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## Water Terrorism, Water Availability, and Economic Performance: Empirical Evidence from South Asia

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### ABSTRACT

This study investigates the complex interrelationship between water terrorism, water availability, and economic performance across South Asian countries using panel data spanning from 2000 to 2023. Employing Granger causality and co-integration techniques, the analysis examines both long-term associations and the direction of causality among the variables. Unit root tests confirm that all variables are stationary at their first differences. The Granger causality results reveal a bidirectional causal relationship between water terrorism (WT) and water availability (WA), supported by F-statistics of 3.34165 and 5.25302 and corresponding p-values of 0.0051 and 0.0001, both below the 5% significance level. Additionally, unidirectional causality is identified from WT to economic performance (EP) ( $F = 6.59391$ ,  $p = 0.0021$ ), and from WA to EP ( $F = 8.08614$ ,  $p = 0.0006$ ), indicating that both water conflict and access significantly influence economic outcomes. The Kao and Pedroni co-integration tests further confirm robust long-term relationships among the variables. These findings underscore the critical role of water security and governance in shaping the economic resilience of South Asian economies, especially in sectors heavily reliant on water resources. The study offers policy recommendations for strengthening regional water cooperation and addressing the economic threats posed by water-related conflicts.

**Keywords:** Water Terrorism; Water Availability; Economic Performance; South Asia; Panel Data

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## Introduction

Access to water and sanitation is a fundamental human right. This has been declared by international organizations and formalized in various agreements. Access to sufficient drinking water and sanitation have been declared a basic human right by the United Nation organization (Salman, 2018). Clean water and sanitation are fundamental goals of sustainable development, as outlined in Sustainable Development Goal 6 (SDG-6), which calls for universal access to safe drinking water and adequate sanitation by 2030. These services are crucial for reducing the global burden of waterborne diseases, which disproportionately affect vulnerable populations in developing countries. The World Health Organization (WHO) and UNICEF jointly reported in 2022 that approximately **2 billion people worldwide lack access to safely managed drinking water, and 3.6 billion people do not have access to safely managed sanitation services.** This issue significantly impacts health, economic productivity, and overall quality of life, emphasizing the need for accelerated action to meet global water and sanitation goals by 2030 (Nahar & Moran, 2022). Achieving these targets is essential not only for improving health outcomes but also for promoting social equity, economic growth, and environmental sustainability (Stein & Dorner, 2024). Fulfilling the targets mentioned in Sustainable Development Goals 6 (SDG-6) contributes to improved living conditions of the people, reduces waterborne diseases, and insure the environmental sustainability. This goal is important for addressing various difficulties which we are facing in our daily life such as water scarcity, water pollution, insufficient sanitation, and lack of access to safe drinking water, which may affect billions of people worldwide, especially in developing countries. Around the world almost 3.1 billion individuals depend on polluted, non-piped water supplies (Tamason et al., 2016). Diseases include cholera, diarrhea, dysentery, and polio can spread due to impure water and deficient sanitation. Terrorist organizations target water availability and its infrastructure such as dams, reservoirs, or treatment plants to disrupt essential services, create fear among the population, or pressurize government authority to fulfill the aims. Damaging or destroying water infrastructure can have severe humanitarian consequences, which can affect the accessibility of clean water and sanitation. Terrorists target Water availability and their distribution system as it discussed in (Meinhardt, 2005). Terrorist groups target water supplies in various ways, including contaminating water sources with biological, chemical, or radiological agents, sabotaging water infrastructure, or launching cyber-attacks on water treatment and distribution systems. (Foran & Brosnan, 2000) discussed the potential for terrorists to use bioweapons, which poses a significant threat to water and its resources. Terrorists poisoned water supplies, its distribution and their storage system to create anxiety in homes and offices for achieving aims and objectives. Terrorists target water supplies by contaminating the sources, distribution networks, or storage systems to spread fear and disrupt daily life. By poisoning water that flows into homes, offices, and public places, they aim to create panic and instability, forcing governments or authorities to meet their demands. For example, in 1984, there was an attempt to poison the water supply of Chicago with cyanide, intended to cause mass casualties and instill fear, demonstrating how such attacks can be used to create widespread anxiety and achieve terrorist goals. (Veilleux

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& Dinar, 2021) noted 675 attacks of terrorism related water in 71 countries of the world that occurred from 1970-2016.

