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IMPACT OF NATURAL DISASTERS ON FOOD SECURITY IN PAKISTAN

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ABSTRACT

Food security is the situation in which all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy life. Natural disasters can severely disrupt food security by damaging crops, livestock, and infrastructure. They often lead to immediate food shortages and long-term impacts on food availability and access. This study investigates the impact of natural disasters on food security in Pakistan using a quantitative approach and secondary data spanning from 1990 to 2022. Pakistan, with its diverse topography and climate variations, is highly susceptible to natural calamities like floods, earthquakes, and droughts, which significantly affect its agricultural productivity and food security. The research employs a multiple regression model to explore how natural disasters, along with factors such as high-yielding variety (HYV) seeds, irrigated area, climate change index, and pesticide usage, influence daily per capita caloric intake as a measure of food security. The Fully Modified Ordinary Least Squares (FMOLS) method is used to address the complexities of cointegrated data and provide accurate parameter estimates. Results reveal a significant negative impact of natural disasters and climate change on food security, while the use of HYV seeds and increased irrigated areas positively influence caloric intake. The study highlights the critical need for improved water management and agricultural practices to mitigate the adverse effects of natural disasters and climate change on food security in Pakistan. The study's quantitative findings reveal a significant negative impact of natural disasters on food security in Pakistan, evidenced by a coefficient of -0.055 for the disaster variable (DIS) with a p-value of 0.041, indicating statistical significance at the 5% level. Additionally, strong positive correlations are observed with agricultural variables: the irrigated area (LIA) has a coefficient of 2.42, while high-yielding seed varieties (LHS) have a coefficient of 0.085. The regression model demonstrates excellent fit, with an R-squared value of approximately 0.95, indicating that the independent variables account for about 95% of the variability in food security outcomes. Overall, these results highlight the vulnerability of food security to natural disasters and the critical role of agricultural advancements in mitigating these impacts.

INTRODUCTION

The concepts of "food security" and "food insecurity" are used to describe how families access adequate amounts of nutritious and quality food. Food security became a prominent concern in the 1970s and has continued to receive significant attention ever since. Perspectives on what defines food security vary widely across global, national, household, and individual levels (Duffour k, 2009).

Solutions to food security challenges vary depending on the global context and the specific location of the issue. Arid countries such as Morocco, Bangladesh, and Pakistan encounter distinct difficulties compared to regions in East Asia or sub-Saharan Africa. This discussion emphasizes the unique obstacles faced by the former group, including severe aridity and high soil salinity (FAO, 2015).

Extreme weather events are becoming more frequent and severe worldwide, posing threats to human health, access to clean water, energy, and food, while also hindering efforts to reduce poverty and achieve sustainable development (Managi & Zhang, 2020).

In some cases, severe disasters can devastate a nation's economy, undo years of progress, and inflict immense human suffering. Additionally, the physical and financial impacts of such natural disasters often extend beyond the affected regions, impacting the entire country (Loayza et al., 2012). Catastrophes can disrupt a nation's economic development, either temporarily or permanently. This is particularly alarming given the significant increase in global disaster occurrences in recent decades (Noy & Cavallo, 2009).

The agricultural sector is typically the most severely affected by the unforeseen consequences of these disasters. As stated by the FAO (2015), Over the past 30 years, 67 developing countries have experienced at least one moderate to large-scale disaster. The agricultural sector supports the livelihoods of 2.5 billion people globally, with more than half of the world's agricultural output coming from small-scale farmers, livestock keepers, fishermen, and forest-dependent communities (Tubiello & Rosenzweig, 2008).

These communities are especially vulnerable to disasters that can destroy or damage crops, equipment, resources, livestock, seeds, agricultural produce, and stored food supplies. Developing countries and smaller economies are more exposed to climate change than developed nations, due to their already limited production capacity, heavy reliance on agriculture, greater exposure to extreme events, lack of funding for development, and inadequate implementation of adaptation measures (Noy, 2009; Jawid & Khadjavi, 2019).

Although the agricultural sector is particularly susceptible to the adverse effects of environmental disasters, a review of recent literature reveals that several key aspects of this issue have been largely overlooked. Research on the economic impact of natural disasters has primarily focused on the immediate consequences, such as loss of life, destruction of physical assets, food insecurity, and the depletion of capital (Nguyen & Nguyen, 2020). The occurrence of extreme weather events is increasing in both frequency and intensity. Hazards such as floods, droughts, and storm surges threaten the environment, wildlife, crops, and food supplies (Godde et al., 2021).

Climate change has led to the depletion of aquifers, greater difficulty in accessing water, and challenges in enhancing agricultural productivity (Kirby et al., 2017).

Those living in vulnerable areas and already facing the risk of hunger are most affected by climate change (Mahapatra et al., 2021).

