link response and predictor variables as:

Table 2
List of variables.

Symbol	Variable	Unit	Data Source
DIS	Total affected persons	per million	CRED [57]; UNDRR [58]
INFR	Global infrastructure index	0–100	WDI [68]
HC	Human capital index	0–100	WDI [68]; GSD [69]
GFCF	Gross fixed capital formation	% of GDP	WDI [68]
GDP	GDP/capita	constant 2010 USD	WDI [68]
FDI	FDI, net inflows	% of GDP	WDI [68]
GI	Globalization index	0–100	KOF [70]

$$GDP_{it} = f\left(GDP_{i,t-1}, DIS_{it}, INFR_{it}, FDI_{it}, HC_{it}, GI_{it}, GFCF_{it}\right) \tag{6}$$

where GDP_{it} shows GDP/capita (constant 2010 USD), $GDP_{i,t-1}$ is a one-period lag of GDP, DIS_{it} depicts total affected people due to natural disasters (per million), $INFR_{it}$ is infrastructure Index (0–100), FDI_{it} represents the FDI net inflows (% of GDP), HC_{it} denotes human capital index (0–100); GI_{it} is the globalization index (0–100), $GFCF_{it}$ represents gross fixed capital formation (% of GDP), i denotes sampled countries, and t is the time (1995–2019). GDP is a widely used indicator to express the economic performance of a country, which is linked to improvements in the standard of living [64]. Eq. (6) is expressed in a natural logarithmic form to control outliers, heteroscedasticity [65], and heterogeneity [66]. The coefficients of a double-log model show elasticity of the dependent variable with respect to independent variables (Table 2), as [65]:

$$ln\ GDP_{it} = \beta_{0i} + \beta_{1i}\ ln\ GDP_{it-1} + \beta_{2i}\ ln\ DIS_{it} + \beta_{3i}\ ln\ INFR_{it} + \beta_{4i}\ ln\ FDI_{it} + \beta_{5i} lnHC_{it} + \beta_{6i}\ ln\ GI_{it} + \beta_{7i}\ ln\ GFCF_{it} + \varepsilon_{it} \tag{7}$$

where β_0 is a constant, $\beta_{1\text{-}7}$ shows the regression estimates of predictors, and ε is the error term. Some variables have negative observations, thus, logarithmic transformation was performed using Eq. (8), as [67]:

$$y = ln\left(x + \sqrt{x^2 + 1}\right) \tag{8}$$

It is also possible to estimate Eq. (7) by changing independent variables. Literature on economic growth shows many variables that might impact global economic growth. This study added several socio-economic variables and prepared a panel datasheet. However, some variables were dropped due to the presence of multicollinearity while others were dropped due to the lack of theoretical justification. Finally, this study selected five socio-economic variables to obtain a best-fit regression. However, future studies could drop or add other variables to estimate their role in the disaster-growth framework.

2.2. *Rationale of variable selection in the disaster-growth framework*

This research used five independent variables in the disaster-economy framework. The theoretical roles of selected variables in economic growth and disaster management are described in sub-sections 2.2.1..-..5.

2.2.1. *Global infrastructure index*

The infrastructure index entails four indicators like percentage of the population having access to (a) basic sanitation, (b) electricity, (c) basic drinking water, and (d) clean fuels and technologies. Investment in water and sanitation is beneficial for equity, economic development, security, dignity, and time savings [71]. Sanitation and water increase the resilience of healthcare systems [72]. Electricity is used in three stages of disaster management including mitigation, resilience, and recovery [73]. It is possible to increase the electricity supply from renewable energy, which is an area of interest in the recent era [74]. Thus, Hypothesis 1 (H_1) is proposed as: infrastructure can increase economic growth and decrease the adverse impact of natural disasters.

2.2.2. *FDI inflows*

The FDI inflow leads to economic growth through knowledge transfer, the use of modern technology [75], and an increase in employment and productivity. Lack of finance is a challenge to building disaster resilience. It provides external funding, hence, underpins the achievement of sustainable development in developing countries [76,77]. Therefore, Hypothesis 2 (H_2) is expressed as: FDI inflows lead to economic growth and offset the adverse impact of natural disasters.

2.2.3. *Human capital index*

It is a combination of seven indicators including (a) employment to population ratio, 15+ (% of total), (b) life expectancy at birth (years), (c) population ages 15–64 (% of total) [68], (d) educational equality (0–1), (e) literacy (0–1), (f) health equality (0–1), and (g) kilocalories per person per day (0–1) [69]. It is a proxy indicator useful for assessing sustained and productive employment captured in SDG8 [78]. Growth accounting [79] depicts that human capital significantly contributes to economic growth through improvement in labor productivity [80]. Its role is vital in the several stages of disasters (i.e., before, during, and after) [81]. So, Hypothesis 3 (H_3) is put forward as Human capital can increase economic growth and mitigate the adverse impact of natural disasters.

2.2.4. *Globalization index*

Globalization is a process in which countries integrate into the global economy via trade, capital flows, migration of labor, FDI, and trade [82]. It becomes a driving force behind vibrant economies. It contributes to economic development through technology transfer, trade, economies of scale, and market liberalization [83]. Thus, Hypothesis 4 (H_4) is expressed as Globalization shows an encouraging impact on the economy and reduces the cost of natural disasters.

