Impact of Carbon Dioxide (CO_2) Emissions on Food Security: A Panel Data Analysis

By

SAIMA RANI

M.Phil. Economics

SCHOOL OF ECONOMICS

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SUBMITTED BY:

SAIMA RANI

M.Phil. Economics

(2021-23)

SUPERVISOR

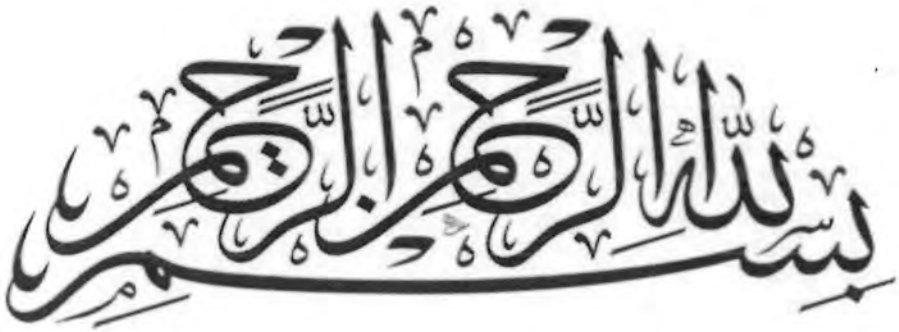
Dr. MUHAMMAD TARIQ MAJEED

PROFESSOR

SCHOOL OF ECONOMICS

QUAID-I-AZAM UNIVERSITY, ISLAMABAD

A thesis submitted to the School of Economics, Quaid-i-Azam University, Islamabad, in fulfillment of the requirements for the award of degree of Master of Philosophy in Economics.



In the Name of Allah, the Entirely Merciful, the Especially Merciful
Al-Fatihah [1: 1], Nobel Quran

DECLARATION

I **Saima Rani** having registration number, 02092113025 student of M.Phil. Economics at the School of Economics, Quaid-i-Azam University, Islamabad do here declare that the dissertation titled "Impact of Carbon Dioxide (CO_2) Emissions on Food Security: A Panel Data Analysis" submitted for the fulfillment of Master of Philosophy (M.Phil.) degree in Economics, is my work and this research not previously presented and not publish anywhere.

Student Name: **SAIMA RANI**

Signature: 

CERTIFICATE

This is to certify that the thesis titled **"Impact of Carbon Dioxide (CO_2) Emissions on Food Security: A Panel Data Analysis** by **Saima Rani** bearing Registration number 02092113025 is accepted in present form by the School of Economics, Quaid-I-Azam University, Islamabad, as satisfying all the requirements for the fulfillment of the degree of Master of Philosophy in Economics.

Supervisor:

Dr. Muhammad Tariq Majeed
Director and Professor,
School of Economics,
Quaid-I-Azam University,
Islamabad.

External:

Dr. Muhammad Akram
Assistant Professor,
School of Economics, Islamic Banking and Finance,
International Islamic University,
Islamabad

Director:

Dr. Muhammad Tariq Majeed
Director and Professor,
School of Economics,
Quaid-I-Azam University,
Islamabad

DEDICATION

Instant research work is dedicated to all men who work hard not because it always pays, but because they will do all they can to make sure their families have the best. Therefore, the present phase of my life has been completed because of all the strong men including my hardworking father, inspirational teachers, caring and supportive husband, and my loving brothers who also stand behind me in every phase of life. But I especially dedicate my work to my husband **Muhammad Zahid Akram** who is continues source of motivation and strength..

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Abstract

Climate change and its impact on global food security have been a source of contention among scholars, stakeholders, and politicians throughout the world for decades, Moreover, particularly Carbon Dioxide (CO_2) levels play a vital role in global warming and changing climate which has a worse effect on the food security level. However, at the global level, empirical studies to figure out the influence of CO_2 on the four pillars of food security (availability, utilization, accessibility, and stability) are still lacking. Therefore, research is carried out by taking the panel data for 144 countries from the year 2000 to year 2021. The empirical findings suggest that increasing emissions will increase the prevalence of malnourishment, children's health, and food supply variability and decrease the dietary energy supply which declines the food security level. Furthermore, climate change due to emissions and food prices and population have a negative considerable influence on food security but income and food availability and agricultural land have a positive significant impact. It is suggested that, the following measures should be adopted, emission reduction targets, transition to renewable energy, sustainable agriculture, climate-smart agriculture, nutrition and food education, social safety nets, and boosted purchasing power by reducing inflation rate and raising the income level for increasing food security level at global level.

Key Words: Climate Change, Emissions of CO_2, Food Security, and Panel data

Chapter 1

Introduction:

1.1: Overview of climate change and greenhouse gas emission

The climate is an imperative environmental aspect that determines growth at a global level. Climate change forms changes over an extended period in the environmental factors. The factor contains temperature, quantity of light, rainfall, humidity, gases, wind, air, water, and soil. Climate change disturbs the agriculture sector, livestock, and wind pattern, distribution of rainfall, hydrological cycle, growth, and development of plants. As results of that, the whole food chain is fluctuated and creates insecurity across the world especially the developing nations.

United Nation (2022) also define that, climate change indicates the variation in temperatures and weather conditions, heat waves, heavy rainfall, and droughts which influence global warming. Hoffman et al. (2021) reported that there are three main causes of changing climate, Firstly, natural factors, secondly, human-based activities e.g., greenhouse gas emissions and thirdly land use changes. World Bank (2020) indicates that, since the 1800s, human activities have been the key drivers of climate change. The activities like consumption of fossil fuels like gas, coal, and oil in the agriculture and industry sector will produce greenhouse gas emissions. United States Protection Agency (2021) further elaborates that, transport, industry, energy, agriculture sectors are the main source of emission.

Intergovernmental Panel on Climate Change (2022) demonstrated that man-made emissions had significantly contributed to climate change which is produced by all sectors of the economy. Pollutant emissions from industry, energy generation, and agri-food zones are particularly play

substantial role in climate change. The major source of greenhouse gas emissions from human activity on a global scale is the burning of fossil fuels as shown in figure 1. Further detail of the source of emissions is given below:

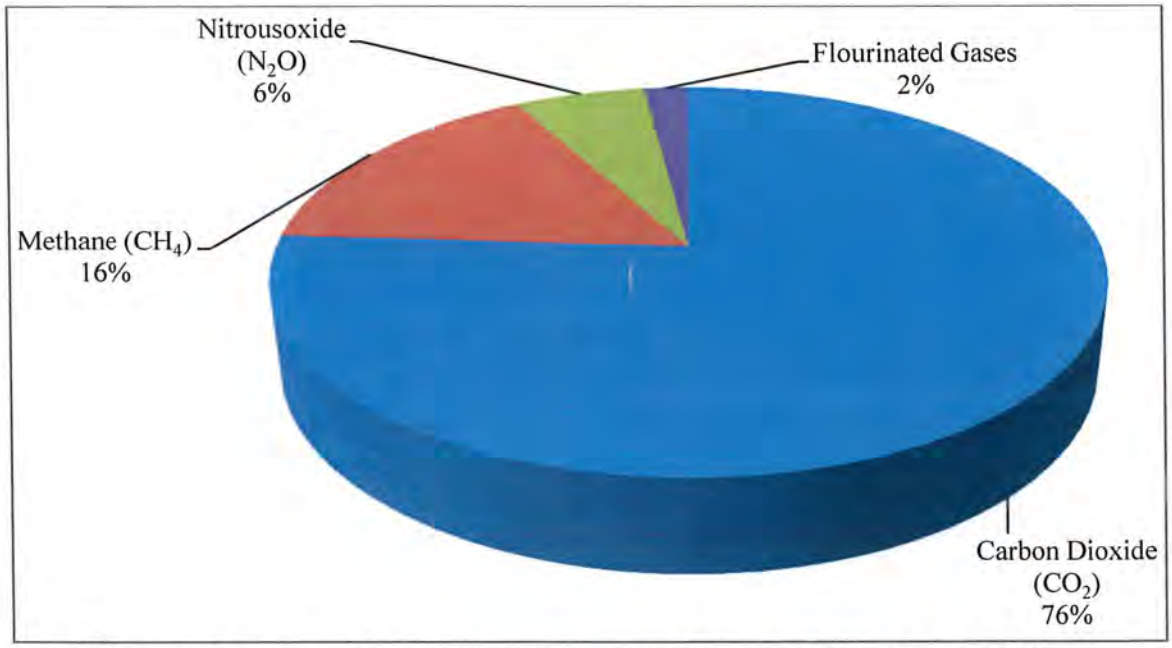

Figure 1: Source of Greenhouse Gas Emission (Intergovernmental Panel on Climate Change, 2022)

The major contributor to the emission is CO_2 having a share of 76 percent in total emissions as shown in below pie chart. Direct human action has an enormous impact and increases the emission of CO_2. The forestry and land use patterns e.g., deforestation, removal of land from agriculture activities, and soil degradation are also the reasons for this emission.

- Methane (CH_4) emissions have a 16 percent share in total emissions around the globe. The major reasons for the CH_4 emissions are the agriculture actions, energy consumption, waste management, and organic material burning.
- Nitrous oxide (N_2O) is the third source of emissions which is produced by the utilization of fertilizer in the agricultural sector.

- The fluorinated gases have a minimum share of emissions which is 2 percent. The industry operations and household usage of the items are the major sources of F-gas emissions in the world.

Therefore, in recent times, the problem of greenhouse radiation has become a global issue which currently, builds great concern to policymakers and different stakeholders.

1.2: Effect of emissions of carbon dioxide (CO_2) on climate change

Moreover, CO_2 are main GHG emission that is initiating climate change. The human-made events have increased atmospheric CO_2 levels, which eventually reason for increasing temperatures and drought. During the photosynthesis process sunlight turns into energy and transforms CO_2 and water into oxygen and sugar. The absorbed CO_2 is preserved in the air till plants die. Therefore, forests play a vital role in catching CO_2. However, at a certain point, increasing temperatures and CO_2 will be beneficial for agriculture. But increasing temperatures and CO_2 also enhance the evapotranspiration from plants and soils and create a shortage of water.

Furthermore, higher levels of CO_2 absorption can increase agriculture crops which also reduce the nutrient quality of staples such as wheat, barley, rice, and potatoes. (Sheng et al., 2016, Zhao et al., 2018), and Loladze (2014) indicate that, it is also established from laboratory research that, mainly staple crop like wheat and rice had and lower plant-based protein and higher level of carbohydrate concentrations of the impact of CO_2 on human nutrition. Teressa (2021) further elaborate that, higher level of CO_2 in the environment also decline the dietary zinc, iron protein, and other macro and micronutrients in staple crops.

