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Consequences of Climate Change on Food Security: Evidence from Asian and Pacific Economies

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ABSTRACT

The purpose of this study is to examine how food security in Asian and Pacific nations is affected by climate change. The main reason for this study is to analyze the impacts of climate change on food security and give some policies on it. To empirically study the relationship between climatic changes and food security, the study uses an essential determinant: the food availability variable, which represents the supply side of food. The study examines the comparison of food availability and the rise in temperature, water availability, arable land, and technological improvement. The study uses penal data on a fixed-effect econometric model, which shows the significance of the relationship between the variables. The results show that all these factors are directly related to food availability. The rise in average annual temperature shows that it is very beneficial for some staple crops in Asian countries. However, the sample countries must implement specific measures to address the issue of food security, such as availability of water, less accusation of arable land, maintaining a particular level of temperature, and keeping farmers in touch with newly innovating technology and use in the agricultural sector.

Introduction

There is a growing demand for food as the population grows. Malthus (1798) stated that the population increases with the geometric mean, but the food increases with the arithmetic mean. In the modern era, the problem of food security is a rising issue that is still being debated. Everyone wants to have a healthy life where there is no shortage of food. So, if people do not get food for an extended period, it causes hunger and sickness. We know that food is essential to health, so food insecurity is still a debated issue. According to FAO (1996), the definition of food security is that everyone, everywhere, has financial and physical access to enough food to satisfy their diet requirements and choices of food for a safe, healthy, and active life. Food availability, food utilization, food stability, and food accessibility are the factors that affect food security. Food security is based on how well agricultural productivity is going for the people linked with the agricultural sector and are employed in food industries (Worku, 2023).

Climate changes affect food security in all four dimensions (Rome, 2008). Climate change (rise in temperature causing growing season length and rainfall leading to floods and droughts) ultimately affects the production of crops, food prices, food supply, and food market (Gregory et al., 2005). So, these factors will also affect humanity's availability of sufficient nutrients. Growing seasonal length impacts many species of crops. The geographic and crop disease ranges of pests have shifted due to environmental changes (Skendzic et al., 2021; Ullah et al., 2023; Mehmood et al., 2023). Temperature changes affect patterns of water irrigation and water availability; strong winds, intensity, and sunlight duration affect many crop yields. The climate change risk to food security is very high in Sub-Saharan Africa, including South Africa, because they are very hot regions (Arshad et al., 2021). Also, Eze (2017) estimated that about 300 million Africans are engaged in cassava production, which is highly sensitive to the rise in temperature, flood, and changing humidity patterns. According to a 2007 study, climate change impacts around 30% of year-to-year fluctuations in tons of crop production per hectare, causing food shortages in affected areas. It increased food prices, so food affordability affected food security (Ekins, 2023).

The main crops grown in Pakistan's agriculture are rice and wheat. There is a decrease of 14.7% to 20.5% in the production of rice and wheat, which raises the prices (Haq et al, 2021). The World Bank claims (2022) that rising food commodity prices push 30 million people to food insecurity in low-income countries. In 2020, 720 and 811 million people did not get enough food. As a result, many people in different parts of the world do not get adequate food (FAO, 2021). According to World Band (2022), there will be 345 million people living in food insecurity. In South Asia, Southeast Asia, and Sub-Saharan Africa, about 80% of the global population is at risk of hunger due to crop failure from climatic changes. Climate change has become the most essential global challenge of the 21st century because of its consequences for ecosystems, human well-being, and ecosystems. It has many effects, but the most important one is its effect on food security, specifically in Asia. Asia is an area where agriculture plays an important role in economic growth and sustenance (IPCC, 2021).

Climate variables change, such as increasing temperature, shifting rainfall patterns, and rising the ability of weather to directly affect the productivity of the crop through food pro the duction system (FAO, 2020). About 60% of the global population in Asia and a vast portion of its people depend on its livelihood (World Bank, 2019). In some countries like India, China, and Bangladesh, climate vulnerability causes disruptions because they face many natural climate changes like droughts, typhoons, and monsoons, resulting in increasing sea levels, which means lower agriculture productivity (Lobell et al., 2011). Moreover, food security is not only for food availability but also involves food utilization, accessibility, and stability (FAO, 2018). When food prices get high due to climate change, it also impacts on people's diets. They will not get sufficient food. Ultimately, it will also affect human health. It goes down day by day by not getting enough food. It will be impossible or difficult for the population to get nutritional diets (IPCC, 2021). Food insecurity will increase hunger, leading to health issues, malnutrition, and socioeconomic instability (ADB, 2020).