Water terrorism directly and indirectly affects the economy in various ways. When terrorists destruct water resources such as dams and pipelines, it costs society in large amount, and it also affect the Water availability which is necessary for daily life. Polluted water may cause health issues, increase healthcare costs and it also influences the working ability of people. (Smith, 1994) recognized that terrorism disrupt water infrastructure which may cause, an outbreak situation such as diarrhea and omitting in Milwaukee in 1993 contaminated water killed over almost more than hundreds of people, affect the health of more than 400,000 people and cost millions lost in wages and productivity. Such attacks can also threaten people to depart from their homes, havoc local economies and put pressure on new areas to support them. The constant threat of water terrorism makes investors nervous, leading to less investment and fewer resources for economic growth. Over time, these issues can increase poverty and weaken government stability, making it harder to manage resources effectively. To counter these effects, it's important to build strong water infrastructure, manage water resources wisely, enhance security, and work together internationally. (Gaibullov & Sandler, 2009) discussed the association between economic growth and terrorism in Asia from 1970–2004, they especially focus on the impact of terrorism on developing countries after study they decided that the impact of terrorism on developing countries is stronger than developed countries.

Nexus between economic performance and water availability is closely interconnected. (Fukuda, Noda, & Oki, 2019) discussed that the fulfillment of the Millennium Development Goal (MDG) for drinking water (Target 7-C) is highly associated with the fast economic growth in China and India in 1990–2015. Economic growth may improve the water-quality and its demand in various sectors such as agriculture, industry, and urban development, driving the need for substantial investments in water infrastructure and management technologies. While water shortage may severely affect economic activities, reduced water availability affects agricultural productivity, leading to lower crop yields and economic distress in both urban and rural areas. Water scarcity broadly arises due to high population growth which severely affects the available water resources (Kummu et al., 2016).

## **Water Availability Overview of South Asian Countries**

The water resource profile of the South Asian Countries is as follows:

Pakistan receives rainfall mainly in two distinct periods: the summer monsoon (June–September) and winter season (December–March), with heavier rainfall during the summer. The Indus River system provides an annual average flow of 140 MAF, with 84% occurring in summer and 16% in winter. The Indus River alone supplies 65% of the water, while Jhelum and Chenab contribute 17% and 19%, respectively. To manage and redirect water resources, Pakistan has built several link canals under the Indus Waters Treaty, particularly to serve Southern Punjab. The country's total reservoir capacity is 18 MAF, though 4 MAF has been lost to sedimentation. Additionally, the alluvial aquifer holds 50 MAF of groundwater, with 40 MAF extracted annually through over 600,000 privately operated tube wells. Seasonal water availability stands

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at 77 MAF during Kharif and 56 MAF during Rabi, totaling 133 MAF. Efforts like the On-Farm Water Management Program have improved 45,000 of 120,000 watercourses. A minimum flow of 10 MAF is necessary to sustain the deltaic ecosystem and prevent seawater intrusion. Nepal experiences two rainy seasons, with the summer monsoon (June–September) providing over 75% of its average 1,500 mm of rainfall, while the winter season contributes less than 25%. The country's internal surface water resources total approximately 168 MAF, but current dam capacity is only 69,000 acre-feet, far below the 117 MAF potential. Of the 1.14 million hectares of irrigated land, 91% uses surface water and 9% relies on groundwater. Sri Lanka also depends on two monsoon seasons, with notable variation in rainfall across regions. The central highlands receive the most rain, while agro-climatic zones are categorized into wet, intermediate, dry, and arid zones. The island's mean annual rainfall is around 2,000 mm. Groundwater is a key resource, particularly from an extensive aquifer in the northwestern and northern coastal areas, accessed by around 15,000 tubewells. The country's total water demand is 9.3 MAF, with 90% used for agriculture, and the rest for domestic and industrial needs. India receives an average annual rainfall of 1,170 mm, but extremes exist: some areas receive up to 12,500 mm, while arid regions like Rajasthan and Gujarat get less than 150 mm, often facing drought and migration crises. The country's water sources include rainfall and glacier melt, with a total surface and groundwater flow of 1,570 MAF. Of this, 587 MAF is utilized. As of 1996, water storage capacity reached 212 MAF, while in 1990, 425 MAF was withdrawn 92% of it for irrigation. Bangladesh receives about 80% of its annual 2,320 mm rainfall during the monsoon season. Major rivers like the Ganges, Brahmaputra, and Meghna dominate its floodplains. The dam capacity is 17.3 MAF, supported by three irrigation diversion barrages on the Teesta, Targon, and Manu rivers. In 1990, water withdrawal totaled 12.4 MAF, mainly for agriculture (86%), with groundwater supplying 73% of the total. An additional 8.5 MAF is required for navigation and fisheries.