Intergovernmental Panel on Climate Change (2022) reported that, emissions of CO_2 have risen intensely from the start of the Industrial Revolution in the world. The world's actual and forecasted emissions of CO_2 from the year 1850 to 2024 are shown below in figure 2.

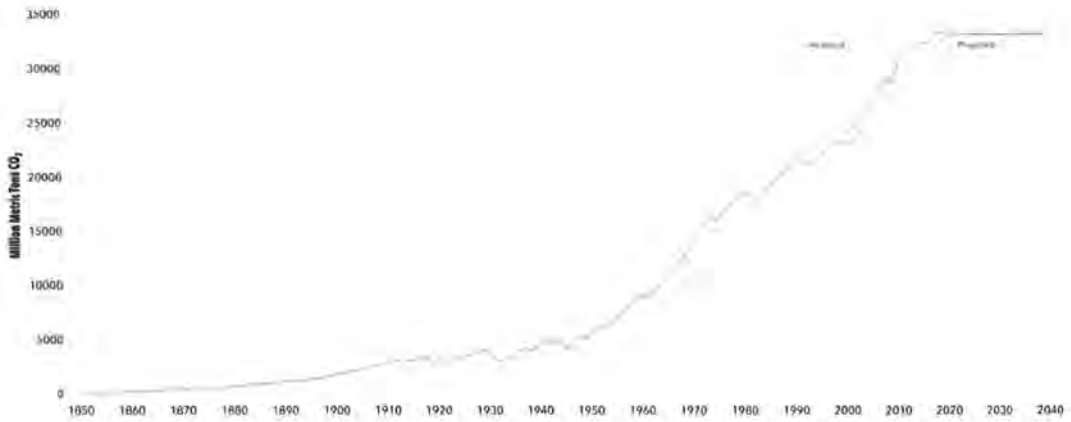

Figure 2: Actual and projected CO_2 Emissions from the year 1850 to 2040 (Intergovernmental Panel on Climate Change, 2022)

According to the Paris Accord Agreement (2015) world leaders have to put huge efforts for the significant decline in CO_2 to ensure the food security across the globe. United Nations (2021) concluded that every country established and determined the achievable targets for moving to green and cleaner energy in the world. These steps play a vital role in transforming the world free from greenhouse emissions and coping with the changing climate effects on the livelihood and food security of human beings.

1.3. Relationship between CO_2 Emissions and Food Security:

Food and Agriculture Organization (2018) reported that, climate change due to emissions CO_2 affects numerous features of the livelihood of the population, like food security, poverty level, and environmental degradation. The literature indicated that main staple crop productivity is declining due to unpredictable temperature variations, rainfall patterns and increasing levels of CO_2 emissions (Syed et al., 2022).

A massive literature addresses the adverse effect of global warming on the agricultural sector especially in production and productivity. During the growing and harvesting season, the crops are overly sensitive to fluctuating rainfall and heat degrees. The cropping system is affected by the rainfall fluctuations and unexpected deviation in temperature level in cropping season due the emissions (Intergovernmental Panel on Climate Change, 2012; Nippert et al., 2006). The weather fluctuations due to the CO_2 emissions at specific times of the crop growing season and without season raising the humidity level, wind level, and hail (Hall, 2017, Gardiner et al., 2016; Singh et al., 2017) are illustrations of different weather events which can farm production and productivity.

Syed et al. (2022) conclude that there is an adverse effect of changing climate on food security. Therefore, it is one of the key challenges in the 21st century. The growing population puts pressure to fulfill the future food demand whereas, food crops production and productivity and create food insecurity at the global level. The results are also validated by Ray et al. (2019) that changing climatic conditions severely affect food security across the globe. That insecurity situation can interrupt the agricultural productivity, value chains, and price mechanisms in the market. Therefore, researchers and policymakers need to be study the difficulties in global demographics and the effect of climate food security to meet the future food demand of the nations.

It is depict from the literature that, the emissions affect the all pillars of food security level in the world. Furthermore, a stable food supply chain is the guarantee of food accessibility and climate impacts disturb the supply chain of food, and that breaks the physical accessibility for food in many ways.

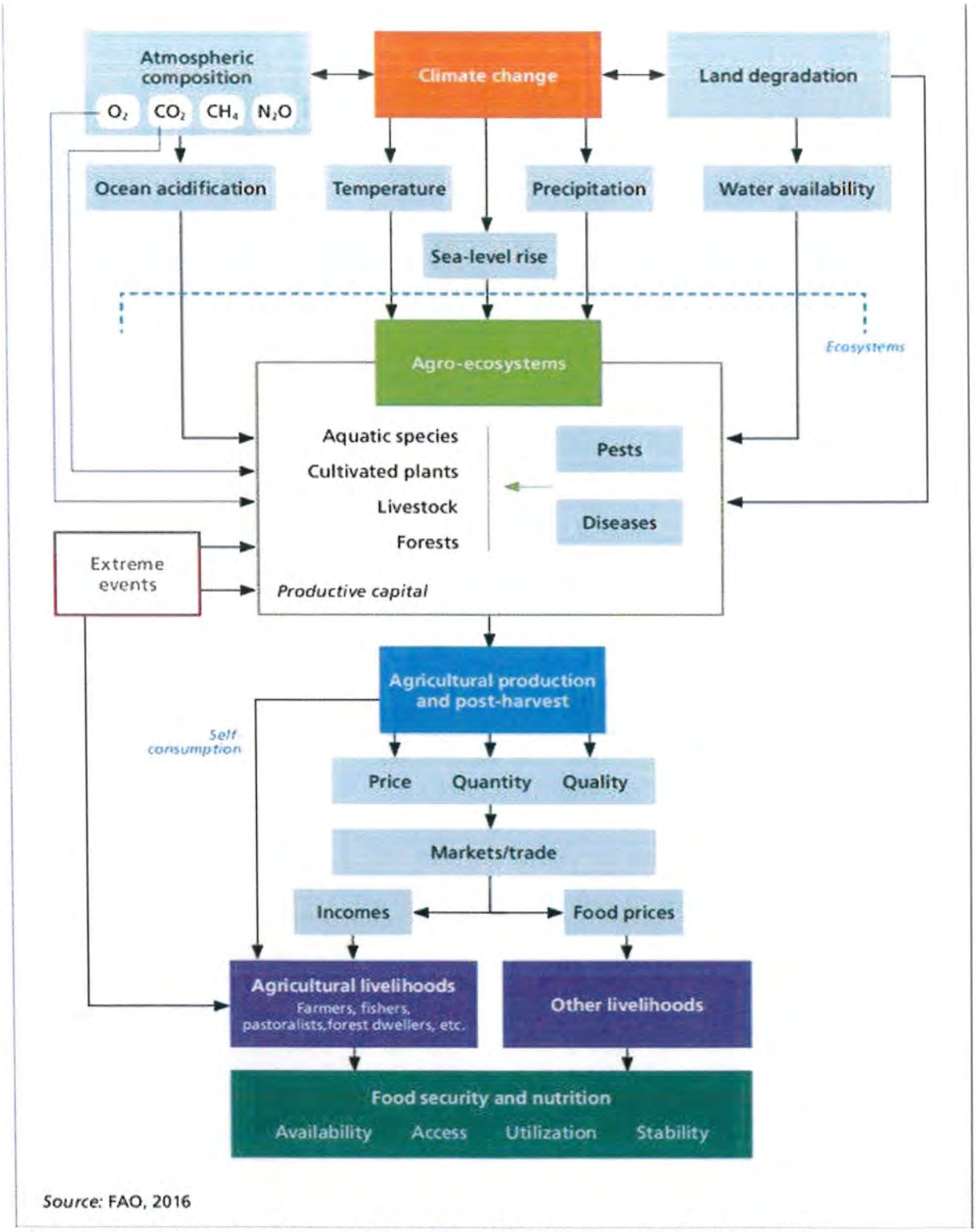

Figure 3: Climate Change and Impact on Four Pillar of Food Security (Food and Agriculture Organization, 2016)

However, Nissan and Ulbrich (2017) conclude that risky weather events heavy rainfall, floods, storms, and snow also affect infrastructure like roads and bridges creating unsafe situations for people to physically access the markets and create food insecurity. In addition to that, Garcia (2013) identifies that food insecurity raises the percentage of malnutrition and poor health conditions, especially in children and women, and will adversely affect their educational and productive performance due to improper food utilization.

Ray et al. (2019) indicated that increasing CO_2 levels are affecting food security levels in different regions and it is projected to be considerably upset to meet future demands. However, although there is an increase in food production due to inventions and innovations but nutritional food insecurity is still high due to low income, climate change and population pressure. Food and Agriculture Organization (2018) estimated that two billion people face a deficit in more than one micronutrient, twenty-two percent of children are undersized, and more than eight hundred million humans are undernourished in the world.

1.4: Sustainable Development Goals, Food Security, and Climate Change

Sustainable development goals (SDGs), zero hunger (goal 2), and good health and mental well-being (goal 3) are addressing the food security challenges. Whereas, urgent action required combating climate change (goal, 13) is linked with climate change. However, food security and nutrition security are still a key health challenge, especially in developing countries. It is also identified that, there is dare need to increase the sustainably increase in production through innovation and stable food supply chain across the globe for food security. Moreover, production improves the global supply chain, reduces food losses and

waste, and guarantees that all people have access to nutritious food who suffering from hunger and malnutrition. The think tank throughout the globe considers that eliminating hunger in the next generation is still achievable therefore; they are working to achieve these goals and this research will address the above three goals.

1.5: Pillars of Food Security

In recent times, achieving food security is an imperative issue and a rising alarm of the current period. Approximately 8.9 percent of the global population was predicted to be in a malnutrition situation as reported in 2020 (Food and Agriculture Organization, 2022). Food security is define as when all people, always, have physical and economic access to adequate healthy and nutritious food that fulfills their dietary requirements and preferences for a healthy and good life. Below are the pillars of food security:

1.5.1: Food Availability: it deals with the Physical availability of food availability reports the "supply side" which is determined by the level of food production, stock levels, and net trade.

1.5.2: Food Accessibility: Physical and economic access to food indicates that food production itself does not guarantee household-level food security. Therefore, the level of income, expenditure, and price should be accessible to the people.

1.5.3: Food Utilization: food utilization is defined as consuming enough energy and nutrient intake by persons as the result of good care and feeding practices, food preparation, and diversity of the diet and intra-household distribution of food.