Food security is highly affected by climatic changes; this is an alarming situation for the present era as temperature levels are rising, which is harmful to the production of crops (Wheeler & Braun, 2013). Due to a decrease in crop availability, food decline causes a decrease in supply (White et al., 2011). Food commodity prices will increase and affect the accessibility of food by reducing the purchasing power of individuals (Dawson et al., 2016). Due to crop disease, food stability imbalances occur as well. So, in this study, the problem is the Consequences of Climate Change on Food Security in Asian and Pacific countries. The study aims to analyze how climate change affects food availability in Pacific and Asian countries. Does technological innovation reduce climate change's influence on food availability? To suggest policies dealing with this problem based on our findings.

The rest of the study is structured as follows. Chapter 1 introduces the problem in which the background history, problem statement, and study objectives are detailed. In Chapter 2, there is a Literature Review. In Chapter 3, we specified the model, methodology, and framework under which the study will proceed. Chapter 4 is about the analysis of results, and the final and 5th chapter is the conclusion and policy implications.

Literature Review

The study is about the framework of food security (FAO, 1996), which defines food security based on key dimensions: availability, accessibility, stability, and utilization. This research uses climate change adaptation theory, which reveals how the agriculture system responds to climate change through technological innovation, policy interventions, and mitigation strategies (IPCC, 2021). In this, Sustainable livelihood theory is based on how climate change impacts rural areas' willingness to obtain food production (Chambers & Conway, 1992). Malthusian theory of the population (1798) is also used in this paper, which alerts us to food shortages due to the growing population overtaking agricultural production.

Hanif et al. (2023) presented their study about evidence, confluence, and implications between food security and climate change in African countries. Their research objectives were to find the disturbance in food security status due to increasing changes in climatic conditions in African countries and to give the evidence and research base policy implications for stakeholders. The study uses penal data from 1990 to 2019. The dependent variable is undernourishment prevalence, while temperature and rainfall are independent variables. This study utilized Driscoll-Kraay's second-generation regression analysis to find a comprehensive overview. It used the error correction method with pooled mean group specification for analysis. The study concluded that temperature significantly correlates with undernourishment in the long run. The Driscoll-Kraay coefficient of error correction term indicates a negative and statistically significant trend, suggesting convergence towards long-run equilibrium. Also, the rainfall and temperature exert a U-shaped impact on food security. The country should use drought-sturdy crop varieties. Reforestation can mitigate the effects of soil erosion. Technological improvement is much needed.

Javed et al. (2022) studied whether Asian countries stick to the Sustainable Development Goals on food security and climate change. The study's objective is to concentrate on the actions of Asian Countries. to achieve SDG (zero hunger). Panel data from eight countries is used in Asian countries from 1990 to 2019. This study shows the relationship between food accessibility, economic growth, availability, climate change, and socioeconomic factors. The study's results reveal that there is an increase in undernourishment by increasing the temperature rises and changes in the food supply, by a rise in annual average temperature causing food insecurity by reducing food supply by various environmental factors, reducing the purchasing power of consumers and causing economic issues in countries. According to this study, the policy recommendation is to make Asian countries with sustainable development goals to deal with the problem of food insecurity.

Tirado et al. (2010) investigated their study, which stated climate change and food safety: A review. This study shows that climatic change disturbs food security by variation in the food chain. Climate change causes a rise in temperature, a rise in sea level, variation in rain patterns, a reduction in animal production, human behavior, and socioeconomic socioeconomic factors, and it also affects global trade. This study aims to predict the consequences of climatic changes on food contamination and food Security at many levels in the food chain. The methodology analyzes secondary data from international research on climate change effects on microbiology, food chemical contamination, foodborne diseases, plant health, etc. The study suggests that cooperation across different sectors and countries is essential to evolving food safety challenges due to climate change. It emphasizes the importance of working together to develop and put into action strategies that can adapt to these new risks effectively.