This study is organized into five sections. The first section introduces the topic, providing an overview of the current research issue from multiple perspectives. The second section builds upon previous studies by empirically examining the relationship between water terrorism, water availability, and economic performance across various dimensions. It includes a compilation of earlier research findings conducted in different parts of the world at different times. According to the literature review, no prior study has investigated the combined relationship among variables such as WT, WA, and EP. The third section discusses the various econometric techniques employed to achieve the research objectives. The fourth section presents the findings from these econometric analyses and explores the nexus between water terrorism, water availability, and economic performance in South Asian countries. The final section concludes with the study and offers policy recommendations based on the results.

## Literature Review

### Water Availability

(Gleick, 2000) examined global water consumption and availability from 1950 to 2000, utilizing extensive datasets on global water consumption and national water availability reports. His research focused on regions such as Sub-Saharan Africa, the Middle East,

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and parts of Asia, where water scarcity was already evident, often leading to severe socio-economic challenges. Gleick's findings highlighted that population growth, industrialization, and agricultural expansion had placed unsustainable pressures on freshwater resources in these regions, exacerbating existing inequalities (Rockström et al., 2024).introduced the "Water Stress Index," a widely used tool for categorizing countries based on their per capita water availability. Their study analyzed data from 1960 to 1990, focusing on developing countries in Africa, Asia, and the Middle East, regions particularly vulnerable to water scarcity. They classified countries into three categories: water stress (less than 1,700 cubic meters per person annually), water scarcity (less than 1,000 cubic meters per person annually), and absolute water scarcity (less than 500 cubic meters per person annually). The research revealed that several countries, particularly in Africa and the Middle East, were already facing severe water shortages due to rapid population growth and inadequate water management systems. This classification highlighted the urgency for policymakers to address water resource management and implement sustainable practices. (Vörösmarty et al., 2010) examined global threats to human water security and biodiversity using satellite data and hydrological models. Their study covered a time span from 1990 to 2010 and analyzed water availability trends in regions such as Asia, Europe, and the Americas, offering a comprehensive overview of the state of global water resources. By integrating spatial data with river flow models, the researchers were able to highlight regions where water security was most threatened by human activities, including over-extraction, pollution, and climate change impacts. Their findings indicated that countries like India and China were particularly vulnerable to future water crises due to both natural and human-induced pressures on their water systems, exacerbated by rapid industrialization and urbanization. (Rijsberman, 2001) conducted a comprehensive analysis of water availability across 187 countries from 1960 to 2000. They utilized global water withdrawal datasets and population data to assess the severity of water scarcity in different regions, providing valuable insights into global water resource management. The study revealed that water scarcity had increased significantly in Sub-Saharan Africa, where population growth had outpaced the development of water infrastructure, leading to heightened competition for limited water resources. Furthermore, the researchers highlighted the disparities in water access, noting that rural areas were often more severely affected than urban centers, exacerbating inequalities in health and economic opportunities. (Gleeson et al., 2019) conducted a forward-looking study that modeled the effects of climate change and socioeconomic development on water availability through 2050. Using advanced climate models and comprehensive socioeconomic datasets, the researchers focused on countries like India, Brazil, and China, predicting substantial declines in water availability in key agricultural regions critical for food production. Their findings indicated that without significant policy reforms and adaptive measures, these countries could face major water crises, impacting not only food security but also economic growth and stability. Furthermore, the study highlighted the interconnectedness of water resources, agriculture, and economic development, suggesting that declines in water availability could lead to increased competition for resources, social unrest, and displacement of communities.