1.5.4: Food Stability: it is the stability of the three above-mentioned pillars over time: if food intake is sufficient for today, but not access to food in different periods and that will break your nutritional status, then a person still considers food insecure.

Therefore, to achieve food security all four pillars should be fulfilled simultaneously. However, extreme weather situations, political instability, unemployment, and rising inflation will have an impact on the food security position.

1.6: Scope of Study

Currently, in the situation of prompt change in climate, scarce resources, increasing population, rising inflation, and limited income, it is a challenge to meet the human nutritional food demand. United Nation (2017) estimates that, the world population will reach about 9.7 billion in 2050 which will lead to an increase of about eleven billion by the completion of the current century. On the supply side, with the increasing level of CO_2 emissions along with water shortage and soil degradation, it is difficult to get nutritional and adequate food.

Moreover, it is determine that, there is relationship between food security and climate change factors that happen through temperature, rainfall, and greenhouse gas emissions. Extreme weather events like flooding, wildfires, tornadoes, and hailstorms are becoming more common and strong which limits the food system by affecting crop productivity, seed capital, and large and small ruminates decreasing the income sources. It will create economic pressure and trade unbalance especially in developing countries.

However, it is depicted from the literature that, greenhouse gas emissions especially CO_2 have a significant impact on the food system, but exceedingly rare work is found in the

literature. Whereas, there is no empirical work available on the effect of CO_2 emissions on food security and its allied pillars like food availability, food accessibility, utilization, and stability. Therefore, this research will fill the research gap and provide future policy implications to improve food security around the globe.

1.7: Research Questions

Currently, humans live in delicate environments, especially after the Covid 19; they are always at threat of hunger and poverty, which are affected by climate change (Mahapatra et al., 2021).The undernourishment has increased around the world (World Health Organization, 2020). In the world, the highest percentage of prevalence of stunting in South Asia at 30.7% which is greater than the 22.0% of world average (Micha et al., 2020). However, the adverse climate change effect is one of the biggest threats in the world food security level. Therefore, it is important to study the effect of CO_2 on food security to fulfill the upcoming diverse food demands for the population.

In addition to that, there is a dire need to explore the effect of climatic factors that were previously ignored on pillars of food security for achieving sustainable development goals and meeting the demand for healthy and nutritional food in underdeveloped regions as well as the developed regions of the globe. Therefore, the research has been designed to address the following research questions:

1. What is the effect of CO_2 emissions on average dietary energy supply for food availability and then food security at a global level?
2. What is the effect of CO_2 emissions on the prevalence of undernourishment for food accessibility and then food security at a global level?

3. What is the effect of CO_2 emissions on children who are under 5 years of age stunted, wasted, and overweight in food utilization and then food security at a global level?
4. What is the effect of CO_2 emissions on per capita food supply variability in food stability and food security at a global level?

1.8: Hypothesis and Objectives

The research focuses on the empirical impact of the four pillars (availability, utilization, accessibility, and stability) of food security at the world level by using panel data. Therefore, the following hypothesis and objectives are designed to test the study:

H_{01}: Emission of CO_2 emissions has no impact on the average dietary energy supply.

H_{02}: Emission of CO_2 emissions has no impact on the prevalence of undernourishment.

H_{03}: Emission of CO_2 emissions has no impact on children who are stunted, wasted, and overweight.

H_{04}: Emission of CO_2 emissions has no impact on food supply variability.

H_{05}: Population growth, GDP growth, inflation, share of agricultural land, share of irrigated land, and value of food production has no impact on the four pillars of food security.

1.9: Research Contribution

Based on the above background and available literature, emissions of CO_2 are the major factor that is the main factor of climate change and have a relationship with food security in several ways. The climatic situation could have serious negative impacts and future food

security as well as on nutritional status in the future in the era of globalization where resources are scarce and the population is increasing day by day. However, there are limited research found that have empirically examined the effect of CO_2 on food security pillars on the food security variables like average dietary energy supply, the prevalence of undernourishment, children who are under 5 years of age are stunted, wasted, and overweight, and food supply variability.

Previously, research was conducted on time series data at a country level and panel data at a regional level on food security. The empirical analysis on the global level by using the panel data estimation is still missing from the literature. Therefore, the research is designed to empirically estimate the effect of CO_2 emissions on food availability, food accessibility, food utilization, and food stability on the global level by using panel data.

1.10: Framework of the Study

The thesis contains five chapters in this document. The first chapter contains background information, facts about climate change about CO_2 and, relationship with food security, scope, objective, and develop a hypothesis with research questions. Chapter two includes all the literature cited for developing research questions. However, the methodology to conduct this research is in chapter three, and chapter four describes the results and discussion and then chapter five include conclusion and policy recommendation.

Chapter 2

2.1: Review of Literature

These chapters describe the empirical of previous studies review of previous studies in the context of changing climatic factors and other variables and their effect on food security.

Ringler et al. (2010) adopted a comprehensive climate change scenario (CCC) by using seventeen Global Circulation Models (GCMs) chosen for their relative performance in the Sub-Saharan Africa region. The findings indicated and forecasted that there is a strong probability of high temperatures together with complicated precipitation variations for the year 2050, which indicates that future agricultural production and growth will be affected as a result of climate change. It is concluded that, due to changing weather conditions the costs of production are raising, food affordability is declining, required calories are unavailable, and growing childhood malnutrition is affected in Sub-Saharan Africa.

Kabubo-Mariara and Kabara (2017) estimated the effect of climate change on food insecurity from the year 1975 to year 2012 in Kenya. The research merely focuses on the food availability dimension of food security on major growing crops in Kenya. The secondary data collected on the rainfall, temperature and cereal yield and results are estimated through the multivariate model. The finding suggests that climate change would worsen the food insecurity situation but climatic factors have a non-linear connection with food insecurity.

Ben Zaied and Zouabi (2015) explore the long-term climatic variability of olive crops calculated from twenty-four locations by using the time series from 1980 to 2012 in Tunisia by using the panel cointegration techniques. The result empirically indicates that

rising temperature and rainfall shortfalls have had a substantial impact on long-run olive productivity in all the areas in the last three decades.

Furthermore, **Hagos et al. (2014)** explore the effect of climatic factors on the children who are malnutrition situation in Ethiopia. The panel data collected from the year 1996 to 2004 and applied the panel regression fixed effects model. The targeted variables include, temperature, and rainfall, and dependent variables include children who are stunting, wasting, and underweight for three regions. The findings indicate malnutrition children with stunting and underweight were affected positively by climatic factors. However, the wasted children found a positive relationship but were insignificantly affected by the rainfall and temperature.

Tokunag et al. (2015) explored the effect of solar radiation, precipitation, and temperature on rice, potatoes, and vegetables in eight zones in Japan from the year 1995 to 2006. The authors used dynamic and static panel data analyses. The results depict that, the production of rice falling due to solar radiation. Whereas, increasing temperature and precipitation are caused by a decline the vegetable and potato production.

Wang et al. (2010) estimated the effect of climate change variables (temperature) on food security by taking the panel data from twenty-seven provinces from the year 1985 to the year 2007 in China. The data analyzed by using the fixed and random effect models. The author used agriculture disaster as a proxy of climate change which adversely affects the per capita food consumption. However, temperature change would lead to scarcity in food production and as a result it directly affects the food security in China.

In Pakistan, **Arshed and Abduqayumov (2016)** estimated the long-run influence of climate change on the productivity of wheat and cotton in twelve major districts of Punjab

from the year 1971 to 2010. The authors apply the yearly average rainfall and temperature as a climate change variable. The findings indicate that cotton yield was increased by the rising temperature level. However, rainfalls have a positive influence on wheat productivity. It is conclude that, the cereal and cash crop production directly affect the food availability and utilization in the rural areas.

However, **Kumar et al. (2013)** estimate the effect of the changing climate on agricultural production and then its impact on food security in India. The secondary data collected on temperature and rainfall and cereal production which is major source of food in the rural areas. The panel data was taken for thirteen regions from the year 1980 to 2009 by using the dynamic panel data analysis. The results indicate that climatic factors harm the food security situation index and agriculture food supply.

Kordi et al. (2015) identify the impact of climatic factors like annual temperature and annual rainfall and non-climatic factors like seed fertilizers, labor used, and machinery on wheat production. Therefore, secondary data for eleven regions of Iran from the years 1991 to 2011 are taken for the research. However, the results indicate that there was a non-linear relationship exists between climate variables and wheat supply in Iran. Furthermore, temperature had a positive and significant effect on wheat yield productivity.

Mahrous et al (2019) explore the influence of the world-changing climate on food security in African countries. The panel data analysis for five counties from the year 2000 to 2014 has been applied for data analysis. The author regresses the food security on the agricultural land on cereal production, population, rainfall, and temperature. However, results indicate that temperature hurts food security, whereas, increasing the area under

cereal production enhances food security. In conclusion, climate is a crucial factor to consider for political, social improvement, and economic stability in the region.

Geffersa (2014) studied the influence of climatic change on family food security in fifteen Ethiopian communities in rural regions from the year 1994 to 2009.The longitudinal household dataset drawn from the rural communities of country. The data analyzed employing the fixed effect model. The empirical findings suggested that climate change has adverse and considerable effects on food security over time. Furthermore, results also indicated that other factors like agricultural land and large ruminates will play a vital role in ensuring the food security of families.

Furthermore, **Demeke et al. (2011)** investigated the effect of rainfall variability on food security in rural farm families from year 1994 to 2004 in Ethiopia. The paper indicates the size and unpredictability of rainfall had a substantial impact on food security levels and the vulnerability of farm families in the country. In addition, there were several other characteristics like family size and livestock ownership which have a promising impact on Ethiopian food security at farm areas.

Affoh et al. (2022) researchers looked at the empirical relationship between climatic factors and food security usage in twenty South African nations from year 1985 to 2018. The panel data have been taken and apply the autoregressive distributed lag model. The results indicate that rainfall had a favorable and substantial long-run effect on access to food, food availability, and food usage. On the other hand, temperature influences food access and availability. In the short term, they discovered a association between food availability and CO_2 emissions using panel ordinary least squares and dynamic ordinary least squares. Furthermore, food use was related to temperature, but the relationship with

food accessibility was more causal. The authors recommend that governments should provide suitable financing for food production by subsidizing farmers and establishing a good irrigation infrastructure in the country to ensure food security.