2.2.5. *Gross fixed capital formation*

Capital formation is a basic element of economic growth. Solow [79] stated that capital accumulation leads to expansion in production, which results in economic growth. It depicts a country's production capacity, hence, economic growth due to capital formation also depends on several indicators such as savings, FDI, and interest rates. Capital formation in developing countries is low, which is a hurdle to achieving sustainable growth [84]. Finally, Hypothesis 5 (H_5) is expressed as Capital formation can increase economic growth and reduce the cost of natural disasters.

2.3. Econometric techniques

This research used several tests to achieve the study objectives. The complete empirical analysis involves several steps: (a) development of the index, (b) descriptive statistics, (c) preliminary tests, (d) stationarity test, (e) cointegration test, and (f) regression estimation. A schematic overview of the complete methodology is expressed in Fig. 3.

2.3.1. Index-making

This study adopted the IMF index-making steps namely indicator selection, winsorization, normalization, and PCA weights. It is required to fill 'missing data' for a balanced panel. Winsorization is used to increase robustness, in which outliers are substituted by cutoff values i.e., lowest (5th percentile) and highest (95th percentile) across time and countries. Min-max approach (Eq. (9)) was used for normalization (0,1) as [85,86]:

$$I_x = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{9}$$

The weights of the Principal Component Analysis (PCA) were assigned to each indicator to calculate an index (Eq. (10)), as [85,86]:

$$Index_i = \sum_{i=1}^{n} w_i I_i \tag{10}$$

It is multiplied by 100 to avoid negative logarithmic values in line with other explanatory variables.

2.3.2. Diagnostic analysis

Panel models typically exhibit challenges if not controlled affect robustness and statistical inferences. Cross-section dependence (CD) leads to a loss of efficiency and incorrect test statistics in panel datasets. The Breusch and Pagan [87] LM test is suitable when N is small and T is large [88]. A Lagrange Multiplier test (Eq. (11)) is developed as [89]:

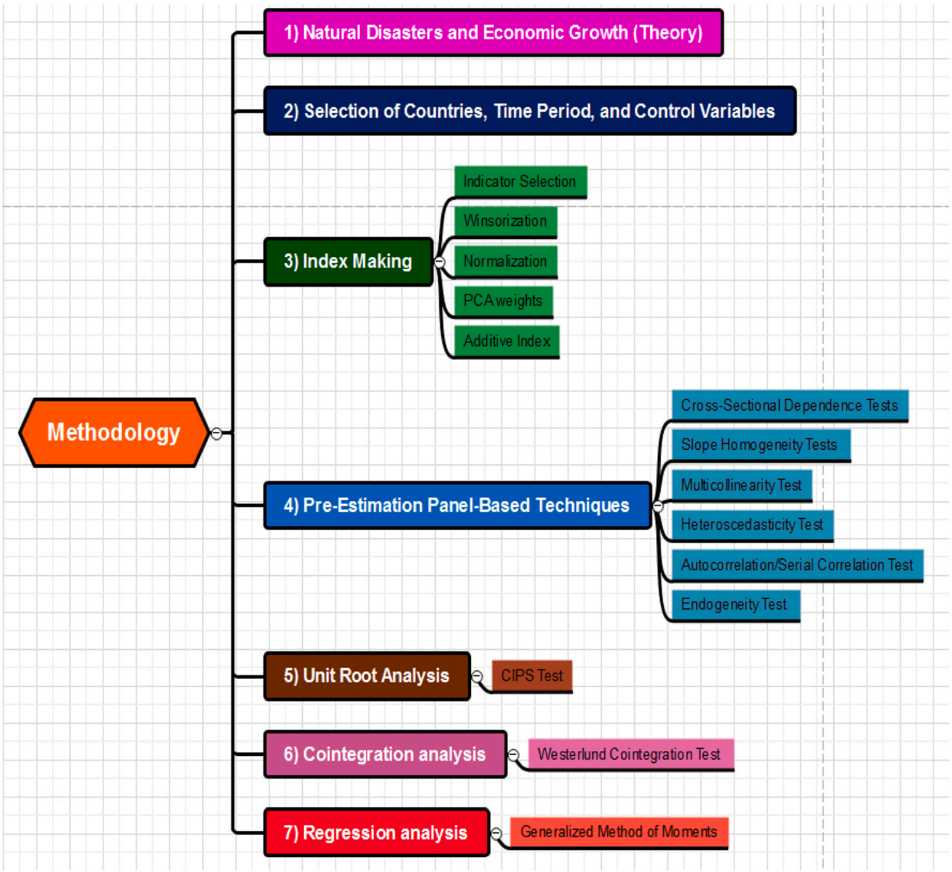

Fig. 3. A schematic overview of complete tests. *Source:* Authors' construction.

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}^{2}\mathscr{X}^{2}_{N(N-1)/2} \tag{11}$$

Second, Pesaran [90] gives the Lagrange multiplier CD test (Eq. (12)) for panels having large cross-sections ($N \to \infty$) and time ($T \to \infty$) expressed as:

$$\text{CD} = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(\widehat{\rho}_{ij}-1)N(0,1) \tag{12}$$

Third, Pesaran et al. [91] give a bias-adjusted LM test (Eq. (13)) expressed as:

$$LM_{adj} = \sqrt{\left(\frac{2}{N(N-1)}\right)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}\frac{(T-k)\widehat{\rho}_{ij}^{2}-\mu_{Tij}}{\sqrt{v_{Tij}^{2}}}N(0,1) \tag{13}$$