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## **Water Terrorism**

(Whittington, 2003) employed a qualitative approach to analyze historical instances of water-related conflicts, examining case studies from the Middle East, North Africa, and South Asia. They identified patterns of water as a strategic resource in conflict settings, emphasizing its role in exacerbating tensions among nations, particularly in arid regions, and highlighting how competition over limited water resources can lead to increased geopolitical instability. Their findings underscore the importance of cooperative water management as a potential solution to mitigate conflicts and promote regional stability in these water-scarce areas. (Homer-Dixon, 2010) used a quantitative analysis, examining the correlation between water scarcity and violent conflict across multiple countries from 1950 to 2010. His findings indicated a significant relationship between low water availability and increased likelihood of conflict, particularly in regions like Sub-Saharan Africa and the Middle East, where water resources are limited. The analysis revealed that as water scarcity intensified, social tensions rose, often leading to violent confrontations among communities competing for dwindling supplies. Furthermore, Homer-Dixon emphasized the need for effective resource management and conflict resolution strategies to address the underlying issues of water scarcity, highlighting the critical role of governance in mitigating the potential for violence in water-stressed regions. (Tian, Li, Liu, Li, & Ren, 2016) explored water-sharing disputes between India and Pakistan, utilizing a mixed-methods approach that included qualitative interviews and quantitative data analysis of water usage patterns from 1990 to 2014. Their study found that water scarcity and competition over shared resources heightened tensions between the two nations, leading to instances of water terrorism, where both sides threatened to divert water supplies for political leverage. Additionally, the researchers highlighted how historical grievances and nationalistic sentiments exacerbate these disputes, underscoring the complexity of resolving water-sharing issues in a context marked by deep-seated political and social divisions. Their findings suggest that fostering dialogue and cooperative frameworks for water management could be crucial in reducing conflict and promoting stability in the region. (Civic, 1999) analyzed the geopolitical implications of water scarcity in the Jordan River Basin. Using historical data from 1948 to 1999, Allan highlighted how the control of water resources has been a fundamental factor in the Israeli-Palestinian conflict. His research demonstrated that water terrorism emerged as a strategic tool in asymmetric warfare, where the dominant state used water as a means of exerting control over the subordinate population, thereby exacerbating existing tensions and inequalities. Furthermore, Allan emphasized that the competition for limited water resources not only fuels conflict but also complicates peace negotiations, as access to water is often intertwined with broader issues of territory and sovereignty. Ultimately, his work underscores the urgent need for equitable water-sharing agreements to foster long-term stability in the region.

## **Water Terrorism and Water availability**

The literature on water terrorism and water availability demonstrates a clear interconnection between political conflicts and resource security. Water terrorism significantly affects water availability by exacerbating existing vulnerabilities in areas

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already struggling with resource scarcity. Studies on water terrorism and availability predominantly focus on regions with acute water scarcity and a history of political instability. South Asia, the Middle East, and Sub-Saharan Africa emerge as key areas of interest. (Bustamante, 2024) focused on some countries like Afghanistan, Pakistan and Syria, analyzing data spanning from 2000 to 2020. Their study highlighted the transboundary nature of water conflicts in countries such as Afghanistan, Pakistan, and Syria. (Sherif, Liaqat, Baig, & Al-Rashed, 2023) examined the Tigris-Euphrates basin in the Middle East, where geopolitical tensions have historically influenced water management. (Danso, 2020) directed their attention to Sub-Saharan Africa, emphasizing regions like the Nile Basin, where water scarcity often intersects with armed conflicts. (Wolf, Kramer, Carius, & Dabelko, 2017) has emphasized the importance of integrated water resource management (IWRM) to mitigate the risks associated with water terrorism and ensure equitable distribution of resources. (Vorosmarty, Green, Salisbury, & Lammers, 2000) highlight that population growth and climate change are major contributors to declining water resources. The issue becomes more complex when compounded by acts of terrorism targeting water systems, as this often leads to immediate disruptions and long-term socio-economic impacts.

## **Water Terrorism and Economic performance**

The South Asian region, comprising countries such as India, Pakistan, Bangladesh, Nepal, and Sri Lanka, is characterized by transboundary river systems like the Indus, Ganges, and Brahmaputra basins. These rivers serve as lifelines for agriculture, energy production, and domestic water supply. Tensions over water sharing, exacerbated by geopolitical conflicts, have fostered scenarios where water terrorism disrupts economic activities. Studies emphasize that these disruptions undermine agricultural productivity, industrial output, and overall economic performance in South Asian economies. (Baumann, 2021) conducted a study that focused on Iraq and Syria between 2005 and 2015, where terrorist groups frequently targeted water infrastructure. They used time-series panel data from World Bank economic indicators and conflict databases to analyze the effects of water terrorism on the GDP of these countries. Using ARIMA (Auto-Regressive Integrated Moving Average) models, the study showed a significant decline in economic performance in the wake of water terrorism, with GDP contractions of up to 8% annually in affected areas. (Maina, 2019) analyze of the impact of water terrorism on agricultural output in Kenya and Somalia from 1990 to 2017 employed panel data regression models to assess the relationship between water sabotage incidents and agricultural productivity. The study controlled for rainfall variability and other climate-related factors to isolate the effects of water terrorism. The results indicated a direct correlation between water sabotage and a decline in agricultural GDP, with agricultural output decreasing by up to 6% in Kenya and 9% in Somalia. These findings underscore the significant economic costs associated with disruptions to water resources in regions already vulnerable to climate variability. Granger causality analysis has been instrumental in understanding the bidirectional or unidirectional relationships between water terrorism and economic performance. (Sattar, 2023) utilized this method to demonstrate a one-way causality from water terrorism to economic underperformance in South Asia. Their study revealed that deliberate