Adesete et al. (2022) studied the connection between emissions of CO_2 and food security in thirty African countries within the region from the year 2000 to 2019. The one-step and two-step system generalized method of moments (GMM) model was applied to capture the panel effect in the Sub-Saharan African Region. The results indicate that the rise in CO_2 emissions leads to a rise in the prevalence of malnourishment which creates food insecurity in food security in the Sub- Saharan African Region. Moreover, climate change in climate and food prices have an adverse significant impact on food security. However, income level and food supply have a positive and meaningful relationship with food security in the region. In addition to that, results also define the decrease in CO_2 emission as predictable for improvement in agriculture productivity and production, decrease in the occurrence of undernourishment rate, and decline the food insecurity. In the end, research concludes that. it must improve the capacity of local production of food by executing strategies that support to enhance the agricultural supply in the region.

Yan and Shahzad (2022) firstly, explore the impact of climate affect the cereal yield shift on food security and gross domestic product in South Asian countries. Secondly, examine the effect of climate change by the policy response through the agriculture subsidy and South Asian Free Trade Area. The research is carried out by the general equilibrium model and empirical framework. The finding indicates that cereal production declined due to climate change, and as a result, prices will increase consumption and gross domestic

product will fall and welfare lost. The agricultural subsidy and SAFTA have found no impact on food security.

Raj et al (2022) review food security and its relationship with climate change: the author accesses the impacts and adaptation approaches for rural communities in the south (rural India) and north (USA) of the globe during COVID-19. The authors first examine the distinctive climate factors, agriculture, demographic factors, and socio-economic structures and then associate the limitations and opportunities to food security modeled due to COVID-19. The results indicate that there are similarities in both regions in terms of dependency on rural, low-income food producers. However, in the pandemic situation, agricultural policies vary and create food insecurity and global hunger in the region. In addition to that, the smallholder marginal farmers lived in the rural areas and faced poverty and food production issues in developing regions.

Ani et al. (2021) investigated the influence of climate change on food security in Nigeria in the six geopolitical regions. The primary data collected through the focus group discussions and key informant interviews from the year 2018 to 2019. The secondary data is collected from the different publish research reports. The target groups are farmers however, a number of NGOs, civil servants, fertilizer sellers, government officials and transporters. However, the results indicate that climate change harmed food security in Nigeria which created instability in the country and built armed clashes over natural resources.

Otekunrin et al. (2021) Food insecurity examined in agricultural farm families in Nigeria. The multi-stage sampling approach was adopted, and 211 agricultural households were selected by using the cross sectional datasets. The logit model is used in terms of utilizing the household food insecurity and access scale technique. The findings indicate that very

less agricultural households were food secure, despite the major source being agriculture. The study concludes that, encouraging education-related intervention programs and providing rural areas with infrastructure amenities including boreholes, electricity supplies, and healthcare options.

Tarasuk et al. (2019) studied the spatial and socio-demographic causes of food insecurity in Canadian families between the years 2011 and year 2012 with a sample of 120,909 households. Furthermore, they used multivariable binary and multinomial logistic regression to measure the presence and severity of food insecurity in the families. The findings depict that, food insecurity exists among households which varies from region to region. Therefore, it is concluded in a study that promising factors like a province, source of income, level of education, and strategies to cope with the insecurity will have more influence on the food security level.

Hall et al. (2019) review the challenge faced by the community in terms of temperature change and its effect on food security for achieving nutrition security in Malawi. The temperature is affecting all pillars of food security: availability, accessibility, utilization, and stability. The author forecasted the volume and quality of the country's food supply are for the year 2050 under the different socioeconomic characteristics and climatic scenarios. The food forecasting is based on food estimation and export for diet and malnutrition evaluation modeling framework. However, the findings suggest that, in the best and optimal scenario, there are adverse effects of change in weather on micronutrient crops, which were associated with the nutrition level and increased incidence of undernourishment in Malawi. Therefore, it is a more urgent concern in the future than

merely the amount of food and supply of energy, this study emphasizes the necessity of going beyond the reliance on dietary energy supply as a measure of food security.

Verschuur et al. (2021) coupled an extreme event attribution (EEA) technique with an explanatory framework that looked at the impact of climate change which worsened agricultural production shocks in Lesotho in the year 2007. Moreover, the author also evaluated how different crops are affected by climate change and provided some understanding of the consequences for food security in the country. The research identifies that changing climate was discovered to be a significant reason for food production shocks in a country. However, research further highlighted that the agriculture sector's unstable position intensifies their trade reliance due to production shocks and the country becomes food insecure. It is concluded that the country needs to adopt now as well as for future strategies and influence the ability to create resilience against climate change to make the country food secure.

Molotoks et al. (2021) examined the worldwide consequences of climatic variability, population, and agricultural land on food security through panel data from the year 1990 to 2019. The researcher estimates the per capita calorie food estimate and export for diet and malnutrition assessment (FEEDME) modeling framework. The analyses revealed that population shifts made the scenarios have a greater influence on future food insecurity. Furthermore, their analyses revealed that population expansion is the key driver of shifting worldwide undernourishment. The study suggests that improving maternal health care and boosting food access will minimize all the effects of predicted population expansion.

Premanandh (2011) explores that food insecurity is a complex subject that extends outside the fundamental view of the incapability of the country to nourish its population in

Thailand by taking the data from the 400 household. The models were tested through the structural equation Modeling. Numerous driving variables, such as population increase, agricultural land availability, water availability for agriculture, climate, and food supply and food accessibility are reshaping the world's food situation. This article examines the major variables causing worldwide food insecurity and emphasizes the importance of implementing science-based technology advances to solve the problem. Although the predictable benefits of modern technology predict a level of food which is sufficient to feed the population.

Fitton et al. (2019) review that rapid population growth, along with growing food consumption, necessitates either a rise in agricultural output or an improvement in agricultural productivity. Therefore, in a time of fluctuating environment and declining water accessibility will agriculture sector and extremely effect the poor section in the world. The possible trends, hazards, and worries to agricultural land use and availability that may result in reduced water supply are evaluated in the paper. Furthermore, the effects of various policy actions on developing risk pressures were investigated. The research concludes that, the growing pollution and static natural resources are serious threat to the food security level.

Abdoulaye et al. (2015) the effect of the inflation variable which is the consumer price index (CPI) on the food security level in Sub-Saharan Africa is examined in this research. It is founded on the idea that price elasticity (changes in food costs) often influences household consumer expenditure, which has an impact on household income. According to the report, food inflation has surged in several study areas, aggressive up of CPIs and

having a knock-on effect on families and the macro economy. Therefore, it has a direct impact on the purchasing power of households and pushes them to food insecurity. As a result, the effects of price elasticity in the context of food prices are a critical food security concern.

Rolnej (2018) the purpose of this research was to demonstrate the link between economic growth rate and food security at the world level from the year 2012 to the year 2015. The secondary data were collected from various sources and applied the panel data techniques. The results revealed considerable geographical disparities in GDP and food security. it shows that higher GDP is connected with higher levels of food security which means that, ensuring the food security occurred in the nations where there is highest growth in per capita GDP. There is a significant association in the variables which depict that it is a fundamental requirement for global food expansion. The safety and security are economic growth and real income progress, particularly in impoverished nations.

Islam et al (2023) explore that one of the most critical elements of food security is food availability. Therefore, to prevent hunger, it is critical to secure global food availability. The main objective of this research is to explore the population growth rates and their impact on essential food availability by using time series data from 1950 to 2021. Furthermore, the semi-log compound growth rate models are used for forecasting, and for stability and decomposition analysis the Cuddly-Della and Valle instability indexes are used. According to the first model, Pakistan's inhabitants are fast expanding, therefore, there is a need to enhance the area and productivity to meet food sustainability.

2.2: Concluding Remarks

This chapter reviews the relevant research published articles to identify the research problem and research question and explore the empirical model which previously applied for panel data estimation. It is concluded that climate change factors play a vital role in determining the food security level in the country. However, there is limited literature found on the emissions of CO_2 and its impact on sections of food security at the country/regional level, but no literature found on the global level. Therefore, the research has been designed to explore the emissions CO_2 effect on a global level by using panel data.

Chapter 3

3.1: Data and Methodology

This chapter deals with the data collection procedure and analytical and theoretical techniques to address the main objective of the research work. The research is designed to empirically estimate the impact of CO_2 emission on four pillars of food security on a global level. Therefore, to estimate the above mentioned hypothesis following procedures are adopted for the validation of research results. The research is based on panel data which is also known as longitudinal data. That data consists of the cross-sectional as well as the time series data. However, it allows taking multiple observations of the same country over different periods. Therefore, the research is based on the secondary data which is collected for 144 countries all over the world from the different sources as mentioned in table 1 from the year 2000 to the year 2021. The four dependent variables of food security, focus variable is emission of carbon dioxide, and control variables are agricultural land, irrigated land, population growth, gross domestic product, inflation rate, and food production. The sample and description of the variables are given below sections.

3.1.1: Sample of the Study

The research is constructed on the longitudinal data and secondary data collected from the year 2000 to year 2021 of the 144 countries across the globe from the FAO and World Bank database of all the regions depending on the availability of the data. However, to measure food security, four models have been constructed therefore the sample size varies from one model to another model. A brief description is given below in Figure 3.1. The figure describes the sample size used in the four models. Food availability is measured for

145 countries for food accessibility is for 145 countries, food utilizations are for 140 countries, and food stability for 141 countries. Therefore, the research is conducted with the available data of dependent, focused, and control variables.