Swamy's [92] slope homogeneity test can control heteroskedasticity and is applicable if "$T > N$" [93]. For large panels ($T, N \to$ to ∞), Pesaran and Yamagata [94] proposed a standardized dispersion to test slope homogeneity ($\widetilde{\Delta}$ test) (Eq. (14)) expresses as:

$$\widetilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\widetilde{S}-k}{\sqrt{2k}}\right) \tag{14}$$

To improve small sample properties, the bias-adjusted form (Eq. (15)) is expressed as [95]:

$$\widetilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\widetilde{S}-E(\widetilde{z}_{it})}{\sqrt{var(\widetilde{z}_{it})}}\right) \tag{15}$$

Multicollinearity may lead to estimation problems including inconsistent parameters, insignificant coefficients, and misleading conclusions. The variance inflation factor (VIF) (Eq. (16)) [96] is used to examine multicollinearity expressed as [97]:

$$VIF_j = \frac{1}{1-R_j^2} \tag{16}$$

Accordingly, multicollinearity may not exist when the mean VIF is less than 5 [98]. Due to heteroscedasticity, OLS estimates are often biased and lead to wrong hypotheses [99]. A modified Wald statistic (Eq. (17)) is used to check group-wise heteroskedasticity in residuals of a fixed-effect regression, expressed as [100]:

$$W = \sum_{i=1}^{N_g}\frac{\left(\widehat{\sigma}_i^2-\widehat{\sigma}^2\right)^2}{V_i} \tag{17}$$

Serial correlation may lead to biased standard errors and inefficient estimation, hence, Wooldridge [101] proposed a serial correlation test that required few assumptions and easy estimation. The β_1 is estimated by regressing Δy_{it} on ΔX_{it}. The term based on the time-invariant covariates and constant (Eq. (18(18) and (19(19)) is expressed as [102]:

$$y_{it} - y_{it-1} = (X_{it} - X_{it-1})\beta_1 + \varepsilon_{it} - \varepsilon_{it-1} \tag{18}$$

$$\Delta y_{it} = \Delta X_{it}\beta_1 + \Delta\varepsilon_{it} \tag{19}$$

Endogeneity is an issue in the determination of regression coefficients. Endogeneity implies a correlation of an endogenous variable with the error term. This may cause inconsistent estimation, wrong interpretations, and deceptive conclusions [103]. In general, the Durbin–Wu–Hausman test is used to confirm endogeneity. It is required that the independent variables are uncorrelated with the error term. Thus, the endogeneity test shows the possible correlation between explanatory variables and residuals (error term). A significant test statistic of this test for an explanatory variable (e.g., natural disaster loss) shows that the variable is endogenous (i.e., it correlates with the error term) [103]. It tests the following hypothesis [104].

H_0: Cov $(\mu_i, x_{it}) = 0$ No endogeneity exists
H_1: Cov $(\mu_i, x_{it}) \neq 0$ Endogeneity exists

2.3.3. Unit root analysis

A nonstationarity time series is responsible for (a) meaningless empirical estimation, (b) issues in model selection, and (c) spurious estimation [105]. It is recommended to apply a cross-sectionally augmented IPS (CIPS) test (Eq. (20)) [106] due to CD. The test statistic is based on standard augmented Dickey-Fuller regression expressed as [86]:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N}\widetilde{t}_i \tag{20}$$

where $\widetilde{t}_i$ is the OLS t-ratio of b_i (Eq. (21)) in the following expression [107]:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i t + \sum_{j=1}^{p} d_{ij} \Delta y_{i,t-j} + e_i \overline{\mathscr{Z}}_t + u_{it} \tag{21}$$

where $\overline{\mathscr{Z}}_t = (\overline{y}_{t-1}, \Delta\overline{y}_t, \Delta\overline{y}_{t-1}, ..., \Delta\overline{y}_{t-p})'$.

2.3.4. Cointegration analysis

Cointegration is a prerequisite to counter spurious estimation. The cointegration exists if two indicators are individually non-stationary but their linear combination is stationary [108]. Due to CD, this study used the Westerlund cointegration test [109], a second-generation test (Eq. (22(22) and (23(23)) expressed as [86,110]:

$$VR = \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{E}_{it}^2 \widehat{R}_i^{-1} \tag{22}$$

$$VR = \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{E}_{it}^2 \left(\sum_{i=1}^{N} \widehat{R}_i \right)^{-1} \tag{23}$$

2.3.5. Regression analysis

Due to endogeneity, within-group estimations or panel OLS lead to biased and wrong estimations [111]. Arellano and Bond [112] and Blundell and Bond [113] propose the GMM for dynamic analysis. The GMM is more suitable than PMG and MG estimators as it can encounter dynamic panel bias which arises due to one-period lag of response variables. Advantageously, (a) it is better for growth models if $N > T$, (b) it deals with endogeneity, and (c) provides efficient and consistent results [111]. The lag of response variable as an explanatory variable is worked as an instrument to counter endogeneity in dynamic analysis [103]. These instruments are known as 'internal instruments' [114]. The GMM removes endogeneity through "internal transformation of data", a statistical tool to deduct previous values from the present values. It reduces observations and increases efficiency [115]. This method has two transformation types namely first-difference (one-step GMM) and second-order (two-step GMM) transformation [103]. However, one-step technique has limitations like the loss of observations if present value of a variable is missing [7]. Therefore, Arellano and Bover [116] endorsed the two-step GMM. It is based on 'forward orthogonal deviations' or subtraction of the average of all future observations of a specific variable [114]. It gives better results in a balanced panel [7]. This research applied the general dynamic GMM assuming (a) some regressors may be determined endogenously, (b) past value influences current value, (c) uncorrelation of the idiosyncratic shock across N, (d) T may be small, and (e) some regressors are not strictly exogenous. This research also used some diagnostic tests to confirm its

Table 3
Descriptive analysis.