Ingram (2011) delivered his studies to investigate food security and its relation to global environmental change using a food system approach. The global demand for food is very challenging because of many factors, including climate change. In 2010, almost 925 million people remained food insecure. This paper aims to assess the global effect of environmental changes on a food system, identify intervention points, and pinpoint areas for further research. This paper uses secondary data to analyze the food chain system. The author concluded that it is very challenging to investigate the food system and global environmental changes; according to his findings, 50% more food will be required by 2030 (2010).

Hanjra et al. (2010) presented their research problem titled. Future food security and Global water crisis in climate change Era. According to this study, food policy is the main goal to eradicate poverty. Still, nowadays, these goals are disturbed by many emerging forces, such as climatic change, energy crisis, and water scarcity. The goal of the study is to analyze the effect of these forces globally on the security of food. This model uses the secondary penal data to estimate future water demand. The analysis shows that the rising income and population increase the demand for food and water. By 2050, the outcome shows that there will be 9 billion people on this planet. So, due to the above emerging forces, the food supply is not increasing at a satisfactory rate. Investments are now vital for future food security. Action is needed on multiple fronts: counter climate change, preserve water and land and minimize food energy consumption, develop resilient crops, upgrade irrigation, boost domestic food production, reform global trade, and tackle other international issues.

Gregory et al. (2011) presented their study topic as the implication of climate change for food security, crop yield, and illnesses. Immense changes in climate behavior affect components of biological interactions in different ways. Climate change is directly affecting Crop yield and Quality. Climate change also indirectly disturbs the crops through diseases. The authors use the combination of integrated modeling from different disciplines and multi-factorial experimentation to advance knowledge for the challenges. Food security has additional geographical, socioeconomic, and political factors. The authors gave conclusions. Enhancing the concept of climate change is also positively related to all these cropping systems and functional diversity for abiotic and biotic stress. So, this is the most effective way to improve sustainability.

Kumar et al. (2016) presented their research study about crop yield and the importance of models for gaining food security for those impacted by climate change. Their study aimed to increase food supply according to the increasing population by taking measures in the present agriculture system and negating the adverse impacts on the planet. Educational tactics and crop simulation models are primary instruments for boosting agriculture supply. Raising the temperature has improved the agriculture sector, but this model predicts many uncertainties. These uncertainties can be removed using a multi-model, including physical and gene-based plant modeling.

Rosegrant et al. (2011) studied climate change's effect on food security and livelihoods. Agriculture is the primary industry in developing nations for livelihood and economic growth. The study aims to search for significant production of cereal commodities under the range of climate changes and general circulation models. Using this model GCM, the production of various crops, such as wheat, maize, rice, etc., under observation was reduced. So, the increased prices due to decreased production also resulted in lower calorie consumption and malnutrition. Agriculture adaptation funding policies are used to minimize the world's food security situation.

Muluneh et al. (2021) describe the effect of climate change on biodiversity and food security. The reasons for Climate change are human activities and natural factors. It results in variations in biodiversity and agriculture production. The study aims to influence how biodiversity, climate change, and food security correlate. Climate change effects are different in different regions and locations. In Africa, yields in agriculture will decline by more than 30% in 2050. Increasing food production could be enhanced by increasing land for agriculture. But it seems a costly solution. So, this research uses bio-energy, forest management, and community-based biodiversity conservation to minimize the effect of climate change.

Brevick et al.(2013) Investigated the possible effects of climate change on soil functions and how they relate to food security. The research aims to discover changes in precipitation patterns due to rising temperatures. Many variables in soil, like carbon, nitrogen, and hydrogen, link it with the atmosphere. Climatic change affects all of these variables, which results in a change in the soil erosion process. This research study concluded that soil-climate interaction is typically addressing future food security.