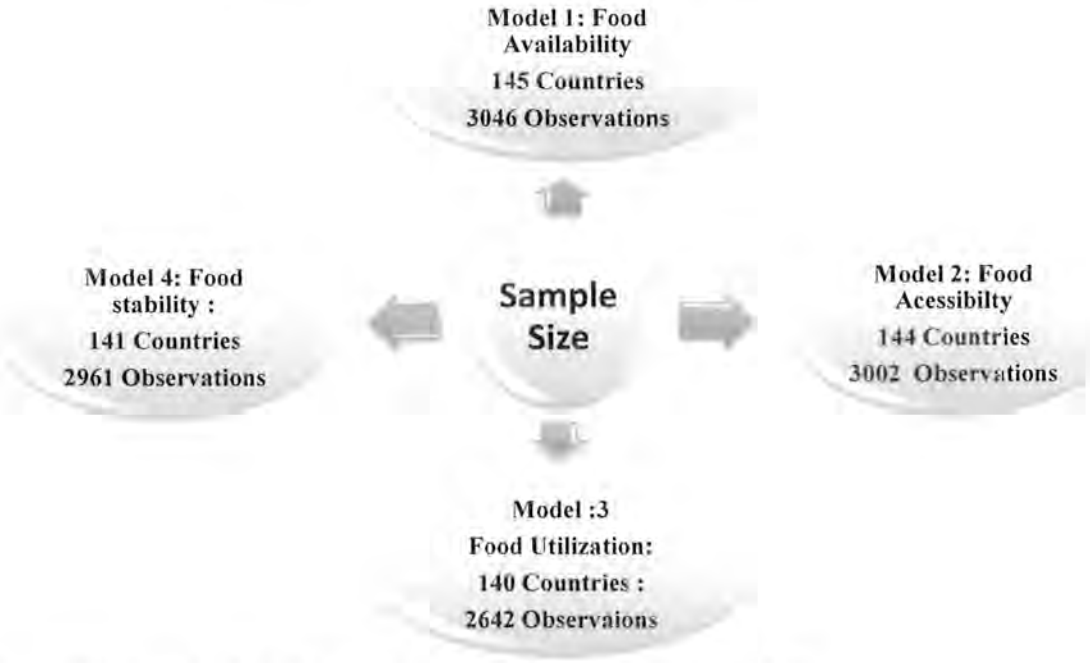

Figure 3.1: Sample size of the four models from the year 2000 to 2021

3.1.2: Description and Data Source of Variables

The table below describes the description of all variables along with their symbol used in the model. However, to estimate the effect on food availability, accessibility utilization, and stability four models were constituted. Food availability is measured through the average dietary energy supply adequacy, and food accessibility is measured through the Percentage of population undernourishment, food utilization is estimated through the percentage of children. The total emission of CO_2 is the focus variable that is a play vital contributor to climate and global warming because it creates heat in the world's atmosphere and that leads to greenhouse emissions.

Table 3.1: Description of Variables in each model under food security ***Symbol Units Brief description***

S.NO	Variable Name	Variable Symbol	Unit	Description of Variables
Dependent Variables				
1.	**Food Availability (Model 1)**	ADES	Percentage	Average dietary energy supply
2.	**Food Accessibly (Model 2)**	PUN	Percentage	Prevalence of undernourishment
3.	**Food Utilization (Model 3)**	CSWO	Percentage	Children who are under 5 years of age are stunted, wasted, and overweight
4.	**Food Stability (Model 4)**	FSV	kcal/capita/day	Food Supply Variability
Focus Variable				
5.	**The emission of Carbon Dioxide (CO_2) is an Important Factor in the Climate Change**	GHCO	kilotonnes	Emission of Carbon Dioxide (CO_2)
Control Variables				
6.	**Agriculture Land**	AL	Percentage	Agricultural land percentage of total land area
	Irrigated Agriculture land	ALI	Percentage	Agricultural land percentage irrigated
	Food Production	FP	Thousand US dollar	Value of Food Production in the Country
7.	**Income**	GDPpc	US dollar	GDPC represents per capita GDP
8.	**Food Prices**	CPI	Percentage	Food prices are estimated with the inflation rate which calculated by the Consumer Price Index in each country
9.	**Population growth**	POPg	Percentage	Population growth rate

However, control variables are agricultural land, food production, gross domestic products, consumer price index, and population growth rate which also contribute to estimating food security across the globe.

Table 3.2: Data Source and Expected Signs for the Variables

Variable name	Data Source	Expected Signs of each model			
Dependent Variables					
ADES	FAOSTAT				
PUN	World Development Indicators and FAO STAT				
CSWO	FAOSTAT				
FSV	FAOSTAT				
Focus Variable					
GHCO	FAOSTAT and IPCC	−	+	+	+
Control Variables					
AL	World Development Indicator	+	−	−	−
ALI	World Development Indicator	+	−	−	−
FP	World Development Indicator	+	−	−	−
GDPpc	World Development Indicator	+	−	−	−
CPI	World Development Indicator	−	+	+	+
POPg	World Development Indicator	−	+	+	+

Furthermore, table 3 indicates the data source and expected sign of the dependent variables. The data is collected from the Food and Agriculture Organization database and World Development Bank indictor's websites. The emission of CO_2 has a negative impact on the

ADES, and a positive with the PUN, CSWO, and FSV according to the available literature. The accessibility of agricultural land and food production will have a positive impact on food availability.

3.1.3: Description of the Variables

According to the World Food Security Committee, food security is founded on four pillars: food availability, food access, food use, and food stability. Food access refers to the physical availability of food and its cost, whereas food utilization refers to the right use of food in terms of fundamental nutrition and knowledge. Food stability is always defined as the ongoing availability and supply of enough food, regardless of economic disruptions. This section describes the variables used to estimate the model.

3.1.3.1: Average dietary energy supply (ADES)

The first section of food security is the food availability to the population. The country is called food secure where enough food with proper quality is available for the entire population either supplied from domestic supply or imports of the product. Food and Agriculture (2013) also reported that availability states the adequacy and stability of the food produced and fulfilled in the country. Therefore, the average dietary energy supply adequacy is the true representative variable for food availability. That measure is used to assess the sufficiency of food available to fulfill the population's energy requirements. It is usually stated as a percentage and indicates the proportion of dietary energy available to a population as compared to the suggested energy intake for sustaining a healthy life.

3.1.3.2: Prevalence of Undernourishment (PUN)

Food accessibility is a vital component of food security. Ericksen (2008) indicated that accessibility is all about physical access in terms of food production and affordability, and having enough resources to buy food is called food secure human beings. The people have enough income and resources to access the food domestically by producing at home or buying from the market or other sources. Therefore, the prevalence of severe and moderate food insecurity/undernourishment is an estimation of the percentage of the population in the country that declares food insecure. It is a critical indicator used to measure food insecurity and malnourishment at the world level. However, the prevalence of undernourishment is estimated by the FAO as a fraction of the population whose food consumption is insufficient to meet their needs and the dietary energy requirements that are compulsory to retain a normal active and healthy life which is expressed as a percentage. Therefore, that variable is used to estimate the food accessibility in the model.

3.1.3.3: Children under 5 Years of Age Stunted, Wasted, Overweight (CHWO)

Food utility is an important pillar of the food security. It is knowledge of the appropriate utilization of nutrition awareness. Food and Agriculture Organization (2013) define that everyone can utilize the proper food, and have access to effective nutritional food, sanitation, and safety measures of the food, and then the country becomes food secure. However, the children's growth is the most common indicator to estimate the nutritional position of the country. Moreover, internationally it is documented as an important health indicator for observing the health status of inhabitants. However, children who have growth obstacles because of unhealthy foods that will cause persistent infections are inclined to have a higher risk of suffering mortality and illness. Therefore, this variable is taken to

indicate the nutritional imbalance and undernourishment resulting in under nutrition (assessed by underweight, stunting, and wasting) and overweight to estimate food security at the global level.

3.1.3.4: Food Supply Variability (FSV)

Food stability is an important section of the food security concept, which joins the other pillars of three pillars to estimate food security over time. The country's stability is based on its volume to provide food at all times. This also explains how insecurity can be transient, with short-term shocks caused by a draught/dry season, a change in work status, or a surge in food prices. There is a relationship between food security and climate change, and it has a direct relationship with food supply variability (Ani et al., 2021). Therefore, the food supply variability indicator is taken to estimate the food stability in the country. The variable captures variability in the availability of food over time by various sources which include food imports, domestic production, and shocks and aids. However, it measures the food supply that can fluctuate from one period to another. Food supply variability can be influenced by different factors which include climate situation, market dynamics natural disasters, and political and economic stability in the country.

3.1.3.4: Emission of Carbon Dioxide (GHCO)

Greenhouse gas emissions are the discharge of gases in the world's atmosphere that contribute to the emissions of greenhouse and as a result, affect climate change. These gases trap radiation and heat and back towards the Earth's surface which leads to an increase in global temperatures. However, CO_2 is the predominant greenhouse with a 76 percent share in total emissions caused by using fossil fuels (coal, oil, and natural gas) in the creation of power, transportation, and industrial activities. Therefore, the emission of

CO_2 has been taken as the climate change variable to explore the impact on four pillars of food security. The data has been taken from the World Development Indicator and Food and Agriculture Organization from the year 2000 to the year 2021.

3.1.3.5: Agriculture Land (AL)

Numerous studies focused on the global challenge of ensuring food security from agricultural land utilization (Stephens et al., 2018; Antle et al., 2017). However, agricultural and agricultural land is closely interrelated because and has a vital role in ensuring the availability and accessibility of food for the increasing global population. However, it also affects and ensures the sustainable use and management of agricultural land to embrace novel and inventive methods such as climate-smart agriculture to preserve global food security. Therefore, agricultural land in overall land refers to cultivated, under-stable crops and stable pastures.

3.1.3.6: Agriculture Land Irrigated (ALI)

Population growth, along with growing food consumption, requires either the extension of an agricultural area or sufficient yield gains from existing resources. the vulnerability of agriculture and climatic shockwaves like droughts and heat stress which affect the national security situation and policies. Therefore, the variable of the percentage of agricultural land irrigated has been taken in the research to estimate food security. The variables provide a portion of the dependency of an agricultural country on irrigation.

3.1.3.7: Food Production (FP)

The value of food production and food security are interrelated, and the foundation of food security and their connection is critical to ensuring access to suitable, safe, and nutritional

food to meet their dietary requirement. However, food production directly has a huge impact on food availability. Moreover, sufficient and efficient food production has played a significant role in food security, because it guarantees that adequate food is produced to meet the nutritional needs of the people. Therefore, keeping in view the importance of the variables, the total food production of all food items has been taken to estimate food security in each selected country.

3.1.3.8: Real GDP per capita (GDPpc)

Income has had a vital role in estimating the food security level of any economy because directly affects the purchasing power and ability to access and afford sufficient, safe, and nutritious food in the country. For example, higher income levels economics allocate more resources to purchasing food adequate income allows people to get diversified food items that include more nutritional elements. Also, they adopt more coping strategies to deal with the shocks and food insecurity situation. Therefore, Gross Domestic Product per capita (GDPpc) are widely used in research to compare the living stander and monitor the economic dynamics in the world.

3.1.3.9: Consumer Price Index (CPI)

World Bank (2023) indicated that the increasing food prices at global, regional, and country levels due to the economic and environmental situation in the world will threaten food security. However, connection between the food prices and security is interlinked. The fluctuations in food prices can have significant effects on food security, particularly in countries where a large section of the people depend on agriculture and have limited purchasing power. Furthermore, the Consumer price index is an important economic indicator used to estimate the fluctuation in the prices of the goods and service basket of

the household over time. It is a key representative to measure the inflation rate or raise food prices in the country.