Over the past decade, South Asian countries have achieved remarkable socioeconomic progress. Despite this, they still confront major challenges, such as reducing poverty and malnutrition, and ensuring access to adequate and nutritious food for their populations to achieve a high quality of life and well-being (Heidkamp et al., 2021).

Pakistan, an agriculture-dependent economy, is among the top 10 countries most affected by global warming, as highlighted by the Global Vulnerability Index. A large portion of its population is economically disadvantaged and less equipped to adapt to climate challenges. The northern regions are particularly vulnerable to threats such as snow, landslides, and floods. Since the early 20th century, Pakistan has faced a steady rise in temperatures, increasing by 0.6 to 1.0 degrees Celsius. Coastal areas have experienced a 10 to 15 percent decline in rainfall, while monsoon regions with high humidity have seen rainfall increase by 18 to 32 percent (Farooqi et al., 2005). Pakistan faces substantial economic losses each year due to climate-related stresses and disasters, as exemplified by the 2010 flood. Since agriculture is the backbone of the country's economy, the destruction of standing crops during such events led to widespread poverty across society (Arif & Farooq 2012).

A report by the National Disaster Management Authority (NDMA) highlights the 2010 flood as the most severe climate disaster to hit Pakistan's economy. This catastrophic event affected nearly 20 million people and caused immense economic losses. The flood, a clear example of climate-induced stress, disproportionately impacted rural poor communities while raising serious food security concerns in urban areas. It also inflicted extensive damage on infrastructure, including communications, energy, transportation, water management systems, and livelihoods (Khan & Salman, 2012). In recent years, the country has experienced significant losses due to floods, with the affected regions consistently falling behind socially and economically. Floods are among the most destructive and costly natural hazards, undoing years of progress. Historically, flooding in Pakistan has been linked to heavy and intense rainfall, with flash floods occurring when such precipitation triggers powerful flood waves (Shah et al., 2022) .

Heavy rainfall in the Hindu-Kush and Karakoram Mountain ranges intensifies glacier melting, leading to an extraordinary surge of water in the Indus River. Unfortunately, Pakistan's once well-managed watershed system has deteriorated. Rampant deforestation in the Sindh and Punjab provinces has weakened the rivers' natural defences against flood waves. Pakistan is among the countries with the lowest forest coverage, losing around 66,718 acres of forest annually, with approximately 5,683 acres of riverside forests disappearing each year (Shah et al., 2022).

The IPCC predicts that rising global temperatures will alter rainfall patterns, leading to increased precipitation. This change could intensify flooding in the Himalayan–Hindu Kush region, including the Indus Basin. Past events, such as avalanches and debris flows, have caused eight floods in the Indus Basin, with more downstream floods expected due to unpredictable rainfall and runoff. The Himalayan and downstream river basins face a higher risk of frequent flood events. Risk perception is influenced by factors like exposure, past experiences, cognitive abilities, understanding of risks, and socio-political context. Assessing risk perception is essential for creating effective disaster management strategies, as it shapes how individuals prepare, adapt, and respond to disasters (Shah et al., 2022).

Communities with heightened hazard awareness tend to exhibit stronger preparedness and coping mechanisms. Social groups skilled in recognizing risks are often better at anticipating disasters, facilitating the spread of disaster-related knowledge within the group. Consequently, it can be inferred that risk perception plays a key role in enhancing community adaptability. However, a significant disparity between actual and perceived flood risks poses a major challenge to effective flood risk management. This issue is further compounded by an inadequate understanding of how communities perceive flood risks, making effective communication about flood risks a pressing concern (Shah et al., 2022).

In Pakistan, a key concern for authorities in addressing climate stresses and natural disaster management is their focus on relief and rescue efforts, rather than emphasizing public education on identifying stresses, assessing risks, and managing them effectively. Priority should be given to raising awareness about the connection between individuals' livelihoods and their readiness to face these challenges. Unfortunately, this critical aspect is currently being neglected by the country's officials (Rafiq & Blaschke, 2012).

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Significance of the study

Food security has become a crucial and expansive topic in various policy initiatives globally. Countries around the world are actively working to enhance their food security, acknowledging its paramount significance. The task of providing sustenance to a nation's population, as well as the entire world, elucidates the reason why food security holds immense importance for both developed and developing nations. In other words, this problem has an impact on nearly every aspect of society and the economy, influencing not only the accessibility of food and the methods of feeding people, but also various other areas. Climate-related elements have significantly contributed to the increase in global food insecurity. The effects of climate change, resulting from global warming, have brought about extreme weather conditions such as heatwaves, heavy rainfall, floods, and droughts. Natural disasters result in extensive destruction and have a significant impact on all aspects of society, particularly on food security, including floods, droughts, and pest attacks. This research employs certain factors to compensate for the losses caused by calamities. For instance, when floods transpire, they result in extensive destruction of cultivated land. To address these damages, we employ high-yielding seed varieties (HYV seeds) and expand the area of irrigated land. As a result of these measures, agricultural production experiences a rapid increase. However, when the dry season commences, agricultural growth is hindered as crops rely on water. To overcome this obstacle, we utilize underground water (water efficiency) through advanced technology, which visibly enhances agricultural output.