Variables	Panel	Mean	Minimum	Maximum	Standard Deviation
DIS	HICs	2487.498	0.000	263575.200	14111.55
	UMICs	16369.900	0.000	355957.700	42975.47
	LMICs	26126.840	0.000	909694.00	73145.78
	LICs	21824.080	0.000	535208.00	65952.67
INFR	HICs	97.251	67.773	100.000	5.671
	UMICs	82.439	30.207	99.159	14.796
	LMICs	48.869	0.000	98.075	28.077
	LICs	14.676	0.000	88.409	17.564
HC	HICs	77.307	53.011	93.931	8.458
	UMICs	57.179	25.105	78.563	11.422
	LMICs	41.238	15.696	78.583	14.492
	LICs	27.114	11.692	52.688	8.423
GDCF	HICs	22.493	11.074	40.632	4.264
	UMICs	22.500	4.033	44.519	5.931
	LMICs	23.592	2.000	69.287	7.711
	LICs	17.923	0.293	59.723	8.504
GDP	HICs	31173.010	4556.438	79406.660	17353.04
	UMICs	4240.360	1077.190	15190.100	3070.117
	LMICs	1714.925	242.344	4828.626	1006.989
	LICs	609.835	183.548	1900.093	332.847
FDI	HICs	4.321	−40.414	86.589	8.478
	UMICs	3.849	−5.007	23.537	3.258
	LMICs	3.283	−37.155	43.912	4.457
	LICs	3.628	−4.846	46.275	5.533
GI	HICs	78.240	47.531	91.157	8.480
	UMICs	61.628	38.172	82.172	8.388
	LMICs	51.642	24.452	76.065	9.948
	LICs	40.198	22.532	54.294	7.410

reliability like (a) serial correlation test to confirm the absence of serial correlation (i.e., first and second-order serial correlations) [114] (b) the Sargan test to check the overall validity of the instruments, and (c) the Hansen [117] test to check instrument validity [7].

3. Results

3.1. Summary statistics

Table 3 reveals the summary statistics of variables in four income groups (see Appendix A). Descriptive evidence shows natural disasters are worst in LMICs and LICs compared to HICs. Natural disasters are responsible for human loss, which appears higher in LMICs (26,126.8/million) followed by LICs (21,824.1/million), UMICs (16,369.9/million), and HICs (2487.5/million). The damage is lower in HICs. We observe the heterogeneous distribution of income level (i.e., GDP per capita) across income groups, thus, income level is relatively high in HICs compared to LICs. This infers high disparities between high and low-income countries that can be minimized through cooperation and financial support. Infrastructure plays a key role in economic stability by improving the standard of living. The infrastructure index is better in HICs (97.251) and less in LICs (14.676). In terms of external funding, FDI is higher in HICs (4.321%) than UMICs, LICs, and LMICs. The human capital index is higher in HICs and lowers in LICs. The globalization index shows a higher level of globalization (economic, social, and political) in HICs (78.240) followed by UMICs (61.628), LMICs (51.642), and LICs (40.198). The mean of capital formation shows that there are not many differences in HICs, UMICs, and LMICs.

Fig. 4 shows the frequency of natural disasters in income groups. It shows a cumulative score of natural disasters in all countries from a specific income group. The total number of natural disasters appears higher in LMICs followed by UMICs, HICs, and LICs. The occurrence of natural disasters was less in LICs because the total number of selected LICs was only 16.