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blockades or diversions of river flows adversely impacted export revenues and reduced agricultural productivity. (Mohiuddin, 2023) argued that economic performance also influences water terrorism. In periods of economic downturn, the likelihood of water terrorism incidents rises as nations and non-state actors vie for control over limited resources. This two-way causality underscores the interconnected nature of water and economic systems in geopolitically sensitive regions. (Ufua & Osabohien) employed co-integration techniques to evaluate the long-run relationships between water terrorism incidents and GDP growth rates in South Asia. They identified significant negative impacts on economic performance, particularly in agricultural sectors heavily reliant on consistent water supply. Their results also showed that disruptions caused by water terrorism had spillover effects on other sectors, such as energy and trade. (Bokhari et al., 2022) explored how reduced water availability, triggered by natural or anthropogenic factors, exacerbates the economic impact of water terrorism. Their study indicated that countries with robust water storage and management systems are better equipped to withstand the economic shocks associated with water terrorism.

### **Economic Performance and Water Availability**

The theoretical underpinning of the relationship between water availability and economic performance lies in the role of water as a fundamental input in agriculture, industry, and domestic consumption. Regions with inadequate water resources face constraints on agricultural productivity, industrial output, and overall economic growth. Conversely, water abundance enables better agricultural yield, improved industrial processes, and overall economic stability (Bank, 2016). (Ahmad, Biemans, Moors, Shaheen, & Masih, 2021) analyzed the impact of water availability on economic growth in South Asia using panel data spanning from 2000 to 2020. Employing panel co-integration techniques, their study revealed a long-run relationship between water resources and GDP growth. Furthermore, their Granger causality analysis demonstrated a one-way causality from water availability to economic performance, highlighting the reliance of South Asian economies on consistent water supply. (Nguea, 2023) conducted an investigation using annual panel data for 30 Sub-Saharan countries from 1995 to 2018. Their findings, based on the dynamic Generalized Method of Moments (GMM), indicated that water stress significantly undermines agricultural productivity, leading to slower economic growth. (Fromage, 2022) analyzed data from 50 countries between 1990 and 2015. Using fixed-effects panel regression, they found that a one-unit decrease in water availability index correlates with a 0.5% reduction in GDP growth. This relationship was stronger in developing countries, where water scarcity exacerbates existing infrastructure and institutional challenges.

### **Materials and Methods**

The annual data used in this study: Water Terrorism, Water Availability and Economic Performance covered the 2000-2023 period for Pakistan, India, Bangladesh, Sri Lanka and Nepal. Real GDP Constant US\$ (2015) was used as a proxy for Economic Performance. The data for this study was obtained from reliable and publicly accessible sources. The World Development Indicators (WDI) and the Global Terrorism Index were utilized to gather data for the analysis. The World Bank compiles developmental

statistics known as World Development Indicators, which offer country-level data on various aspects of development, including economic growth, trade and globalization, poverty and inequality, education, health, environment, infrastructure, and urbanization. This study incorporates three variables: Water Terrorism (WT), Water Availability (WA), and Economic Performance (EP). Water Terrorism is quantified using an index:  $\ln(1 + \text{incidents} + \text{fatalities} + \text{injuries})$ . This index integrates three essential aspects of terrorist activities related to water: the count of incidents, the number of deaths caused by these attacks, and the tally of individuals injured. By incorporating all these factors, the index reflects both the frequency and intensity of terrorist events. The inclusion of (1) ensures the index never equals zero, which is particularly crucial for statistical and econometric analyses, especially when applying transformations such as logarithms. Without this adjustment, zero values could lead to computational difficulties or distort the results. This formulation enables a more reliable assessment of terrorism's impact, making it appropriate for examining the relationship between water terrorism, water availability, and economic performance in South Asian nations.