LITERATURE REVIEW

Zohu et al. (2019) conducted a study to explore the factors influencing the stability of food supplies for rural households in northern Pakistan. To identify the key determinants of food insecurity, the researchers used binary logistic regression analysis. The results highlighted several important variables that play a significant role in determining whether a household faces food scarcity. These factors included education level, remittances, gender, unemployment rate, inflation rate, assets, age, and health issues.

Asghar and Salman (2018) conducted a study to examine the impact of agricultural financing on food stability and crop production in Pakistan, a country struggling with reliable access to food. The study highlighted that providing credit to the agricultural sector could boost food production and improve food security. The researchers found that borrowers saw an increase in productivity after using loans to invest in higher-quality agricultural inputs. Their findings suggested that eliminating financial barriers could lead to greater agricultural output, helping to ensure a stable food supply for all. This research offers valuable insights for policymakers, particularly in strengthening credit markets to improve food security policies and practices.

Khan et al. (2018) investigated the socioeconomic factors influencing food security in the Jhang district of Punjab, Pakistan. Despite Pakistan's status as a leading agricultural producer over the past four decades, the study highlights ongoing challenges with food insecurity and poverty. The issue of food insecurity has intensified nationwide due to frequent floods, droughts, and a growing imbalance between the availability of essential food items and consumer demand. Although various regulations have been introduced to control the availability and pricing of essential goods, food insecurity remains a persistent concern. The research specifically examines the sociodemographic factors contributing to food scarcity in Jhang, one of 80 districts in Pakistan facing similar issues. Using a logistic regression model and data from 200 respondents, the study reveals that nutritional stability is significantly and negatively affected by factors such as the age of the household head, exposure to negative shocks, and limited education (up to 12 years), with odds ratios of 0.69, 0.7325, 0.74, and 0.853, respectively. In contrast, the odds of achieving nutritional stability improve substantially, by 0.082, 3.878, 5.22, 5.864, and 15.74 times, for households with 2 to 6 members, 7 to 10 members, or additional earning members. These factors significantly enhance the likelihood of better nutritional outcomes. To combat food insecurity, the study recommends measures such as providing low-interest loan programs, ensuring affordable access to agricultural inputs, and delivering timely information about supply shocks.

Materials and Methods

Theoretical framework of the study

This methodology section outlines the approach used to examine the relationship between natural disasters and food security, with natural disasters serving as the independent variable and food security as the dependent variable. The study aims to assess how various aspects of natural disasters, including their frequency, severity, and type, influence food security outcomes in affected regions. A combination of quantitative and qualitative analyses will be employed to analyze historical disaster data alongside indicators of food availability, accessibility, stability, and the resilience of local food systems. This integrated methodology is designed to reveal the mechanisms by which natural disasters impact food security, providing insights to inform the development of strategies for enhancing resilience in vulnerable communities.

This study adopts a quantitative approach and relies on secondary data for its analysis. This study is set in Pakistan, a South Asian and Middle Eastern nation spanning approximately 881,913 square kilometres, with a population exceeding 220 million. Bordered by India, Afghanistan, Iran, and China, Pakistan's strategic location underscores its geopolitical significance. The country experiences various natural disasters, including floods, earthquakes, and droughts, due to its diverse terrain. Pakistan's climate varies, ranging from arid conditions in the north to a more temperate climate in the south, which significantly influences agricultural activities and productivity. Agriculture is a vital sector of the economy, providing employment to a large portion of the population. The country boasts an extensive irrigated area crucial for cultivating staple crops such as wheat and rice. However, challenges like water scarcity and inefficient irrigation systems remain prevalent, prompting ongoing efforts to improve water management and foster agricultural sustainability.

Data sources

The study relied on secondary data to analyse the impact of natural disasters on food security in Pakistan. It utilized annual time series data from 1990 to 2022, sourced from several esteemed organizations in Pakistan, including the Pakistan Bureau of Statistics (PBS), the National Disaster Management Authority (NDMA), the World Development Indicators (WDI), the Fertilizer Industry Coordination Committee (FFC), the Food and Agriculture Organization (FAO), and the Pakistan Meteorological Department (PMD). These institutions provide essential data across various domains, such as population demographics, disaster response, climatic trends, agricultural statistics, and global development indicators.

Data analysis technique

The Fully Modified Ordinary Least Squares (FMOLS) model was used to assess the long-term impact of natural disasters on food security, given its suitability for analysing relationships between non-stationary time series variables. In this study, food security is the dependent variable, while natural disasters, high-yield variety (HYV) seeds, irrigated area, climate change index, and pesticide use serve as independent variables representing key factors affecting agricultural productivity and food availability.