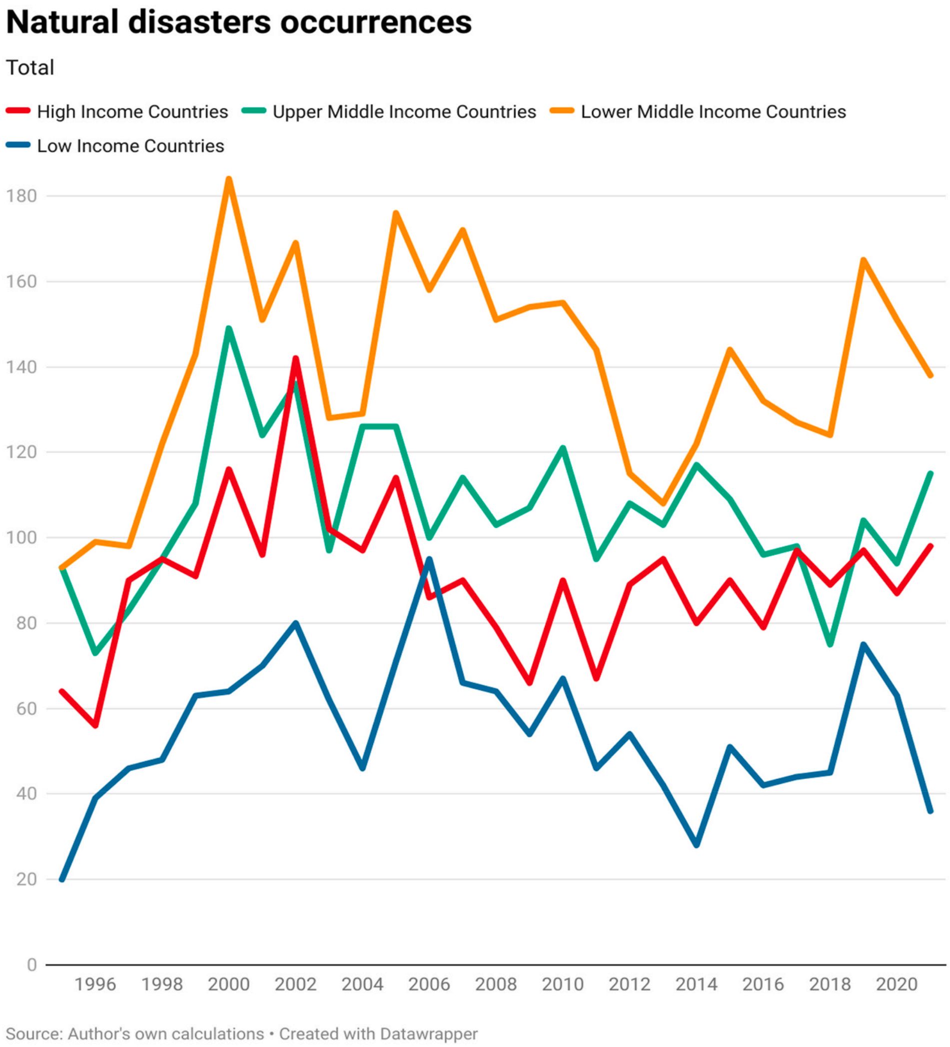

Fig. 4. Frequency of natural disasters across income groups.

3.2. Diagnostic tests results

Table 4 presents the findings of different pre-estimation panel-based techniques to diagnose panel challenges before model estimation. The test results in Table 4 provide strong evidence of CD in all panels. It implies that a shock in one economy is easily transmitted to other economies. The slope tests confirm slope heterogeneity across panels. The analysis also confirms serial correlation and heteroskedasticity in all panels. It appears that endogeneity is an issue in all panels, however, the proposed GMM model is capable of controlling for this bias. Table 5 presents the VIF values for each variable in each panel. The VIF is less than 5 for each variable in each panel. Moreover, the mean VIF is also less than 5 for each panel. As a rule of thumb, a mean VIF less than 5 implies no potential multicollinearity [98]. So, no issue of multicollinearity is detected among variables in all panels.

3.3. Stationarity and cointegration analysis

Table 6 shows the order of integration for selected variables using the CIPS test. While some variables are not stationary at the level i.e., GDP/capita, human capital index, and gross fixed capital formation, all variables are first-difference stationery. The stationarity of sampled variables is required for reliable regression coefficients. The significant test-statistic of the Westerlund cointegration test (Table 7) shows panel cointegration between variables in all income groups.

3.4. Regression results

Fig. 5(a–d) shows the effect of natural disasters, infrastructure, FDI, human capital, globalization, and capital formation on GDP/capita in four income groups such as HICs (Fig. 5a), UMICs (Fig. 5b), LMICs (Fig. 5c), and LICs (Fig. 5d). The one-period lag of income level is positive, which implies that historical effects of income level have a favorable impact on the current status of income level. This infers rich countries continue to be richer whereas poor countries continue to exhibit traits of multidimensional poverty. An increase in natural disasters is observed to decline economic productivity across income groups, however, the income reduction effect is more revealing in LICs than in wealthy economies. Empirically, 1% rise in total persons affected due to natural disasters declines income level by 0.001% (HICs and UMICs), 0.002% (LMICs), and 0.006% (LICs). Long-term improvements in infrastructure spur economic productivity especially in HICs—followed closely by UMICs LICs, and LMICs. Thus, 1% increase in infrastructure improves income levels by 1.594% (HICs), 0.766% (UMICs), 0.103% (LICs), and 0.065%. Similarly, the role of external funding plays a crucial role in economic productivity—as observed evidence is more impactful in low-income economies compared to wealthy economies. Specifically, 1% increase in the FDI inflows expands income level by 0.045% (LICs), 0.013% (UMICs), 0.004% (LMICs), and 0.003% (HICs). The escalation effect of human capital on economic productivity is only evident in high, upper-middle, and lower-middle-income economies. Thus, 1% increase in the human capital surges GDP/capita by 0.139% (UMICs), 0.114% (HICs), and 0.112% (LMICs). The empirical evidence shows 1% rise in globalization (economic, social, and political) increases income levels by 0.440% (UMICs), and 0.342% (HICs). This implies the role of globalization in expanding economic productivity is significantly high in upper-middle-income economies compared to high-income economies. An increase in gross capital formation is more favorable to economic productivity in upper-middle-income economies—followed by low-, lower-middle-, and high-income economies. Thus, 1% increase in capital formation improves GDP/capita in UMICs (0.081%), LICs (0.058%), LMICs (0.056%), and HICs (0.053%). The AR (2) statistic, Sargan test, and Hansen test show the absence of second-order serial correlation and validity of instruments used for model estimation.

4. Discussion

The positive coefficient of one-period lag of GDP/capita indicates that economic growth is favorable for a longer period. Therefore, an increase in GDP/capita has useful economic benefits in both short- and long-run. This implies the formulation and implementation of policies for sustained economic growth will improve future economic productivity. Natural disasters, an alarming global issue, are identified as events that ruin the economic and developmental process, especially in developing countries. Natural disasters are

Table 4
Pre-estimation panel-based techniques.