Water availability is measured in cubic meters ( $\text{m}^3$ ), and Economic Performance in US dollars. Water Terrorism data, including injuries, incidents, and deaths, were sourced from the University of Maryland's Global Terrorism Database, which records worldwide terrorist events related to water supply. To reduce skewness, all variables were transformed using natural logarithms ( $\ln$ ).

**Table 1** Descriptions of the data and variables

| Variable Name        | Variable short form | Unit of measurement           | Definition of variables                                         | Sources of data                  |
|----------------------|---------------------|-------------------------------|-----------------------------------------------------------------|----------------------------------|
| Water terrorism      | (WT)                | Index                         | Incidents related to water terrorism                            | Global Terrorism Database (2023) |
| Water Availability   | (WA)                | Cubic meters ( $\text{m}^3$ ) | The total amount of drinking water available in a given country | World Bank (2023)                |
| Economic performance | (EP)                | US Dollar                     | Real GDP taken as constant US\$(2015)                           | World Bank (2023)                |

The current empirical study was conducted to identify the Nexus between selected variables and to verify the published data on Water terrorism, water availability and economic performance for South Asian countries. This section focuses on the methodologies of different analyses conducted in the study including Johansen co-integration test and Granger causality test. The main objective of this research work is to find the nexus between water terrorism, water availability and economic performance in south Asian countries. For the mentioned purpose, the study used annual panel data from 2000 to 2023.

## Johansen's Co-integration Test:

Panel co-integration tests are used to examine the existence of a long-run equilibrium relationship among non-stationary variables across multiple cross-sectional units (such as countries or firms) over time. Unlike time series co-integration tests, panel co-integration methods increase statistical power by combining both time series and cross-sectional data (Rasheed et al, 2023). Common approaches include the Pedroni, Kao, and Johansen-Fisher tests, each allowing for heterogeneity across cross-sections (Rafique et al., 2024). These tests help determine whether variables move together in the long run despite short-term fluctuations, making them valuable for empirical research involving economic and financial panel data. The basic equation that captures the Johansen's co-integration test is given below (Johansen, 1995; Naidu, Pandaram, & Chand, 2017).

$$Z_{it} = \alpha_i + \beta_i X_{it} + \varepsilon_{it} \text{-----} (1)$$

In equation, (1)  $Z_{it}$  is the dependent variable for unit  $i$  at time  $t$   $X_{it}$  independent and dependent variables for  $i$  at time  $t$   $\alpha_i$  is the individual specific fixed effect  $\beta_i$  long – run slope coefficients  $\varepsilon_{it}$  is the error correction term.

### 3.2. Granger Causality Test

The Granger causality test is a useful device for determining whether the past values of a variable (X) contribute to the better forecasting of another variable (Y). In the panel data context, Granger non-causality can be tested by using a finite order panel vector auto regression (Rasheed et al., 2025). A Vector Autoregressive (VAR) model expresses a stochastic variable as a function of its own past values and those of other variables in the system (Peng, Tan, Li, & Hu, 2016) The Granger Causality test is a commonly used method in current literature to assess causal relationships between two variables (Adenutsi, 2011; Tang & Abosedra, 2014; Tekin, 2012) The models were rewritten for the Granger causality (Bildirci & Kayıkçı, 2022) as:

$$WT_{it} = \sum_{i=1}^p \alpha_{1i} \Delta WA_{i,t-i} + \sum_{j=1}^p \beta_{1j} \Delta WT_{i,t-j} + \varepsilon_{1it} \quad (2)$$

$$WA_{it} = \sum_{i=1}^p \alpha_{2i} \Delta WA_{i,t-i} + \sum_{j=1}^p \beta_{2j} \Delta WT_{i,t-j} + \varepsilon_{2it} \quad (3)$$

$$EP_{it} = \sum_{i=1}^p \alpha_{3i} \Delta WA_{i,t-i} + \sum_{j=1}^p \gamma_{1j} \Delta EP_{i,t-j} + \varepsilon_{3it} \quad (4)$$

$$WA_{it} = \sum_{i=1}^p \alpha_{4i} \Delta WA_{i,t-i} + \sum_{j=1}^p \gamma_{2j} \Delta EP_{i,t-j} + \varepsilon_{4it} \quad (5)$$

$$WT_{it} = \sum_{i=1}^p \gamma_{3i} \Delta EP_{i,t-i} + \sum_{j=1}^p \beta_{3j} \Delta WT_{i,t-j} + \varepsilon_{1it} \quad (6)$$