FMOLS effectively addresses issues of endogeneity and serial correlation, ensuring more reliable estimates of the relationships among these variables. This approach is particularly relevant due to the intricate interactions between environmental and agricultural factors that shape food security. By employing FMOLS, the study not only identifies significant long-term impacts but also provides valuable insights to guide policy decisions aimed at mitigating the adverse effects of natural disasters on food systems.

Empirical model

The following model is employed to evaluate the impact of natural calamities on food safety.

$$FS_i = \beta_\circ + \beta_1 D_{dis,i} + \beta_2 CI_{cla,i} + \beta_3 D_{ia,i} + \beta_4 Hs_{hyv,i} + \beta_5 Ps_i + e_i \qquad (1)$$

In this model, FS represents food security, measured as daily per capita caloric intake in kilocalories per person per day. B0 denotes the constant term, while B1 through B5 are coefficients representing the impact of the independent variables. The variable "dis" refers to natural disasters, "cla" represents the climate index, which is derived from average temperature and CO_2 levels, "ia" indicates the irrigated area, "hyv" signifies the use of high-yielding seed varieties, and "ps" reflects pesticide use.

i. Dependent Variable

Food security

Food security refers to the state in which individuals consistently have access to an adequate amount of nutritious and safe food that satisfies their dietary needs and preferences, enabling them to lead a healthy and active life. In simpler terms, it means that everyone has the ability to regularly obtain enough safe and nutritious food (CFS, 2012). In this study, food security was assessed by measuring the caloric intake per person.

ii. Independent variable

Natural disaster

Natural disasters differ significantly in their predictability and impact. The threat they pose is especially severe when they affect large populations, resulting in major social and economic consequences. The economic losses from such events can vary greatly between countries. Common types of natural disasters include droughts, floods, extreme weather conditions, temperature extremes, landslides, wildfires, volcanic eruptions, and earthquakes (Ritchie, Rosado and Roser 2022) . Globally, the total number of natural disasters has nearly reached three hundred, with flooding and extreme weather events being the most prevalent (Ritchie, Rosado and Roser 2022). Natural disasters are measured using a binary variable, where a value of 1 is assigned when a disaster occurs and 0 when no disaster is present.

HYV seeds

HYV seeds, or high-yielding variety seeds, are engineered to enhance crop productivity and increase resilience to environmental challenges. These seeds are developed using advanced breeding methods and genetic modifications to ensure they can adapt to diverse environmental conditions. Muthoni et al (2013) found a positive correlation between the availability of certified seeds and food security. Consequently, the current study is expected to observe a similar positive outcome.

Irrigated area

The proportion of farmland equipped with irrigation systems has been steadily rising, resulting in better water supply and increased agricultural productivity. This shift reflects a growing awareness of the importance of efficient water use in agriculture, alongside innovations in irrigation technology. It is projected that nearly two-thirds of the crop production growth needed in developing countries over the next several decades will come from improved yields per unit of land. Around one-fifth will be driven by the expansion of arable land, with the remaining one-eighth attributed to higher cropping intensity. According to the FAO, nearly two-thirds of the increase in arable land is due to the expansion of irrigated areas (Rhoades, 1997).

Climate change index

Agriculture is considered one of the economic sectors most susceptible to climate change. In assessments of climate impacts, the focus has predominantly been on crop production (Long et al., 2006; Schierhorn et al., 2014). The composite index offers a comprehensive measure of how climate change affects agricultural productivity and food security by factoring in both temperature and CO_2 levels. As temperatures rise and CO_2 concentrations increase, the index highlights the difficulties farmers face in adjusting to shifting growing conditions and the potential risks to food production.

Pesticide

Chemical substances like pesticides and fungicides are frequently used in agriculture to combat pests and diseases that can harm crops and lower yields. By effectively managing these threats, farmers can safeguard their crops, leading to better harvests. This, in turn, has a direct impact on food production, as higher yields result in more food being available for consumption. Pesticides are widely acknowledged as essential for agricultural progress, as they help reduce crop losses and improve both the quantity and quality of food, making it more affordable.

Table 1. Description of variables

Variables	Abbreviations	Unit of measurement	Data Source
Food Security	FS	Daily per capita caloric intake is measured in kilocalories per person per day.	FAO (2022) ourworldindata (2021)
Natural Disaster	DIS	1 if there is disaster, 0 otherwise.	PMD, NDMA, FAO, FFC, IWMI, (2020,2021 & 2022)
Climate change index	CLA	The climate index is constructed from both (average temperature and CO2).	ourworldindata (2022)
Irrigated area	IA	1 if the cultivated area is Irrigated, 0 otherwise, (area irrigated measured in (million hectares).	FAO (2022)
HYV seed	HYV	High-yielding variety of Seeds measure in (1000 tons).	FAO (2022)
Pesticide	PS	Pesticides measured in (tons).	FAO (2022)

Estimation Techniques

The study explores the connection between food security and natural disasters through a statistical analysis using EVIEWS software, which is specifically designed for econometric data analysis. The researchers aim to understand how natural disasters affect food security by employing an empirical approach based on real-world data. To enhance the reliability of their results, they apply the Fully Modified Ordinary Least Squares (FMOLS) method, a sophisticated technique that addresses issues like trends and non-stationarity in time series data, providing more accurate estimates of the relationship between these two important factors.