Mahrous et al. (2019) conducted studies on the food security of East Africa and climate change in East Africa. The study aimed to evaluate how food security in the EAC is impacted by climate change. The panel data from 2000-2014 is used in this study. To proceed with the study, the researcher took variables like temperature, rainfall, population size, and land area, which are under production. All these variables affect food security. The study's result showed that food security is affected by temperature, although increasing land areas and precipitation positively ensure food security.

Peter et al. (2010) described their study as climate change and food security. This study shows that food security is under stress, which reduces food security. Climate change and other environmental factors may be the reason for these pressures. Climate change may impact the food chain, such as the effect on crop production due to rainfall or cooler or warmer temperatures, which is a cause of the changing food system. Food security is changing due to globalization and urbanization. Food availability is different in different regions. W AI et al. (2008) summarized their study statement about climate change and food security. According to this study, the change in food supply will affect market flow, production, human health, and transportation costs. The food system is affected by climate change through possible internal and international migration. Agriculture, forestry, and fisheries are not being affected by climate change. The four dimensions, food system stability, availability, utilization, and accessibility, are also impacted by climate change. Sajjad et al. (2017)

investigated their study that Pakistani Evidence supports the claim that climate change affects the productivity of essential crops. This study shows that food security is being threatened by climate change. The study aims to investigate the impact of changes in climate, like changes in sunshine, humidity, and temperature. From 1989 to 2015, they used the time series data. The result of this study shows that increasing temperature is harmful to food production and has a negative impact.

In contrast, positive or minimum temperature does not harm food production. Giacomo et al. (2013) explained their study's statement is management of land, climate change and sustainable land, and food security. This investigation reveals that in the absence of degrading soil and water resources; sustainable land management can maximize food production. The objective of this study is to determine how green land management becomes a cause of the increase in growth. Organic fertilization reduces carbon dioxide emissions. The benefits of implementing sustainable land management are greater in regions with higher rainfall. Rain distribution is an essential factor in reducing the effect of adopting specific sustainable land management practices.

Schmidhuber and Tubiello (2007) summarized their study, whose global global, under climate change, is food security. This study describes the effect of climate change on food security. It has been observed that there are four elements of food security, i.e., utilization, availability, access, and stability; simulation studies explain first. Socioeconomic development significantly impacts the risk of hunger, ranging from 5 million to 170 million. The study reveals that the effect of climate change on food security is significant. Hamid et al. (2020) investigated their study, which stated a change in climate and food security. This investigation shows that it has been observed that climate change will have extensive effects on food security. This paper's objective is to analyze the complex relationship between climate change and food security. It explores that there is a dual relationship between both.

The impacts of extreme climate change will affect accessibility. It might be physical as well as economic. Martin et al. (1999) described their study's climate change and food security statement. This study shows that more production is expected in significant sectors, and less production is expected in small sectors. The Food and Agriculture Organization provides data on food costs and hungry individuals (FAO, 1988). By the 2080s, the number of people at risk of hunger will likely be 80 million due to climate change. It has been noted that climate change would negatively impact some areas. Heather et al. (2010) shows that climate change is unavoidable. The impact of climate change on food security is very significant. Climate change is composed of a summarized study statement: shift in climate and security of food in African areas. It is a systematic literature review—with three components such as accessibility, availability, and utilization. The study aims to review the forecast of higher market prices, lower land productivity, effects on livelihood, and a rise in hunger. Adjustment methods were also explored all around the region.

Wheeler & Braun (2013) explained their study, stating that climate change affects food security globally. This study shows that the world's advancements free of hunger could be highly disturbed. Due to the short-term change in the supply, food system stability may be at risk due to climate change. However, the potential impact is less clear at a regional scale. The study aims to determine how food access and utilization will be indirectly impacted. Climate changes affect individuals' and households' incomes, as well as their health.

Claudia et al. (2010) described that the change in climate affects the security of food in African countries that viewed climate change scenarios comprehensively. This study reveals the shift in climate that affects, dependently on this scenario and model the Global Circulation Model (GCM). The impact changes clearly and significantly. The objective of their study was how a comprehensive climate change scenario (CCC) explains that for 2050, higher temperature and mixed precipitations change. The study results show that climate change will result in product price and yield changes and higher food prices. Most studies focus on regional and global climate change instead of specific vulnerabilities countries and strategies of adaptation. Although research has widely investigated crop yield Minimization due to the rise in temperature and erratic rainfall (IPCC, 2021). In addition, previous studies focused on the system of agriculture production at a significant level and have ignored it. The impact of change in climate on small scales like farmers who have the leading role in agriculture system (World, 2019).