Econometric Problem	Diagnostic Tests	HICs		UMICs		LMICs		LICs	
		Test-stat.	Prob.	Test-stat.	Prob.	Test-stat.	Prob.	Test-stat.	Prob.
CD	Breusch and Pagan LM	564.90***	0.000	585.9***	0.000	789.2***	0.000	176.5***	0.001
	Pesaran CD	12.18***	0.000	7.766***	0.000	5.464***	0.000	0.713	0.476
	Pesaran LM adj	22.79***	0.000	18.62***	0.000	15.69***	0.000	5.733***	0.000
Slope heterogeneity	Swamy's test	140,000***	0.000	130,000***	0.000	160,000***	0.000	61328.33***	0.000
	$\tilde{\Delta}$ test	17.459***	0.000	20.489***	0.000	22.255***	0.000	15.963***	0.000
	$\tilde{\Delta}_{adj}$ test	21.172***	0.000	24.846***	0.000	26.988***	0.000	19.358***	0.000
Serial correlation	Wooldridge test	138.711***	0.000	163.384***	0.000	192.323***	0.000	72.776***	0.000
Heteroskedasticity	Modified Wald test	7408.28***	0.000	3230.56***	0.000	6192.78***	0.000	461.25***	0.000
Endogeneity	Durbin–Wu–Hausman test	47.04***	0.000	160.03***	0.000	17.13***	0.000	65.72***	0.000

Notes: ***,**,* represent statistical significance at 1%, 5%, and 10% level.

Table 5
Multicollinearity VIF test.

Variables	HICs		UMICs		LMICs		LICs	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
lnDIS	1.30	0.767	1.07	0.935	1.00	0.997	1.03	0.966
lnINFR	1.88	0.532	2.19	0.458	1.71	0.586	1.40	0.713
lnFDI	1.08	0.930	1.14	0.876	1.08	0.922	1.43	0.700
lnHC	2.08	0.480	2.19	0.458	1.51	0.660	1.23	0.813
lnGI	2.21	0.453	1.36	0.733	1.63	0.615	2.02	0.495
lnGFCF	1.15	0.871	1.11	0.935	1.02	0.976	1.41	0.708
Mean VIF	1.62		1.51		1.33		1.42	

Table 6
Stationarity analysis.

Variables		Level: Trend and intercept				First difference: Intercept			
		HICs	UMICs	LMICs	LICs	HICs	UMICs	LMICs	LICs
lnGDP		−1.943	−1.823	−1.403	−2.620	−2.656***	−3.366***	−3.187***	−3.938***
lnDIS		−5.263***	−4.851***	−5.043***	−4.785***	−6.007***	−6.096***	−6.129***	−5.891***
lnINFR		−3.096***	−3.270***	−2.588*	−2.698*	−4.148***	−4.937***	−4.796***	−4.606***
lnFDI		−3.988***	−3.625***	−3.124***	−3.099***	−5.767***	−5.407***	−5.332***	−5.050***
lnHC		−1.880	−2.264	−2.074	−1.429	−4.018***	−3.930***	−4.165***	−4.134***
lnGI		−2.347**	−3.306***	−2.685**	−3.317***	−4.611***	−4.984***	−4.748***	−4.727***
lnGFCF		−1.920	−2.542	−2.393	−2.971***	−3.633***	−4.086***	−4.129***	−5.321***
Critical values	*1%*	*−2.81*	*−2.81*	*−2.73*	*−2.88*	*−2.30*	*−2.30*	*−2.23*	*−2.38*
	5%	*−2.66*	*−2.66*	*−2.61*	*−2.72*	*−2.15*	*−2.15*	*−2.11*	*−2.20*
	10%	*−2.58*	*−2.58*	*−2.54*	*−2.63*	*−2.07*	*−2.07*	*−2.04*	*−2.11*

Notes: ***,**,* denote statistical significance at 1%, 5%, and 10% level; lags: 4.

Table 7
Westerlund test results.

Panel	Variance ratio	
	Statistics	Prob.
HICs	4.485***	0.000
UMICs	2.704***	0.003
LMICs	5.472***	0.000
LICs	3.890***	0.000

Notes: *** represents statistical significance at 1% level.

accountable for economic losses although economic costs of disasters are higher in LICs. This is consistent with the destructive role of natural disasters on economic development reported in the available literature. For example, Shabnam [39] reported 0.005% decline in GDP/capita for one thousand out of one million population disturbed by floods in 187 countries. The economic damage is also reported in 171 countries [118], 21 Caribbean countries [42], and Pakistan [41]. Another study [25] reported that severe natural disasters showed an adverse impact on economic growth (−0.016), fiscal balance (−0.011), and FDI (−0.0271) in the B&RIC.

The mild effect of disasters on economic productivity was reported in HICs due to high infrastructure development, supporting developing nations with technological and financial assistance could help mitigate lifelong disaster-related damages. It is suggested to minimize disaster losses via resilience-building [119]. Resilience refers to opportunities that prepared a society and speed up restoration plans [120]. Resilience is a fundamental part of disaster management plans, as disaster-related damages are less in resilient communities. The Sendai Framework set seven targets to increase resilience [27].