Tests for Diagnostics

The study employed several diagnostic tests to identify and address potential statistical issues that could undermine the validity of the analysis. Multi-collinearity occurs when independent variables in a regression model are highly correlated, which can distort the results and make it challenging to assess the individual impact of each variable. Heteroscedasticity refers to non-constant variance in the error terms, which can lead to inefficient estimates and unreliable hypothesis testing. Autocorrelation arises when residuals (errors) from a regression are correlated, commonly observed in time series data, and can also affect the accuracy of the results. By using these diagnostic tests, the researchers aimed to ensure the robustness of their model, thereby strengthening the reliability of their findings on the relationship between food security and natural disasters.

Test for Multi-collinearity

In a standard linear regression model, the independent variables are expected to be uncorrelated with one another (Gujarati, 2006). To assess multicollinearity, the study used the variance inflation factor (VIF). Multicollinearity is a common issue in regression analysis that can undermine the reliability and interpretability of the results. It is crucial to identify and address multicollinearity using appropriate methods to ensure robust and meaningful findings in empirical research and data analysis. When multicollinearity is present, the parameter estimates no longer meet the Best Linear Unbiased Estimators (BLUE) criteria of the conventional linear regression model. The study employs the VIF to detect multicollinearity in the model.

Test for Heteroscedasticity

In regression analysis, it is essential that the variance of the error term remains constant across all levels of the independent variables; if this condition is not met, it results in a violation of the homoscedasticity assumption, leading to heteroscedasticity. This violation can cause inefficient estimates and unreliable statistical tests, potentially skewing the analysis results. To detect heteroscedasticity in the model, the study employed the Breusch-Pagan test. This test checks whether the variance of the errors is linked to the independent variables, helping to identify any issues that might undermine the validity of the regression results. By using the Breusch-Pagan test, the study ensures that the assumptions of the regression model are satisfied, thereby improving the reliability of its conclusions.

Removal of Heteroscedasticity

To address the heteroscedasticity identified in the regression model, the study applied White's heteroscedasticity-robust standard errors. This method adjusts the standard errors of the coefficient estimates to account for the non-constant variance in the error terms, resulting in more reliable statistical inference. By using these robust standard errors, the researchers ensure that the estimates remain valid despite the presence of heteroscedasticity, leading to more accurate hypothesis testing and confidence interval estimates. This adjustment strengthens the overall robustness of the regression analysis, making the study's conclusions more trustworthy even with the variability present in the data.

Unit Root test

A unit root test is used to assess whether a time series is stationary or non-stationary over time. Stationarity means that the statistical properties of a time series, such as its mean and variance, remain constant over time. This stability is essential because many statistical methods, including regression analysis, assume that the data is stable. When a time series has a unit root, it indicates that the series is non-stationary, often characterized by persistent trends or cycles, meaning the values may drift over time instead of reverting to a long-term average. For example, a steadily rising stock price or economic indicators that fluctuate with trends can exhibit unit roots. The presence of a unit root complicates analysis because traditional statistical methods may yield misleading results, such as overstating correlations between variables due to shared trends rather than actual relationships. As a result, detecting a unit root is a crucial step in time series analysis. If one is found, analysts may need to transform the data, such as by differencing, to achieve stationarity before applying further statistical techniques.

The Fully Modified Ordinary Least Squares

Philips and Hansen (1990) introduced the Fully Modified Ordinary Least Squares (FMOLS) method to estimate a single co-integrating relationship among non-stationary variables, making it an essential tool in econometrics. FMOLS is particularly valuable for analysing and modelling relationships where variables do not have a constant mean and variance over time, a common characteristic of economic data. By incorporating methods that address issues like cointegration, endogeneity, and serial correlation, FMOLS improves the accuracy and reliability of regression results. This refinement leads to more robust conclusions in empirical studies, offering deeper insights into the dynamics of economic relationships over time. As a result, FMOLS helps researchers better understand how various economic factors interact and evolve, aiding in more informed policy decisions and economic analysis.

Summary of descriptive statistics

The statistical summary for the selected variables is provided in Table 2. Descriptive statistics are used to highlight the key characteristics of the data, helping to better understand the fundamental attributes of the variables. The relevant data for the variables used in this study can be found in Table 2, which includes the mean, median, maximum, minimum, and standard deviation. In statistical terms, the mean refers to the average value of the data. The median, on the other hand, is the value that divides the data into two equal halves. To find the median, the data must first be arranged in either ascending or descending order.