Model and Methodology

Introduction to the Model

The focus of this study is to analyze the effects of climate change on security. This model is based on a framework that analyzes the relationship between determinants of food security and disturbances in environmental phenomena caused by climatic change (Rome, 2008). We will also incorporate some macroeconomic variables to analyze the outcomes of our study empirically. The data estimation will be conducted across different Asian and Pacific countries over various periods and will be implemented in this model.

Model Specifications

The framework of this panel data model is to estimate the linear relationship between the dependent (endogenous) variables and one or more independent (exogenous) variables across both time and cross-sectional dimensions, while accounting for unobserved heterogeneity through fixed or random effects. Linear regression analysis is a method used to estimate the value of one variable in relation to another. The economic theory used in this study will be converted into a mathematical form. Suppose that Y is endogenous and X_1 and X_2 are exogenous variables, so its mathematical form is:

Y = f(X1, X2)

Then, we will change this mathematical equation into an econometric model to run a linear regression analysis to use the statistical data to find this problem:

$$Y_{it} = \beta_0 + \beta_1 X1it + \beta_2 X2it + \varepsilon_{it}$$

Where,

There are several cross-sections, represented by i, and t is the time series mean, indicating that the model is using penal data. ε is the residual or error term, defined as the residual that captures all unknown factors affecting the relationship between the dependent and independent variables. β0, β1 and β2 are the regression coefficients that indicate the magnitude of change in the dependent variable resulting from a change in the independent variable (Cohen et al., 2014). This is the framework that this study will use.

Variables and Data Source

We will use the annual secondary penal data from 2009 to 2021 for 17 Asian and Pacific countries in our empirical investigation. Table 3.3 below presents the symbols, descriptive definitions, and sources of data for the independent and dependent variables that will be used in this study. Here, food availability (FA) is taken as the dependent variable, and the other variables include temperature (TEM), Technological improvement (PAT), arable land (ABL), and water availability (WA).

Table 1: Showing symbols, definitions, and sources of variables.

Symbol	Name Of Variable	Description	Source
FA	Food availability	Food production index	WDI
TEM	Temperature	% change in annual temperature	CKP
PAT	Technological improvement	Patent applications, nonresidents + Patent application, residential	WDI
ABL	Arable Land	Percentage of land area.	WDI
WA	Water availability	Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	WDI

FAO = Food and Agricultural Organization, and CKP = Climate Knowledge Portal

Econometric Model

The combination of time series and cross-sectional data is known as penal data (Hsiao, 2022). The purpose of this study is to examine the correlations between independent variables using panel data on food availability. As this is penal data and periods are less than 15 years, we assume that this data is stationary. To regress this penal data of different variables, we will use a random effect model and a fixed effect model (Stephenson, 2015). The Hausman test will be implemented to determine which model is more suitable for our analysis: a random-effects model or a fixed-effects model. The null hypothesis under the Hausman Test is a model with random effects, and the alternative hypothesis is a fixed effect (Hausman, 1978). Shehzad et al. (2017), and Munir et al., 2022 employ this test in their study on South Asia, using the Marshall-Lerner condition to determine whether their model has a random or fixed effect, assessed by panel data. Many theories are based on panel data theory, which analyzes the impacts of different variables that explain economic phenomena. Parry et al. (1996) use penal data in their study, which is a new evaluation of Global food security and climate change. We will use data from 2009 to 2021, which is more than 12 years old. Therefore, this study is assumed to use non-stationary data (Arshad et al., 2018, Munir et al., 2020). The study focuses on Asian nations to investigate how climate change affects food supply. The fixed effects model will be used to perform this penalized data regression analysis. We use the fixed effects model (FE) when studying the impact of variables over a period. The functional form of FE is:

$$Y_{it} = \beta_1 X_{it} + \alpha i + u_{it}$$

Here, X is an independent variable, Y is a dependent variable, t represents the time, i represent the entity, and α_i (i = 1,..., n) is an intercept for each cross-section or entity, β_1 is the coefficient, and u is the residual (Princeton, 2007). As in this study, we are using Food availability as the dependent variable and arable land, water availability, temperature, and technological improvement as independent variables, so our general equation will be:

$$FA_{it} = \beta_0 + \beta_1 AL_{it} + \beta_2 WA_{it} + \beta_3 PAT_{it} + \beta_4 TEM_{it} + u_{it}$$