Contrary to this, Guo et al. [2] mentioned that meteorological disasters show a favorable economic effect through human capital in China. The study identified human capital as a tool to mitigate the consequences of natural disasters on economic growth. Focusing on human capital would be helpful to develop an effective disaster management policy. Human capital significantly contributes to economic productivity in all panels, excluding LICs. It is because the average human capital index is only 27.114 in LICs. The rise in economic growth is attributed to human capital development in 100 countries [121] and OECD countries. A 1% increase in schooling is reported to increase economic growth by 0.249% in OECD countries [122]. Another study [123] showed that 1% increase in primary enrollment and life expectancy improves economic growth by 0.082% and 0.490%, respectively in Sub-Saharan African countries. This implies that enhancing human capital via education, healthcare facilities, training, employment generation, and skills development, thus, it is an important tool to strengthen the capacities of individuals and communities. It is required to enhance social capital in society due to its key role in recovery. It acts as fellowship, mutual sympathy, goodwill, and social relationships between individuals and families. It is suggested to increase social capital through education.

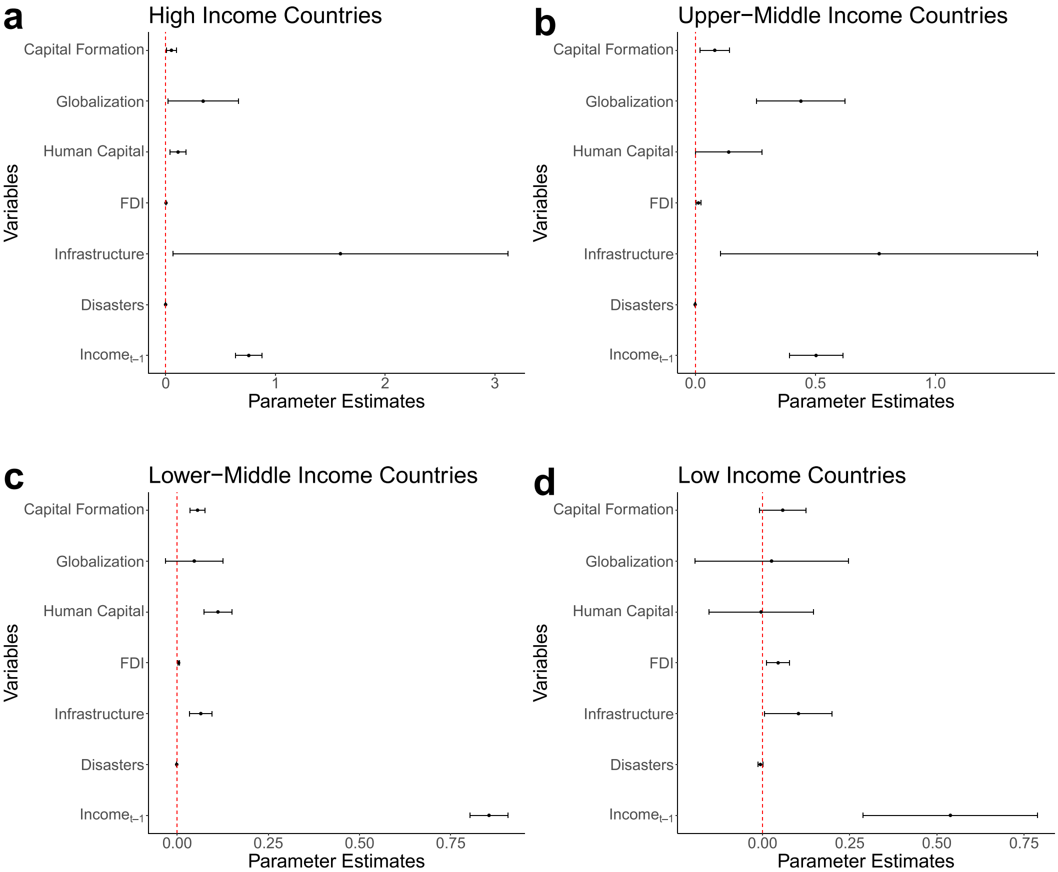

Fig. 5. (a–d) Estimated parameters using GMM technique (a) High-income economic model (b) Upper-middle-income economic model (c) Lower-middle-income economic model (d) Low-income economic model. *Notes:* AR (1)—**HICs** [-2.64*** (0.008)], **UMICs** [−1.72* (0.085)], **LMICs** [−3.48*** (0.001)], **LICs** [−2.23** (0.025)]; AR (2)—**HICs** [-0.94 (0.348)], **UMICs** [−0.46 (0.643)], **LMICs** [-0.90 (0.570)], **LICs** [−1.36 (0.174)]; Sargan test—**HICs** [66.11 (0.107)], **UMICs** [52.3 (0.256)], **LMICs** [43.79 (0.276)], **LICs** [79.03 (0.710)]; Hansen test—**HICs** [18.93 (0.995)], **UMICs** [20.35 (0.990)], **LMICs** [28.64 (0.889)], **LICs** [7.68 (0.999)]. ***,**,* represent statistical significance at 1%, 5%, and 10% level.

Along with human and social capital, physical capital accumulation is vital for economic benefits. The economic benefits of physical capital formation are evident in all panels. The expansion in economic growth due to capital formation is also reported in 5 South Asia countries [124], Nigeria [125], India [126], 193 countries [127], 43 OIC countries [128], South Asia [65], and 46 HICs [84]. Increasing the share of fixed capital increases production, which in turn is beneficial to generate employment, raising income, and alleviating poverty. It promotes inclusive growth, sustainable industrialization, and innovation [129]. It is suggested to increase fixed capital through the conversion of saving into investments.