According to the findings of this research, no outliers are present in the data. This conclusion is drawn from the observation that there are no significant differences between the mean and median values for any of the variables. An outlier is typically defined as a data point that substantially deviates from the rest of the data. The standard deviation provides an estimate of the average distance between the data points and the mean

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Table-2 Descriptive statistics

	LFS	D1	LCI	LIA	LHS	LPS
Mean	7.77	0.73	1.07	2.92	5.49	9.32
Median	7.78	1	1.31	2.94	5.42	9.38
Maximum	7.84	1	1.68	3	6.66	10.24
Minimum	7.71	0	0.004	2.82	4.15	8.51
Std. Dev.	0.03	0.45	0.52	0.05	0.73	0.37

Descriptive statistics help in identifying key data characteristics such as the median, mean, and standard deviation. During the study period, the mean value represents the overall average of the dataset, which is an important measure. Among the six variables analyzed—Food Security, Natural Disaster, Climate Change Index, Irrigated Area, HYV Seed, and Pesticide, the highest mean value was 9.3205 for Pesticide, while the lowest mean value was 1.0723 for the Climate Change Index. The table 2, above provides a summary of these descriptive statistics.

Test for Multi-collinearity

Multicollinearity is a significant issue in regression analysis when predictor variables are highly correlated. This correlation can lead to several problems, such as instability in the estimation of regression coefficients. Even small changes in the data can cause large fluctuations in the estimated coefficients, making it difficult to assess the individual impact of each predictor. Additionally, multicollinearity increases the standard errors of the regression coefficients, which reduces the accuracy of the estimates and may obscure meaningful relationships between variables. As a result, hypothesis tests become less reliable, weakening the overall validity of the model. Furthermore, multicollinearity complicates model selection and validation, as it violates the assumption that predictors are independent.

To address these issues, it is essential to carefully select variables, apply data transformation methods, or use regularization techniques like ridge regression. These approaches can help mitigate the effects of multicollinearity and improve the accuracy and reliability of regression analysis.

Multicollinearity can be detected using tools like the Variance Inflation Factor (VIF) and tolerance tests. The VIF measures how much the variance of a regression coefficient is inflated due to correlation with other predictor variables. A VIF value greater than 10 suggests significant multicollinearity, indicating that the variance of the coefficient is ten times higher than it would be if the predictor were uncorrelated with others. Tolerance, in contrast, measures the proportion of variation in a predictor that is not explained by other predictors. VIF provides numerical insights to help researchers identify and address multicollinearity, ensuring more accurate coefficient estimates and better model interpretation.

Table-3 Results of VIF

Variable	Centered VIF
D1	1.11
LCI	1.88
LIA	2.91
LHS	1.27
LPS	1.45

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The analysis of Variance Inflation Factors (VIFs) in the regression model, based on a dataset from
1990 to 2022 with 33 observations, provides important insights into the potential presence of multicollinearity among the predictor variables. Multicollinearity can affect the precision and reliability of the regression coefficient estimates.

For instance, the VIF for **D1** is 1.11, indicating very little multicollinearity. This suggests that **D1** has only a weak correlation with the other predictors, ensuring the stability and accuracy of its coefficient estimate. Similarly, the VIF for **LCI** is 1.88, also pointing to minimal multicollinearity. While there is some correlation with other variables, it does not substantially influence the regression results.

The VIF for **LIA** is 2.91, reflecting moderate multicollinearity. Although it is still well below the critical threshold of 10, this indicates that **LIA** has a moderate correlation with other predictors. However, this level of multicollinearity is generally not problematic and does not necessitate any corrective measures.

The VIF for **LHS** is 1.27, suggesting minimal multicollinearity, which indicates a low correlation with other variables in the model and contributes to the stability of its coefficient estimate. Lastly, **LPS** has a VIF of 1.45, which again reflects minimal multicollinearity, confirming that **LPS** is not significantly correlated with other predictors, ensuring reliable coefficient estimation.

Overall, the VIFs for all the explanatory variables are well below the threshold of 10, indicating that multicollinearity is not a major concern in this regression model. The majority of the VIFs are close to 1, signaling low correlation between the independent variables, which enhances the accuracy of the coefficient estimates and strengthens the model's interpretability, ensuring that it is appropriately specified in terms of multicollinearity.

Test for Heteroscedasticity

In regression analysis, heteroscedasticity occurs when the variability of the residuals (errors) changes across different values of the independent variables. This violates a key assumption of ordinary least squares (OLS) regression, leading to inaccurate coefficient estimates and distorted standard errors. As a result, hypothesis tests and confidence intervals may become unreliable, potentially leading to incorrect conclusions.