Where;

FA_{it} is the dependent variable for entity i and time t. AL, WA, PAT, and TEM are the Independent Variables for entity i at t, and u is the error term (residual).

Empirical Analysis

Fixed Effect (FE) and Random Effect (RE) Estimation

We are using STATA to estimate the coefficients of the variables. First, we check that the data is strongly balanced. Then, we generate the natural log of all variables except AL, and finally, the FE is applied to the variables.

Table 2: FE Regression results

LFA	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
AL	.039	.015	2.55	.011	.009	.069	**
LWA	.447	.082	5.45	0	.285	.609	***
LPAT	.055	.019	2.89	.004	.017	.092	***
TEM	.086	.022	3.81	0	.041	.13	***
Constant	-.03	.572	-0.05	.958	-1.158	1.098	
Mean dependent var		4.587	**SD dependent var**				0.134
R-squared		0.277	**Number of obs**				221
F-test		19.140	**Prob > F**				0.000
Akaike crit. (AIC)		-343.177	**Bayesian crit. (BIC)**			-326.187	

**** p<.01, ** p<.05, * p<.1*

The FE model shows that specific characteristics, such as country- and firm-specific factors, do not change over time but have an influence on the dependent variable. The FE model removes these effects by focusing on group variation. All the coefficients of variables are significant. The Pro>F is also significant, meaning it is less than 0.5, so there is a high probability that the model must be a Fixed effect model (Princeton, 2007). Now, we will apply the RE model to estimate the Hausman hypothesis. The null hypothesis under the Hausman Test is a model with random effects, and the alternative hypothesis is a fixed effect (Hausman, 1978).

Table 3: RE Regression results

LFA	Coef.	St.Err.	Z-value	p-value	[95% Conf	Interval]	Sig
AL	.0008659	.0007991	1.08	0.279	-.0007003	.002432	
LWA	-.004115	.0137243	-0.30	0.764	-.0310141	.0227841	
LPAT	.0046952	.0037081	1.27	0.205	-.0025726	.011963	*
TEM	.0004125	.0015949	0.26	0.796	-.0027134	.0035384	
Constant	4.541971	.0791348	57.40	0.000	4.38687	4.697073	

*** p<.01, ** p<.05, * p<.1

A random effect indicates that specific characteristics are not correlated with independent variables and are randomly distributed. These results are highly insignificant, as the Z-statistics are also negligible. The p-value (Ch2 = 0.7054) indicates that the model is not accepted.

Hausman Test

Now, the study applies the Hausman test to determine which model should be chosen between FE and RE. The results of the Chi-square test serve as the foundation for the Hausman test. It chooses FE or RE based on the Chi-Square, probability, and the degree of freedom. After storing the FE and RE in the STATA Hausman Test is implemented, whose results are given below:

Table 4: Hausman Test

	HAUSMAN TEST : The null hypothesis is rejected and the alternative is accepted			
	-----Coefficients ------		**(b-B)**	**SQRT (Diag (V b-V_B))**
	(b) FE	**(B) RE**	**Difference**	**S.E.**
AL	.0388359	.0008659	.03797	.0151905
WA	.4473566	-.004115	.4514716	.080999
PAT	.054742	.0046952	.0500467	.0185889
TEM	.0856073	.0004125	.0851948	.0224031

By performing the Hausman test, we found that the appropriate model is the fixed effects model. FE estimations are more consistent and efficient. After running the Hausman test, the Chi-square value is less than 0.05, i.e., Prob > chi2 = 0.0000, so it is highly significant for FEM. Therefore, the null hypothesis of the Hausman effect will be rejected, and the alternative hypothesis will be accepted. This suggests that the fixed effect model has stronger values, making it preferable to the random effect model.