Infrastructure improvements escalate economic growth in all panels but its magnitude is comparatively higher in HICs. It is because the average infrastructure index is 97.251 in HICs and only 14.676 in LICs. Mamingi and Martin [130] reported a positive connection between infrastructural development and sustainable development. Immediate efforts are required to decrease this disparity, as infrastructural development is linked with socio-economic development and resilience-building. The provision of sanitation and clean drinking water may eventually lead to a better health profile. Better health of workers can increase their income through an increase in productivity. Chakamera and Alagidede [131] reported economic loss due to a disturbance in the electricity supply. Thus, investments in infrastructure have economic, social, and environmental benefits.

FDI inflows show a positive impact on GDP/capita in all panels. The coefficient of growth-FDI is higher in LICs, which indicates the potential of external funding in improving economic growth in LICs. FDI is important to ensure foreign reserves and economic prosperity, especially in developing countries. The economic expansion is 0.013% for 1% increase in FDI in South Africa [132]. The impact of FDI inflows together with human capital is positive on economic growth in Malaysia [133]. The 1% increase in FDI inflows positively affects economic growth (0.002–0.008%) in SAARC countries [134]. Hence, FDI has economic benefits and mitigation effects by increasing disaster resilience. FDI inflows include foreign capital, knowledge spillovers, new technology, improved marketing, and managerial skills in developing countries [135]. However, it is important to investigate the environmental costs of FDI inflows in developing countries. The pollution haven hypothesis shows that FDI inflows may deteriorate the environment with the adoption of fossil fuels and energy-intensive technologies in the production process [136]. According to Batala et al. [20], severe natural disasters were accountable for adverse consequences on FDI but trade openness and income level were identified as positive drivers of FDI in South Asian economies. Further, FDI is more sensitive to natural disasters in B&RIC [25].

Globalization can play a favorable role in technological improvement, mobility of people and capital, and knowledge dissemination [137]. The KOF globalization index reflects social, economic, and political dimensions to construct an overall index [137]. Thus, globalization shows a favorable impact on economic growth in developed countries (HICs and UMICs) only. This implies increasing global integration (economic, social, and political) across low and lower-middle income economies will ensure peace, technology transfer, knowledge, mutual understanding, and sustainable development.

Therefore, policymakers could integrate the economic impacts of natural disasters into economic planning or sustainable development programs. This could be helpful for countries to achieve sustainable development targets along with effectively coping with climate change events (i.e., natural disasters).

5. Conclusions

The SDG 11.5 target implies the need of reducing the cost of natural disasters. Yet, studies on dynamic analysis of natural disasters and socio-economic indicators are limited across income groups. Thus, this research examined the economic effect of natural disasters in the world. Our empirical strategy included developing an infrastructure index using relevant indicators. Second, we developed a human capital index to evaluate its role in the disaster-growth debate. We investigated the impact of natural disasters, infrastructure, FDI inflows, human capital, globalization, and gross fixed capital formation on income levels in 98 countries from 1995 to 2019. We developed an infrastructure index and human capital index based on IMF index-making procedure. The two-step GMM reveals that disaster-related loss to human beings has income reduction effects in all panels. The infrastructural development is beneficial for economic growth in all panels. External funding, viz. FDI is favorable for economic growth in all panels. The positive association between human capital and economic growth in HICs, UMICs, and LMICs confirms the importance of enhancing human capital via education, healthcare, skills development, training, and employment. The impact of globalization is positive on economic growth in HICs and UMICs. Capital formation positively affects economic productivity in all panels.

Empirical analysis has significant policy insights, particularly in disaster-prone countries. Due to the reduction effect of income on natural disasters, increasing disaster resilience could improve the preparedness and restoration processes. The implementation of mitigation policies (i.e., early warning mechanisms, up-to-date emergency management plans, latest technologies, training, and responses) could minimize human and economic loss. Focusing on increasing the share of fixed capital to increase production activities, foreign exchange earnings, production activities, trade, and financial development could increase resilience, mitigate disaster loss, and speed up the recovery process. Governments could allocate some budget to enhance disaster readiness and speedy recovery of affected people and communities. Due to the growth-specific impact of infrastructure, governments in developing countries could invest more in infrastructure to boost economic productivity. FDI inflows improve economic stability and mitigate disaster-related losses via disaster resilience. Thus, it is suggested to enhance domestic and foreign investments in sanitation, water supply, and electricity. Enhancing global partnerships through globalization is required to provide early warning systems, immediate financial aid, food supply, emergency equipment, and medicines to disaster-prone areas in low-income economies. Improving social capital, viz. human capital through activities and education acts as fellowship, mutual sympathy, social relationships, and goodwill—affecting disaster recovery and economic productivity.

There are limitations to this research. First, our disaster indicator doesn't explicitly account for the effect of man-made or technological disasters, which needs more investigation. Second, the panel selection is based on income groups, ignoring analysis based on geographical location or continent. Thus, researchers could investigate the effect of natural disasters on economic growth by controlling for geographical effects. Third, we used a dynamic panel estimation procedure, however, future studies could apply spatial or advanced estimation techniques to study disaster-growth relationships. Fourth, we used aggregated economic indicators, hence, researchers could assess the sectoral-based impact of natural disasters (i.e., agriculture, industry, and services). Finally, in terms of mitigation, further studies could examine the role of resilience-building in mitigating damages due to natural disasters.

Author contribution statement

Muhammad Tariq Iqbal Khan: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Sofia Anwar: Conceived and designed the experiments; Wrote the paper.
Samuel Asumadu Sarkodie: Analyzed and interpreted the data.
Muhammad Rizwan Yaseen: Performed the experiments.
Abdul Majeed Nadeem: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

Appendix A. List of selected countries

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