3.1.3.10: Population Growth (POPgr)

Population growth rate indicates the rate at which a population increases or decreases over a year which, is usually expressed as a percentage in the World development indicators. However, the rising population increases the demand which creates food imbalance and insecurity. According to Malthus (1986) hypothesized the theory that the population is increasing speedily whereas agricultural production and food are not sufficient to meet the requirement for food for the world. Therefore, the high growth of the population has become a key hazard to all pillars of food security.

3.2: Theoretical Framework

Theoretical frameworks play a pertinent role in research which provides an organized and strong groundwork for conducting research. It also supports in formulation of research questions, data collection and analysis, and the understanding of outcomes. Furthermore, it supports to define and explain the notions, variables, and associations being studied. However, by establishing the theories and concepts, the research findings are more likely to have broader applicability and generalizability which enhances the credibility and relevance of the research outcomes. There are many ways of modeling food security pillars. However, this research applies the uses grouping of conventional utility theories, supply, and demand as used by (Adesete et al., 2022). In addition to that, utility-driven food is related to the satisfaction level acquired by the person. Therefore, higher food consumption, food utilization, food accessibility and food stability of utility would outcome

in a drop in food insecurity. These are the assumptions proposed for this study for theoretical framework:

3.2.1: Conventional Utility and Modified Supply Demand Theory

In economics, Utility theory is to understand the individual's behavior to make choices under conditions of uncertainty or risk. These theories find to explain how human behavior by assuming that individuals are rational decision-makers who seek to maximize their overall well-being or satisfaction level is known as "utility". Therefore, in this research, we assumed that consumer maximizes their satisfaction level with the given choices and achieve food security with scarce resources. Therefore equation 3.1 shows the utility function.

$$U = f(Z) \quad \text{---------- (3.1)}$$

Whereas,

U=Utility

Z= Basket of Food Commodities X1, X2, X3----------Xn

$$Z = (X1, X2, X3\text{----------}Xn) \quad \text{---------- (3.2)}$$

Therefore,

$$U = F(X1, X2, X3\text{----------}Xn) \quad \text{---------- (3.3)}$$

Furthermore, food commodities depend on the:

$$Z = F(\text{climate factor, other factors}) \quad \text{----------(3.4)}$$

The climate factor used in the research is the emission of CO_2 which rises in the atmosphere due to human activities and contributes to global warming and climate change

which leads to numerous and severe risky weather events, like droughts, heat waves, and floods in the world. Furthermore, these events can have negative effects on crop yields, disrupt production, and decrease food security levels in the country.

1. Income (Gross domestic product)
2. Population growth (Population)
3. Food price (Consumer price index)
4. Food Supply (Value of Food Production)
5. Agriculture land (Percentage of agriculture land of total land)
6. Irrigated agriculture land (Percentage of irrigated land of total agricultural land)

3.2.2: Linkages between Utility, Average Dietary Energy Supply (FSAV), and Food Security

The average dietary energy supply is adequate quantities of food with proper quality available for the entire population. Then that will call the food-secure population in the world. Whereas,

1. Food utility is positively related to the average energy dietary supply

$$If \sim FSAV$$

2. utility is positively associated with food security

$$Uf \sim FS$$

3. Level of satisfaction interprets to the increasing the rate of average dietary supply which enhances the food security level in a country.

$$Uf \sim FS \sim FSAV \text{ (Average energy dietary supply)}$$

According to the theory utility resulting (U) from the intake of the food commodities basket which is (X1, X2, X3... Xn) increases which mean consumers would be available for more and more nutritional food, and higher satisfaction will lead to enhance the food security level. However, the higher food supply variability leads to a higher satisfaction level of the consumer which increases the food insecurity in a country.

3.2.3: Linkages between Utility, Food Security and Prevalence of Undernourishment (FSAC)

Accessibility is all about physical access in terms of production and affordability and having enough resources to buy the nutritional food called food secure. Therefore, it is a critical component of food security. The relationship between food utility and pre-prevalence of undernourishment and food security is given below.

1. the utility is adversely associated with the prevalence of undernourishment rate (FSAC)

$$Uf \sim -FSAC$$

2. Food utility is positively linked to food security because it increases the food security level.

$$Uf \sim FS.$$

3. Food security (utility) decodes the prevalence of malnourishment rates and undernourished populations.

$$Uf \sim FS \sim FSAC\ (PUN)$$

The theory utility derived (U) from the intake of the food commodities which are (X1, X2, X3,.. Xn) increases which mean consumers would get more and higher satisfaction will

According to the theory utility derived (U) from the intake of the food commodities which are (X1, X2, X3... Xn) increases which mean consumers would get more and higher satisfaction will lead to enhanced food security level. However, the higher number means lesser availability of nutritional food and satisfaction level of the consumer which increases the food insecurity in a country.

3.2.5 Linkages between Utility, *Food Supply Variability (FSST)* and Food Security

Food supply variability is always a continuous supply and access to sufficient and nutritional food regardless of shocks that smash the economy in a country. Therefore the per capita food supply variability indicator has been taken to estimate the food security. The variable captures the variability in the availability of food over time by various sources which include food imports, domestic production, and shocks and aids.

1. Food utility is inversely related to the food supply variability

$$Uf \sim -FSST$$

2. Food utility is positively associated with food security

$$Uf \sim FS$$

3. Food security (utility) is inversely with food supply variability in the country

$$Uf \sim FS \sim -FSST \text{ (Food supply variability)}$$

According to the theory utility derived (U) from the intake of the food commodities which are (X1, X2, X3... An Xn) increase which means consumers would get more and higher satisfaction will lead to enhanced food security level. However, the higher food supply

variability leads to a higher satisfaction level of the consumer which increases the food insecurity in a country.

3.2.6: Graphical Illustration of the demand, and Utility theory and effect of Emission of Carbon Dioxide

The original demand, supply, and utility curves are U, DD, and SS; correspondingly, E is the original equilibrium point of supply and demand curves. However, the U is the preferable buddle on of the indifference curves and budget line which also denotes the level of food security in the country. However, the higher the utility resulting from the food group then the upper will be the food security and lower IC means lower utility and food security will be low. Furthermore, if more greenhouse gas emission creates the event of climate change like heat waves, drought, and rainfall that will directly impact and decline the food production level in a state which shifts the supply curve upward from SS from SS1. That shift moves the equilibrium point at E1 and declines the quantity produced in a country move from Q3 to Q1.

Moreover, the equilibrium quantity produces falls to Q1 from Q3 by changing the equilibrium point E1 from E. Furthermore, not enough food available, therefore, food demand would drop to the same extent as the food supply. Due to the drop in equilibrium quantity, the utility curve also shifts downward from IC to IC1 due to the decrease in food quantity. However, there is a significant decline in satisfaction levels due to food consumption. the graph depicts the variance between U_2 and U representing the **price effect** which is because of climate change on food security because price surges due to the shortage of supply and increasing demand which affects consumer income.

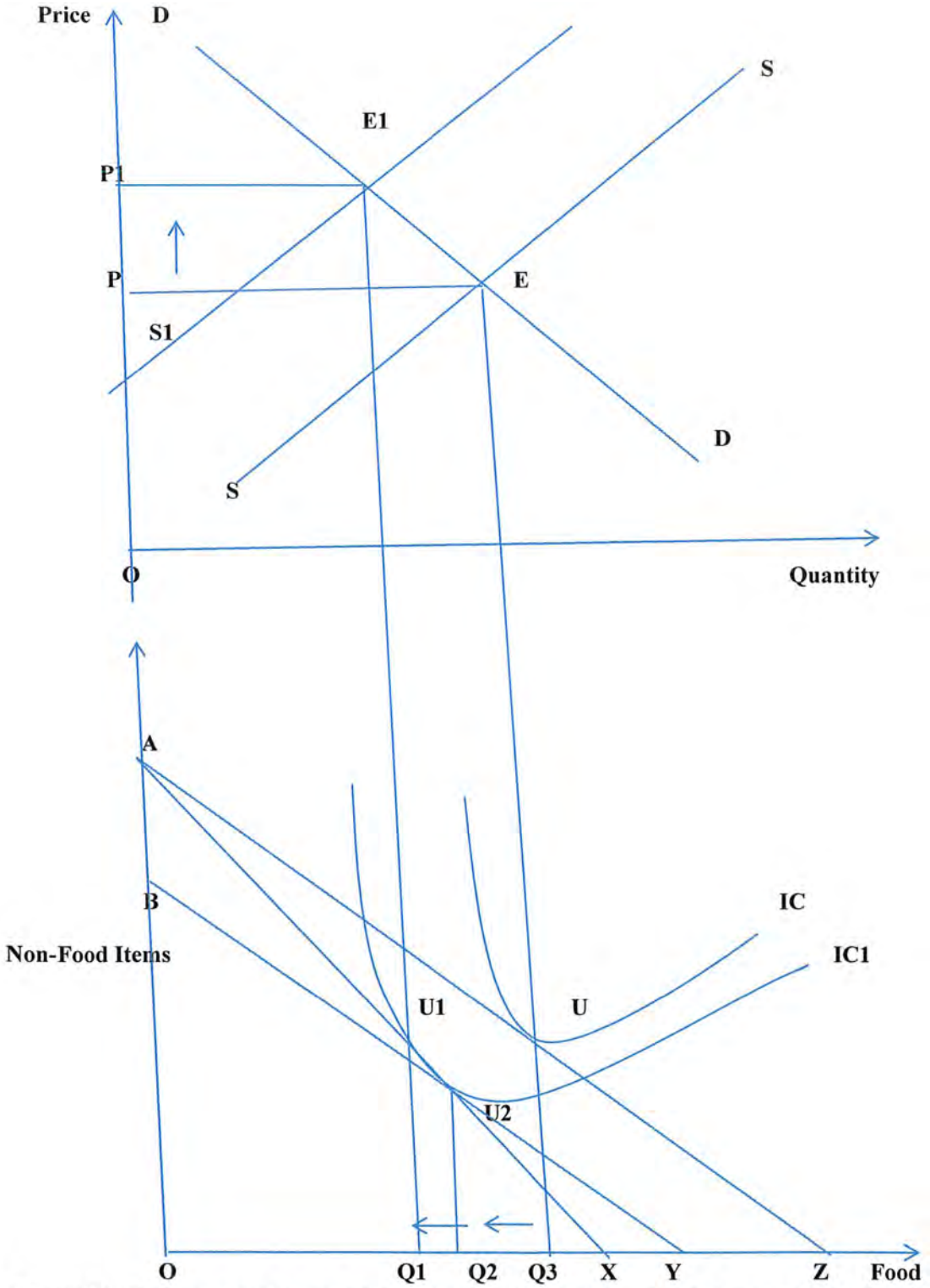

Figure 3.2: Demand, supply, and utility of consumer food security and raising CO2 emissions

The real income fall, causes utility to shift inward from U on IC to U1 on IC1. That effect is called the **income effect** which occurs due to changing climate change on food security and the decline in the equilibrium capacity from Q3 to Q2. In the upper graph, higher food prices would be the reason that consumers reduced their demand for food items and shifted to non-food commodities. As a result of that, the equilibrium quantity falls further from Q1 to Q2. However, the Q2 equilibrium shows that the **substitution effect** and this happen because of the climate change on different pillars of food security.