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 77.10

Prob > chi2 = 0.0000

Now we move towards the interpretation of results with the FE model.

Interpretation of Results

Table 5: FE Regression results

LFA	**Coef.**	**St.Err.**	**t-value**	**p-value**	**[95% Conf**	**Interval]**	**Sig**
AL	.039	.015	2.55	.011	.009	.069	**
LWA	.447	.082	5.45	.000	.285	.609	***
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Constant	-.03	.572	-0.05	.958	-1.158	1.098	

**** p<.01, ** p<.05, * p<.1*

Food availability with Arable land

From our results, it is clear that the relationship between food availability and arable land is positively significant, as the t-value is equal to 2.55. This indicates that increasing arable land leads to a 3.9% rise in food availability. Additionally, from some old studies, we observed that FA is related to the supply of food, and the primary source of food supply is agriculture. Therefore, it is evident that arable land plays a crucial role in ensuring food availability. This important factor, the availability of food, is severely impacted by climate change (Schneider et al., 2011).

Food Availability with Water Availability

The relationship between food availability and water availability is significantly positive. In this case, the t-value is 5.45, indicating a strong and straightforward relationship. If the water availability increases by 1%, the food availability will increase by 45%. Water and land are the two most important factors for agricultural production, and their availability is essential for this purpose (Schneider et al., 2011).

Food Availability with Technology

The results of the relationship between FA and technology are also showing very favorable results. FA with a PAT shows a t-value of 2.9. This means that the increasing use of technology is also increasing food availability day by day. With technological advancements, the agricultural field has seen the addition of new machinery, which enhances the farm process and introduces new seeds and fertilizers, thereby increasing crop yields (Premanandh, 2011).

Food Availability with Temperature

These analyze the impact between average surface temperature and food availability. The primary focus of our analysis is Asian Countries, so the results contradict the historical theory. The relationship between the FA and TEM shows a significant relationship between food availability and temperature. In this case, the t-value is equal to 3.81, and a 1% increase in temperature will result in an 8.6% increase in food availability. This is perhaps because, as we took data from Asian countries, the main staple foods of Asians are rice, Wheat, and other grains, and all these crops are highly temperature dependent.

Conclusions

This paper addresses the issue of climate change affecting food availability in Asian and Pacific countries. First, we examine the historical background of how climate change has affected various determinants of food security. There are four main factors in food security. These are the availability of food, food utilization, food accessibility, and food stability (FAO, 2009). We also observed these deterrents as negative, as well as under certain aspects and conditions; they are positively related to changed environmental behavior (Hasegawa, 2021). The primary objective of the study is to examine the impact of climate change on food availability and to investigate how technological innovation mitigates the effects of climatic changes and adverse environmental conditions on food supply.

A crucial factor in food security is food availability, as it determines the supply side of food. We analyze the relationship between food availability, arable land, water availability, patents (technology innovation), and temperature. Food availability is taken as the dependent variable, and the remaining variables are taken as the independent variables. We used penalized data and applied the econometric technique of a fixed effects model. The results of our analysis show that food availability is directly related to arable land, water availability, and average surface temperature. We conclude that all these environmental factors are essential for food availability in Asian regions. This is because food availability needs require arable land, water availability, and an average surface temperature for better crop yields in Asian countries. Moreover, we also examined the technological innovation variable to determine if there is any improvement in food production with the use of technology. The results reveal a highly significant relationship between food availability and the use of technology. The introduction of HYV seeds and machinery gave a considerable boost to crop productivity.