The **Breusch-Pagan test** is a diagnostic method used to detect heteroscedasticity in a regression model, which occurs when the variance of the residuals differs depending on the values of the explanatory variables. To perform this test, the first step is to run a standard OLS regression to compute the residuals. Next, the squared residuals are regressed against the original independent variables. The test statistics from this secondary regression follows a chi-square distribution. If the Breusch-Pagan test statistic is significant, it indicates the presence of heteroscedasticity, meaning the residual variance varies with the values of the predictors. Detecting heteroscedasticity is crucial, as it can lead to inefficient estimates and unreliable standard errors, ultimately undermining hypothesis tests and confidence intervals.

Table-4 Heteroscedasticity test Breusch-Pagan (BP) result

F-Statistic	1.15	Prop	0.36
R-Squared	5.77	Chi-square	0.33
Sum of squaerd (SS)	5.61	Chi-square	0.35

The results of the Breusch-Pagan test suggest no significant evidence of heteroscedasticity in the regression model. The F-statistic is 1.144671, with a p-value of 0.3614, indicating that the assumption of homoscedasticity cannot be rejected at conventional significance levels. Additionally, the Observed R-squared (Obs*R-squared) value is 5.771741 with a p-value of 0.3291, and the Scaled explained sum of squares (SS) is 5.608892 with a p-value of 0.3462. The chi-square statistics further support the absence of heteroscedasticity, as their p-values are greater than 0.05. Therefore, it can be concluded that the variance of the residuals remains consistent across different levels of the independent variables, confirming the presence of homoscedasticity.

Unit Root test

A unit root test is a statistical method used to assess whether a time series is stationary or non-stationary, which is essential for accurate time series analysis. Stationarity means that the statistical properties of the series, such as its mean and variance, do not change over time, an assumption underlying many econometric models. A time series with a unit root is considered non-stationary, often displaying trends or patterns that can lead to unreliable results in regression analyses. Common tests for detecting unit roots include the Augmented Dickey-Fuller (ADF) test, among others. Each of these tests takes a different approach, with the ADF specifically testing the null hypothesis of a unit root to check for stationarity. Performing a unit root test enables analysts to identify the necessary transformations, such as differencing or detrending, to stabilize the time series, which improves the reliability of subsequent modeling and enhances the accuracy of empirical analysis and forecasts.

Augmented Dickey-Fuller (ADF) test

The Augmented Dickey-Fuller (ADF) test is an important statistical tool used to assess whether a time series contains a unit root, which would indicate non-stationarity. This test is vital in time series analysis, as many statistical techniques assume stationarity—meaning the statistical properties of the series, such as its mean and variance, remain unchanged over time. The ADF test operates under the null hypothesis that a unit root exists, while the alternative hypothesis suggests the series is stationary. It estimates a regression model that incorporates both lagged values of the time series and its differences to address potential autocorrelation. The test statistic obtained is then compared to critical values. If the p-value is smaller than the chosen significance level (usually 0.05), the null hypothesis is rejected, indicating that the series is stationary. If the p-value is higher, it suggests the presence of a unit root. The ADF test is commonly available in statistical software, offering researchers a reliable method for evaluating the stationarity of time series data and informing subsequent steps, such as differencing the data to achieve stationarity if necessary.

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Table-5 Descriptive statistics of (ADF)

ADF	Statistic	prob
Fisher Chi	234.123	0.01
Choi Z-Stat	-13.009	0.02

The results from the unit root tests provide strong evidence against the null hypothesis of non-stationarity in the time series data. The ADF - Fisher Chi-square statistic of 234.123, with a p-value of 0.01, suggests that at least one time series in the panel is stationary, leading to the rejection of the null hypothesis that all series contain a unit root. Likewise, the ADF - Choi Z-stat of -13.009, also with a p-value of 0.02, further supports this conclusion, indicating a significant deviation from non-stationarity. Both tests confirm the presence of stationarity in the data, meaning the series can be analyzed without concern for unit roots, thereby validating subsequent statistical modeling and analysis.

The Fully Modified Ordinary Least Squares (FMOLS)

FM-OLS is a critical tool in econometrics, particularly in cointegration analysis, as it enhances traditional OLS by addressing the challenges associated with cointegrated data. This is essential for identifying long-term relationships between non-stationary time series variables, which is key to understanding economic dynamics and making accurate predictions. FM-OLS provides more reliable and precise estimates of parameters, improving the overall quality of the analysis.

FM-OLS plays a crucial role in cointegration analysis by effectively handling endogeneity issues. In the case of cointegrated series, the correlation between variables over time can lead to biased estimates when using standard OLS. By applying instrumental variables or other techniques to distinguish between endogenous and exogenous variables, FM-OLS ensures unbiased and consistent coefficient estimates.

Moreover, FM-OLS accounts for the dynamics of cointegrated variables by allowing for the adjustment of short-term dynamics while estimating long-term equilibrium relationships. This is important in economic and financial modeling, as understanding both short-term fluctuations and long-term trends is vital for decision-making and policy development.