3.3: Econometrics Model

Econometric models play a vital role in applying statistical and mathematical methods to analyze the above-mentioned data to justify the theory. However, the main goal is to quantify and scope of the economic relationships, evaluate the theories, and build the causal and effect of the variables and predictions about economic outcomes. Furthermore, these techniques support the researcher's established causal relations between economic variables. However, it is a backup for governments and policymakers to use econometrics to assess the effect of numerous policies. Therefore, this segment describes the econometric model used in the research to get the outcome and effect on food security in the world.

3.3.1: Model Specification

Recalling the equation 3.4 in the above section

$$Z = f(\text{climate factor, other factors}) \text{ ----------(3.4)}$$

Consumption of food commodities depends on the factors.

Climatic factor (greenhouse gas emission of carbon dioxide) **GHCO**

Other Factors **(OF)** are.

Income (Gross domestic product) **GDPpc**

Population growth (Population) **POPg**

Food price (Consumer Price Index) **CPI**

Food Supply (Value of Food Production) **FP**

Agriculture land (Percentage of agriculture land) **AL**

Irrigated agriculture land (Percentage of irrigated land) **ALI**

Food security depends on the

$$FS = f(GHCO, OF) \text{ ---------- (3.5)}$$

Transforming Equation.3.5 to a Cobb–Douglas function,

$$FS = A(GHCO)^{\alpha}(OF)^{\beta} \text{ ----------(3.6)}$$

A = intercept in each model

The natural logarithm of Equation 3.6

$$Ln(FS) = Ln(A(GHCO)^{\alpha}(OF)^{\beta}) \text{ ---------- (3.7)}$$

$$Ln(FS) = Ln(A) + Ln(GHCO)^{\alpha} + Ln(OF)^{\beta} \text{ ---------- (3.8)}$$

$$Ln(FS) = Ln(A) + \alpha Ln(GHCO) + \beta Ln(OF) \text{ ---------- (3.9)}$$

$$Ln(A) = \rho$$

The four econometric models were developed to estimate the food security on the globe by using the panel data estimations. The four models have been developed in the study to identify the impact of the emission of CO_2 and other factors on the pillars of food security.

1. Food Availability (Average energy dietary supply)
2. Food Accessibility (Prevalence of undernourishment)

3. Food Utilization (Children who are under 5 Years of Age stunted, wasted, and overweight)
4. Food Stability (Food Supply Variability)

3.3.1.1: Food Availability Model

In the research food availability is captured through the average dietary energy supply in the world. The country is called food secure where adequate quantities of food with proper quality are available for the entire population either supplied from domestic supply or imports of the product. The empirical model is designed from the equations 3.10 has been developed.

$$LnADES_{it} = \rho + \alpha LnGHCO_{it} + \beta_1 LnGDPpc_{it} + \beta_2 LnCPI_{it} + \beta_3 LnPOP_{it} + \beta_4 LnAL_{it} + \beta_5 LnALI_{it} + \beta_6 LnFP_{it} + \mu_{it} \text{ ------ } (3.10)$$

Whereas

i: Cross-sectional data of 145 countries all over the world

t: time series data of the country from the year 2000 to 2021.

ρ is constant term; α is regression coefficient of focus; $\beta 1 ... \beta 5$ are regression coefficient of control variables; and εit error term in equation (3.10).

3.3.1.2: Food Accessibility Model

Food accessibility will measured through the occurrence of undernourishment in the population in the world. The occurrence of severe and moderate food insecurity/nourishment is an estimation of the percentage of the population in a country

declared food insecure. It is a critical indicator used to measure food insecurity and malnourishment at the world level. The empirical model is designed from equations 3.11 has been developed.

$$LnPUN_{it} = \rho + \alpha LnGHCO_{it} + \beta_1 LnGDPpc_{it} + \beta_2 LnCPI_{it} + \beta_3 LnPOP_{it} + \beta_4 LnAL_{it} + \beta_5 LnFP_{it} + \mu_{it} \text{ ------ } (3.11)$$

Whereas

i: Cross-sectional data of 144 countries all over the world

t: time series data of the country from the year 2000 to 2021.

ρ is constant term; α is regression coefficient of focus; $\beta 1 ... \beta 5$ are regression coefficient of control variables; and εit error term in equation (3.11).

3.3.1.3: Food Utilization Model

Food utilization is measured through the variable taken to indicate the nutritional imbalance and undernourishment resulting in under nutrition (assessed by underweight, stunting, and wasting) and overweight to estimate the effect on food security in the world. It is a critical indicator used to measure malnourishment and food insecurity at the world level. The empirical model is designed from the equations 3.12 has been developed.

$$LnCSWO_{it} = \rho + \alpha LnGHCO_{it} + \beta_1 LnGDPpc_{it} + \beta_2 LnCPI_{it} + \beta_3 LnPOP_{it} + \beta_5 LnALI_{it} + \beta_6 LnFP_{it} + \mu_{it} \text{ ------ } (3.12)$$

Whereas

i: Cross-sectional data of 140 countries all over the world

t: time series data of the country from the year 2000 to 2021.

ρ is constant term; α is regression coefficient of focus; $\beta 1 ... \beta 5$ are regression coefficient of control variables; and εit error term in equation (3.12).

3.3.1.4: Food Stability Model

Food stability is an important section of food security, which joins all pillars to estimate the effect on food security. That also elaborates that uncertainty can be temporary with fleeting period shockwaves the result of a draught/dry or a variation in employment position and increase in food prices. The variable captures variability in the availability of food over time by various sources which include food imports, domestic production, and shocks and aids. The empirical model is designed from the equations 3.14 has been developed.

$$LLnFSV_{it} = \rho + \alpha LnGHCO_{it} + \beta_1 LnGDPpc_{it} + \beta_2 LnCPI_{it} + \beta_3 LnPOP_{it} + \beta_5 LnAL_{it} + \beta_6 LnALI_{it} + \mu_{it} \text{ ------ } (3.14)$$

Whereas

i: Cross-sectional data of 141 countries all over the world

t: time series data of the country from the year 2000 to 2021.

ρ is constant term; α is regression coefficient of focus; $\beta 1 ... \beta 5$ are regression coefficient of control variables; and εit error term in equation (3.14).

3.4: Panel Data Techniques

Panel data is also recognized as longitudinal which includes the cross-sectional and time series dataset in which the conduct of countries in time in different years. Over the different time which offers advantages for studying changes over time and across different units. Arellano (2001) wrote in his book that, traditionally, time series parameters relied on concepts of stationary, pre-determinedness, and uncorrelated shocks. Cross-sectional parameters, on the other hand, relied on exogenous instrumental factors and random sampling for identification. Therefore, the panel has data developed by joining the time series and cross-sectional scopes.

It is also discovered in the literature that its original motivation was the aim to leverage panel data for managing unobserved time-invariant heterogeneity in cross-sectional models. Furthermore, it allows the researcher to control for parameters such as country cultural factors or variables that change over time but not across entities (i.e., national policies, federal regulations, international agreements, etc). This is because it considers individual differences. However, it allows us to include variables at many levels of study (e.g., students, schools, districts, and states) for multilevel modeling. The analysis has the following advantages.

1. It permits the researcher to regulate the unobserved entity or individual who will be affected by the dependent variables.

2. The panel data also support and provide true and more information and statistical influence by using data from multiple periods by comparing to cross-sectional data alone.

3. The panel data estimation can provide perceptions of causal and effect relationships and policy impacts. Therefore, researchers to monitor the before and after interventions of the effect.

3.4.1: Pre-estimation techniques

Pre-estimation tests are diagnostic tests and procedures that are conducted before appropriating a statistical model to assess the assumptions, data quality, and potential issues that might affect the reliability and validity of the analysis. These tests help ensure that the underlying assumptions of your chosen model are met and that your data is suitable for the analysis you intend to perform. Here is the following test applied before the estimation.

3.4.1.1: Cross-sectional Dependence Test

The cross-sectional dependency test deal with macro panels with lengthy time series. The null hypothesis in the Breusch-Pagan LM test of independence is that residuals are not linked across individuals.

H_0 = Residuals are not correlated

H_1 = Residuals are correlated

It is very imperative to evaluate the cross-sectional dependence of panel data models. However, Adesete et al. (2022) reported that the test would indicate whether any policy has a spillover effect of any policy regarding climate change will affect among the used countries. The cross-sectional dependence test also supports this research in a way that would statistically establish whether or not climate change in any of the nations under consideration would have a multiplier effect among them.

3.4.1.2: Normality Test

In the analysis, it is important to assess the normal distribution of the data in the model. Therefore, the Jarque-Bera test is used to determine whether a given dataset has the skewness and kurtosis that would be expected in a normal distribution. It is often used as a test for normality, particularly in cases where the sample size is moderate to large. Carlos Jarque and Anil K. Bera are the founders of the test. Therefore, that test is used to diagnose the normality of the data. The Null hypothesis is.

H_0 = series normally distributed

H_1 = series not normally distributed

3.4.1.3: Hetroscedasticity Test

In a panel regression analysis, there is an important assumption of homoscedasticity which means there constant variance of residuals. It is an important assumption because violating this can affect the rationality of statistical inference including hypothesis tests and confidence intervals. Moreover, can lead to inefficiency in parameter estimation and can bias the standard errors of coefficients, incorrect parameters, and resulting incorrect conclusions about the effect of variables. Therefore, to estimate the hetroscedasticity the null hypothesis is

H_0 = Homoscedasticity (constant variance)

H_1 = Hetroscedasticity (not constant variance)

3.4.1.4: Multicollinearity Test

The correlations between the explanatory variables initiate a multicollinearity problem. As a result, the correlation coefficient for these two variables appears to be the most natural technique to discover multicollinearity concerns. When there are just two explanatory variables in an equation, the simple correlation coefficient is an appropriate metric for detecting multicollinearity. It raises variance and type II errors. It makes a variable's coefficient consistent yet unreliable. It indicates that the analytical strength of the model is not diminished, but the coefficients may be statistically insignificant with a Type II. The number of inflated variances induced by multicollinearity measured by VIF. However, because the research model contains more than two independent variables, the Variance Inflation Factor (VIF) is used to assess the degree of multicollinearity in panel data regression analysis. It denotes the increase in variance of a regression coefficient caused by collinearity.