Based on our findings, we recommend that when there is no arable land availability and water availability, these factors have very negative impacts on food production. The government should enact laws regarding the allocation of arable land for the industrial sector. The government should create policies that allow the use of land types that are not suitable for agricultural purposes. The government should provide easy loans for tube wells, which will make freshwater available to poor farmers. Governments must take an active role in developing and enforcing policies that foster long-term, strategic change. We suggest several responsibilities for governments to address these challenges effectively. For a healthy food system, governments should adopt a multi-level, coordinated approach to ensure a sustainable food supply. Key actions include implementing taxation and subsidies as fiscal incentives and disincentives for the food business and consumers, prioritizing food security and nutrition in assistance programs, and setting standards for food additives. All food purchases should be subject to procurement criteria set by the government, which uses schools or workplaces to promote healthy eating and incorporate nutrition into healthcare. Policies should include nutrition standards for marketing to children, front-of-pack labeling, and a focus on evidence-based strategies to reduce health disparities. Additionally, supporting food and nutrition research, as well as public-private partnerships and cross-agency leadership, is essential. Monitoring, evaluation, and global health collaborations will ensure policies are effective and equitable.

Policies to control climate change

Considering the present environmental crisis, the rapid development of efficient mitigation and adaptation strategies is critical. A comprehensive literature review identified three primary approaches to tackling climate change: radiative forcing geoengineering methods, negative emissions technologies, and traditional mitigation approaches. It is crucial to emphasize that a single solution cannot address climate change; instead, a combination of viable technologies and methods should be implemented, provided they are both technically and economically feasible. As discussed earlier, relying solely on decarbonization efforts will not suffice to meet the Paris Agreement targets. Consequently, alternative abatement methods are necessary. While radiative forcing geoengineering, aimed at managing the Earth's radiation balance, presents an intriguing concept, it cannot serve as a long-term fix because it ignores the underlying cause of climate change. However, it might offer short-term respite until greenhouse gas concentrations are lowered and stabilized. However, the necessary technologies still need to be developed and tested, and their potential side effects are carefully considered, which could take considerable time.

In contrast, negative emissions technologies offer a more robust solution, particularly when combined with existing efforts to decarbonize. Though some of these technologies are still in the early stages, biogenic-based sequestration methods are more advanced and ready for immediate deployment. Carbon capture through photosynthesis is a proven and straightforward process, but it requires integration into a broader technological framework, which has been discussed in the review. Carbon pricing for harmful emissions is still in its infancy, with availability mostly limited to voluntary markets for a small number of removal techniques and virtually nonexistent for the majority of the technologies examined. This is one of the main challenges. Except for afforestation and reforestation operations, carbon pricing systems are currently insufficient to provide financial support for carbon removal initiatives. This might alter when carbon markets develop. Governments and policymakers must establish frameworks and policy tools that prioritize carbon pricing to accelerate the development of negative emissions initiatives. Moreover, the financial sector should enhance its support for these projects by providing greater access to capital and introducing effective market-based incentives. Currently, biogenic-based sequestration projects are well-positioned to leverage financial and policy support, as many related technologies are now ready for deployment. However, it is crucial to develop and implement efficient carbon pricing systems that focus on carbon removal. Additionally, increased funding for technology research and development will be essential to advance these efforts.

The government should maintain a moderate average surface temperature to reduce emissions. Climate change has become a tangible truth, significantly impacting the security of food in areas of study, with houses facing heightened vulnerability due to these changes. As a response, Effective adaptation techniques must be developed immediately. Analysis of the past three decades of national meteorological data for the district reveals noticeable fluctuations in both annual temperature and rainfall patterns. The coefficient of rainfall variation indicates substantial instability during the primary growing season, further exacerbating the challenges for farmers. A household's level of food security is determined by its demographics, including age, size, family composition, and economic circumstances, such as the availability of cultivated land and annual income. In response to these challenges, farmers in the district have developed several adaptive mechanisms. These include the use of improved crop and livestock production techniques, adjusting harvesting and planting dates, implementing water and soil conservation practices, and expanding and diversifying income and irrigation sources.

Furthermore, improving land management practices, ensuring timely access to climate information, expanding income-generating opportunities, and adopting higher-yielding crop varieties are crucial strategies for mitigating the risk of food insecurity in the face of climate change. To effectively address the issues, it is essential to provide accurate climate information, educate households on various adaptation strategies, and empower female-headed households by encouraging their participation in income-generating activities. These measures are key to enhancing the community's ability to adapt to shifting weather conditions.

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