FM-OLS further strengthens econometric analysis by expanding the range of tools available for managing complex data structures. Its ability to handle issues like autocorrelation, heteroscedasticity, and other statistical challenges in time series data enhances the reliability and validity of empirical findings, thus improving the trustworthiness of economic research.

Table-6 Result of Fully Modified Ordinary Least Squares

Variable	Coefficient	Std.Error	T-Statistic	Prob
D1	-0.055	0.023	-2.39	0.041
LCI	-0.31	0.05	-6.2	0.0000
LIA	2.42	0.13	18.61	0.0000
LHS	0.085	0.04	2.12	0.035
LPS	0.07	0.04	1.75	0.075
R-Squared		0.95		
Adjusted R-squared		0.93		

The results of the Fully Modified Least Squares (FMOLS) regression analysis, with **LFS** as the dependent variable, reveal significant relationships between **LFS** and the independent variables included in the model. The dataset, spanning from 1991 to 2022 with 32 data points, was adjusted accordingly. The estimation procedure excluded cointegrating equation determinants and used a long-term covariance estimation with a Bartlett kernel and a fixed bandwidth of 4.0, following the Newey-West method.

The coefficient for **D1** is -0.055, with a standard error of 0.023, leading to a t-statistic of -2.39 and a p-value of 0.041, indicating a significant negative relationship at the 5% significance level. For **LCI**, the coefficient is -0.31 with a standard error of 0.05, yielding a t-statistic of -6.2 and a p-value of 0.0000, pointing to a strong negative correlation. In contrast, **LIA** shows a strong positive association with **LFS**, with a coefficient of 2.42, a standard error of 0.13, a t-statistic of 18.61, and a p-value of 0.0000. **LHS** also exhibits a positive relationship, with a coefficient of 0.0847, a standard error of 0.0381, a t-statistic of 2.12, and a p-value of 0.0345, showing statistical significance. Finally, **LPS** has a coefficient of 0.07, a standard error of 0.04, a t-statistic of 1.75, and a p-value of 0.075, indicating marginal significance at the 10% level.

The model demonstrates a strong overall fit, with an **R-squared** value of 0.95 and an **adjusted R-squared** of 0.93, suggesting that approximately 92.57% of the variability in **LFS** is explained by the independent variables. The regression model is well-specified, as indicated by the standard error of 0.065 and the sum of squared residuals of 0.113. The long-term variance is calculated at 0.004. The average value of **LFS** is 7.8, with a standard deviation of 0.03. Overall, the findings suggest that the model provides a reliable explanation of the factors influencing **LFS** over the studied period.

Conclusion

This study provides a comprehensive analysis of how natural disasters influence food security in Pakistan, examining several factors including **Food Security** (FS), **Natural Disaster (DIS)**, **Climate Change Index** (LCI), **Irrigated Area** (LIA), **High-Yielding Seed Varieties** (LHS), and **Pesticides** (LPS). The research utilizes annual time series data from 1990 to 2022, sourced from credible institutions such as the **Pakistan Bureau of**

Statistics (PBS), **National Disaster Management Authority (NDMA)**, **Fertilizer** Industry Coordination Committee (FFC)**,** Pakistan Meteorological Department (PMD)**,** Food and Agriculture Organization (FAO)**, and** World Development Indicators (WDI). The study highlights key relationships among these variables and food security.

Descriptive statistics reveal some variability in the data, but no significant outliers, suggesting that the data is consistent and reliable for analysis. The **Variance Inflation Factors (VIF)** show minimal multicollinearity among the predictor variables, enhancing the credibility of the regression coefficients. Results from the **Breusch-Pagan test** indicate the absence of heteroscedasticity, confirming that the residual variances remain stable across different levels of the independent variables. Additionally, the **ADF test** suggests the data is free from unit roots, ensuring the independence of residuals and improving the accuracy of model predictions.

The **FMOLS regression** results underscore the complex relationship between natural disasters and food security. The analysis reveals a significant negative impact of natural disasters on food security, as indicated by the negative coefficient for **DIS** with a p-value of 0.041. This finding emphasizes the vulnerability of food security to natural calamities and highlights the importance of implementing effective disaster mitigation strategies. Conversely, the strong associations between **LIA** and **LHS** suggest that technological and agronomic approaches could play a key role in enhancing food security in the face of environmental challenges.

The model's substantial **R-squared** value of 0.95 and **adjusted R-squared** value of 0.93 reflect its strong explanatory power, indicating that the independent variables collectively account for a significant portion of the variation in food security outcomes. The study provides important insights into the impact of natural disasters on food security and emphasizes the need for integrated disaster risk reduction and agricultural innovation strategies to bolster food security in Pakistan. This research not only addresses gaps in existing literature but also lays a strong foundation for future policy and practical measures aimed at mitigating the effects of natural disasters on food security.

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