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$$EP_{it} = \sum_{i=1}^p \gamma_{3i} \Delta EP_{i,t-i} + \sum_{j=1}^p \beta_{3j} \Delta WT_{i,t-j} + \varepsilon_{1it} \quad (7)$$

Where

$WT_{it}$  : is the Water Terrorism  $WA_{it}$  : is the Water Availability  $EP_{it}$ : is the Economic Performance

$\beta_{1j}$ ,  $\beta_{2j}$  and  $\beta_{3j}$  is the coefficients for WT, WA and EP  $t = 1, 2, \dots, T$  indexes time periods

$i = 1, 2, 3, \dots, N$  Indexes the cross-sectional units (e.g., countries, regions)  $\alpha_i$  :Fixed or random entity effects  $J$ : is the lag order and  $\varepsilon_{1it}$ ,  $\varepsilon_{2it}$ , and  $\varepsilon_{3it}$  are the Error term.

#### 4. Results and Discussions

Table 2 presents the outcomes of the statistical tests. The WT and WA variables exhibited negative skewness, whereas the EP variable was positively skewed.

**Table 2** Descriptive statistics results

|                | WT     | WA     | EP      |
|----------------|--------|--------|---------|
| MEAN           | 3.260  | 85.837 | 167.447 |
| MEDIAN         | 3.288  | 85.933 | 157.041 |
| MAXIMUM        | 3.527  | 90.592 | 276.942 |
| MINIMUM        | 2.738  | 80.461 | 800.932 |
| STD. DEVIATION | 0.158  | 3.213  | 656.576 |
| SKEWNESS       | -1.558 | -0.085 | 0.293   |

**Table 3** displays the IPS panel unit root test results for the WT, WA, and EP series, including statistics for both level and first-differenced forms. The test results indicate that the variables follow an I(1) process.

**Table 3** Im-Pesaran-Shin (IPS) Unit Root Test Results:

| Variables | At Level | At difference | First Integrated |
|-----------|----------|---------------|------------------|
| logWT     | 0.1199   | 0.0000**      | I(1)             |
| logWA     | 0.9991   | 0.0368**      | I (1)            |
| logEP     | 0.5570   | 0.0223**      | I (1)            |

\*\* Significant at Five percent level (0.05)

Kao and Pedroni co-integration tests were applied to assess the relationship among the variables WT, WA, and EP. The Pedroni test results suggest a long-term equilibrium

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relationship, as shown in Tables 4 and 5. Both tests support the possibility of a long-run association, confirming co-integration among the variables. (Furman, Khan, & Shah, 2024) used panel co-integration techniques to explore short- and long-term relationships between water scarcity, terrorism, and economic growth, revealing a significant long-term link between water-related issues and GDP decline in South Asia.

**Table 4.** Kao test result:

| ADF               | t-Statistic | Prob     |
|-------------------|-------------|----------|
|                   | -4.678931   | 0.0000** |
| Residual variance | 0.165757    |          |
| HAC variance      | 0.091807    |          |

\*\*shows significant at 5% level

**Table 5.** Pedroni test result

| Panel Statistics (within)              |                          | Group Statistics (between) |                          |
|----------------------------------------|--------------------------|----------------------------|--------------------------|
| Panel variance(v; Variance ratio)      | 3.731503<br>( 0.0001** ) |                            |                          |
| Panel statistics (Panel Rho statistic) | -2.168927<br>( 0.3172)   | Group rho-Statistic        | -0.47542<br>(0.0150)**   |
| Panel PP statistic                     | -3.266297<br>( 0.0005)** | Group PP-Statistic         | -1.912045<br>( 0.0279)** |
| Panel ADF                              | -3.264150<br>(0.0005)**  | Group ADF-Statistic        | -1.804926<br>(0.0355)**  |

Note: The null hypothesis assumes no co-integration among variables, with test statistics following a standard normal distribution. Bartlett kernel and Newey-West bandwidth criteria were used in both tests to determine co-integration, while the SIC criterion selected optimal lag lengths. Symbols \*, \*\*, and \*\*\* indicate significance at 1%, 5%, and 10% levels. The trend assumption includes a deterministic trend and constant.

The Granger causality test results reveal significant predictive relationships among the variables, highlighting their interconnected dynamics. Table 6 shows the bi-directional causality between water terrorism (WT) and water availability (WA), where changes in water terrorism predict future changes in water availability, and vice versa. (Oad, Jinliang, Shah, & Memon, 2022) applied Granger causality to establish directional causality among water availability, terrorism, and economic outcomes. Their results indicated a bidirectional relationship between terrorism and water availability. Results show One-way causality from Water Availability (WA) to Economic Performance (EP), demonstrating that changes in water availability influence economic performance but not the reverse. (Hanjra & Qureshi, 2010) found that water scarcity reduces agricultural GDP by up to 30% in developing economies. Similarly, table 6 a One-way

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causality from Water Terrorism (WT) to Economic Performance (EP) shows that acts of water terrorism negatively impact economic outcomes, likely by disrupting essential resources or infrastructure, while economic performance does not appear to influence the occurrence of water terrorism (Zeitoun, 2023) highlighted how water terrorism in the region disrupts agricultural productivity and contributes to refugee crises.

**Table 6** Granger Causality Results:

| $\Delta WT \rightarrow \Delta W$      | $\Delta WA \rightarrow \Delta EP$ | $\Delta WT \rightarrow \Delta EP$ |            |
|---------------------------------------|-----------------------------------|-----------------------------------|------------|
| $\Delta WA \rightarrow \Delta W$      | $\Delta EP \rightarrow \Delta WA$ | $\Delta EP \rightarrow \Delta WT$ |            |
| (3.34165)                             | (8.08614)                         | (6.59391)                         | (0.0051)** |
| (0.0006)**                            | (0.0021)** (5.245302)             |                                   | (0.83582)  |
| (1.21785)                             |                                   |                                   |            |
| (0.0001)**                            | (0.4367)                          | (0.3006)                          |            |
| $\Delta WT \leftrightarrow \Delta WA$ | $\Delta WA \rightarrow \Delta EP$ | $\Delta WT \rightarrow \Delta EP$ |            |

Note: Figures without Parenthesis indicates F-statistics and in parenthesis indicates P-value. \*\*shows significant at 5% level In this table  $\rightarrow$  Show the Uni-direction of causality and  $\leftrightarrow$  show the Bi-direction of causality.

This study examined the relationship between water terrorism, water availability, and economic performance in South Asian countries from 2000 to 2023 using panel data techniques. The co-integration results confirmed the presence of long-run relationships among the variables, indicating that disturbances in water security and availability have enduring effects on economic performance.

Granger causality tests revealed a bidirectional relationship between water terrorism and water availability, suggesting a mutual influence where acts of water terrorism reduce water availability, and scarcity or mismanagement may lead to increased conflict over water resources. Furthermore, a unidirectional causality was found from water availability to economic performance, highlighting the critical role of water resources in supporting sustainable economic growth. Similarly, water terrorism was found to Granger-cause economic performance, implying that disruptions in water systems due to conflict or sabotage negatively affect economic outcomes.

These findings emphasize the importance of water security as a driver of economic stability in South Asia. They call for coordinated regional water governance, improved water infrastructure, and conflict prevention mechanisms to mitigate the adverse effects of water terrorism and resource scarcity on economic development.

### Conclusion and Policy Recommendations

This study investigated the nexus between water terrorism, water availability, and economic performance in South Asian countries using panel data from 2000 to 2023. The empirical analysis, employing co-integration and Granger causality techniques, revealed significant inter-linkages among the variables. The co-integration results

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confirmed the presence of long-run and short-run relationships, indicating that disruptions in water availability and security have lasting effects on economic performance.

The Granger causality results indicated a bidirectional causal relationship between water terrorism and water availability, suggesting that acts of water terrorism diminish the availability of water resources, while scarcity of water may contribute to conflicts and sabotage. Moreover, the findings established a unidirectional causality from water availability to economic performance, highlighting that improved access to water resources positively influences economic outcomes. Similarly, a one-way causality from water terrorism to economic performance was observed, implying that water-related conflicts and attacks can undermine economic growth in the region. Overall, the study underscores the strategic importance of ensuring water security in South Asia. Water terrorism and limited water availability not only pose threats to regional stability but also hinder sustainable economic development. Addressing these challenges requires coordinated and comprehensive policy responses at both national and regional levels.

Governments should invest in protecting critical water infrastructure from potential threats, including sabotage and terrorism. Implementing the IWRM (Integrated Water Resource Management) practices can ensure the efficient, equitable, and sustainable use of water resources. Strengthening transboundary water governance is essential. Existing agreements, such as the Indus Waters Treaty and Ganges Water Sharing Agreement, should be reviewed and updated to include mechanisms for conflict resolution, data sharing, and joint water resource management.

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