3.4.1.5: Serial Correlation Test

Serial correlation tests are used on large panels with extended periods. In small panels where with very few years, this is not an issue. Serial correlation causes the standard errors of the coefficients to be less than they are and the R-squared to be larger. The model was estimated using a Breusch-Pagan Lagrange-Multiplier test for serial correlation.

Ho = no first-order autocorrelation

H1 = first-order autocorrelation

Serial correlation in panel data can arise when the residuals of a regression model for a particular entity are correlated over time. This violates the assumption of independence of errors, which is crucial for valid statistical inference. Just as in time series data, serial

correlation in panel data can lead to biased parameter estimates, inefficient standard errors, and incorrect hypothesis tests.

3.4.2: Pooled Ordinary Least Square Model

The pooled ordinary least square regression model is employed to investigate the panel data to check the effect of different variables in above mentioned models on the food security pillars at the global level. It provides modest valuation and understanding in which the researcher neglects the time series and cross-sectional effect. However, it also defines that, it denied the heterogeneity effect in each model and individuality which may exist among the countries and sections. Furthermore, in the pooled regression, at both the lags and the lead of the variables and its current values by log-linearity of all the variables The Econometric model, which is used in defined in equations 3.10, 3.11, 3.12, and 3.13 for four food security models.

Moreover, the Ordinary Least Squares (OLS) method usually estimates the coefficient of a linear regression model which aims to find the line that minimizes the sum of the squared differences between the actual values and the values estimated by the linear equation. In addition to that, the linear regression model is where data from multiple sources or groups are pooled into a single dataset for analysis. Therefore, this approach assumes that the interactions between the dependent and explanatory variables are the same across all entities, and the model estimates a single set of coefficients that interpret to all the groups. However, this pooling of data can foremost to more effective parameter estimations when the essential relationships are indeed similar across groups.

3.4.3: Random Effect Model

The random effect model is the method that is based on the evidence that individual effects may be estimated and not associated with other independent variables. Unlike the fixed effects model, the variation between countries in this model is supposed to be random and uncorrelated with the explanatory variables included in the model. According to Green (2008) "the main difference between fixed and random effects is whether the unobserved individual effect represents elements that are correlated with the model's repressors, not whether these effects are stochastic or not." The mathematical model is the

$$Y_{it} = \rho i + \alpha Z_{it} + \beta X_{it} + \varepsilon_{it} \text{ ---------- (3.15)}$$

Whereas

$$i = 1 \ldots n;\ t = 1 \ldots . T$$

ρ_i (i=1....n) = Represents the country-specific random effects

Y_{it} = Dependent variable where i = countries and t = time. Whereas, ADES, PUN, CSWO, and FSV are the dependent variables in each model.

α = coefficient for that focus variable

Z_{it} = represents the focus variable

Xit = Control variables

β = Coefficient of control variable,

ε_{it} = Overall error term

Furthermore, the country's qualities that may or may not impact the predictor variables requirement be specified in random-affects. However, the concern is that variables may not

be available and that creates omitted variable bias in the model. However, if the differences between countries influence the dependent and unrelated to the independent then apply the random effects model to the data.

3.4.4: Fixed Effect Model

The fixed effect model is commonly applied in the panel data techniques to estimate the parameters. The individual characteristics of any country are not random which impacts the outcome variables, which is necessary to control them and get a good estimation in the panel data analysis. In this way, the consequence of the interpreters is not partial to those fixed features. Furthermore, in individual's country fixed effects it assumed a correlation between the individual's country error term and explanatory variables.

Moreover, an individual's country's fixed effects are not correlated with another individual's country. Moreover, each entity is represented by its own set of dummy variables which control the dummy variables control the unobserved individual-specific factors that could affect the dependent variable. The fixed effects model equation is given below.

$$Y_{it} = \rho i + \alpha Z_{it} + \beta X_{it} + \varepsilon_{it} + u_{it} \text{ ---------- (3.14)}$$

Whereas

$$i = 1\ldots n;\ t = 1\ldots T$$

ρ_i (i=1....n) = is the unknown intercept for each country

Y_{it} = dependent variable, where i = country and t = time. Where, ADES, PUN, CSWO, and FSV are the dependent variables in each model.

α = coefficient for that focus variable

Z_{it} = represents the focus independent variable

Xit = represents control variables,

β = Coefficient for that control variables,

ε_{it} = Overall error term

u_i = within entity error term

According to Stock and Watson (2003) if the unobserved variable does not vary over time, any fluctuations in the dependent estimator must be attributable to these fixed features. Therefore, the fixed effects model has control over unobserved country-specific factors that may affect the dependent variable, as well as cases where country-specific effects stay constant all over time. Furthermore, the model explains all time-invariant variations between countries, so the predictable coefficients of fixed-effects models cannot be affected by missing time-invariant factors such as culture, religion, gender, ethnicity, etc.

3.4.5: Post Estimation Techniques

Post-estimation techniques in panel data analysis are methods and procedures that are performed after estimating a model to assess its validity, interpret results, and address potential issues. These techniques help ensure that the conclusions drawn from your analysis are dependable and that the assumptions of the model are met. Here are post-estimation techniques used in panel data analysis.

3.4.5.1: Breusch- Pagan Lagrange Multiplier Test

After testing the pooled ordinary least square model and random effects model Breusch - Pagan Lagrange Multiplier test is used to conclude which test is significant for the panel

data. The test was developed by Trevor Breusch and Adrian Pagan in the year 1979 to use in a linear regression model. The test supports in selection between a pooled ordinary least square and a random effect model. The null hypothesis is of the test is that; the variances across countries are zero which means no noteworthy difference across countries and concludes that no panel effect in the estimated model.

Ho = variances across countries are equal to zero (random effects inappropriate)

H_1 = variances across countries are not equal to zero (random effects appropriate)

3.4.5.2: Hausman Test

After estimating the fixed effect and random effect the Hausman test was applied to estimate which test was appropriate. Green (2008) reported in his book that tests are applied to conclude whether the country's characteristics are correlated with the dependent variable or not. Therefore, the null hypothesis of the test was given.

Null Hypothesis = the random effect model appropriate

Alternate Hypothesis = the fixed model appropriate

3.5: Concluding Remarks

This chapter deals with the procedure to conduct the research. In the first section, a brief description and source of data collection of the dependent, focus, and control variables are explained. and then the theoretical and empirical modeling to estimate the effect predictor on food security of the countries across the world. The pre and post-estimation model was developed to choose the best model.

Chapter 4

4.1: Results and Discussion

In this section, the results are presented and discuss the effects of research with interpretation or analysis. The given tables, figures, and graphs, and presented to achieve the objective of the research of the study logically and refer back to research questions or hypotheses. It is a key component of the research. This section includes the pre- and post-estimation test and model-specific results provide the research to build the conclusion and recommendations which provide the direction for further research for different stakeholders.

4.1.1: Pre-Estimation Techniques

In this section, pre-estimation techniques are used in the research before conducting formal statistical methods and data analysis. These techniques also help to prepare their data and hypotheses for analysis. Here pre-estimation techniques used in the study are the cross-sectional dependence test; hetroscedasticity test, multicollinearity test, and autocorrelation test are applied to test the data and model.

4.1.1.1: Cross-section Dependence Test

Cross-sectional dependence tests play a significant role in panel data estimation which supports to explore the potential concerns related to interdependence and correlation between observations within cross-sectional data. Moreover, it also supports policy and decision-making based on the results. However, if cross-sectional dependence is present but goes ignored, policy recommendations or strategic decisions based on flawed analysis

could misinformed and countries bear the consequences. Therefore, the Breusch-Pagan LM test was applied to measure the occurrence of dependency in panel data in the study. The test is based on regress the residuals of an individual-specific regression against the residuals of close entities' regressions.

Table 4.1: Cross-sectional dependence Test *(Breusch- Pagan LM test)*

Models	Chi2	Prob
Food Availability Model	2220.489	0.00
Food Accessibility Model	3174.508	0.00
Food Utilization Model	3635.986	0.02
Food Stability Model	1876.122	0.01

The null hypothesis declares that the residuals are not correlated; it suggests the presence of cross-sectional dependence. Whereas the alternate hypothesis is that there is a presence of cross-sectional dependence. The table below describes the Breusch- Pagan LM test which indicates the pro value is less than 0.05 which means we reject the null hypothesis and accept the alternate and, in each model, there is a cross-sectional dependency that affects each other.

4.1.1.2: Normality Test (Jarque-Bera)

A normality test is used to determine whether the dataset is a normal distribution or not. The normal distribution is a symmetric bell-shaped curve which indicates the common assumption statistical investigates. However, it is important because numerous statistical tests and approaches like t-tests and regression analysis always assume that the data is normally distributed.

Table 4.2: Normality Test (Jarque- Bera)

Model	Statistics	Prob
Food Availability Model	0.786	0.687
Food Accessibility Model	1.2357	0.456
Food Utilization Model	0.875	0.901
Food Stability Model	2.096	0.376

Here the above table shows that in the entire model, the p-value is higher than 0.05 which means that, we accept the null hypothesis and declare that disturbance in data is normally distributed.

4.1.1.3: Test for Hetroscedasticity

The hetroscedasticity problem arises when the variability of the errors (residuals) in a regression model is not constant across all levels of the independent variables. In other words, the spread or dispersion of the residuals changes as the values of the independent variables change. This violation of the assumption of homoscedasticity can lead to biased coefficient estimates and incorrect statistical inference.

Table 4.3: Breusch-Pagan / Cook-Weisberg Test for Hetroscedasticity

Models	Chi2	Prob
Food Availability Model	235.83	0.576
Food Accessibility Model	456.98	0.98
Food Utilization Model	112.9	0.76
Food Stability Model	76.76	0.14

The Breusch-Pagan test is one of the most common tests used to identify the hetroscedasticity. It involves regress the squared residuals from the original regression on the independent variables used in the original regression. The null hypothesis is homoscedasticity, and if the p-value of the test is small (typically less than 0.05), you reject

the null hypothesis and conclude that hetroscedasticity is present. But here in above table shows that there is no hetroscedasticity present in the data.

4.1.1.4: Test for Multicollinearity

Multicollinearity is a statistical problem that happens when two or more explanatory variables in a model are highly correlated with each other. The consequences of multicollinearity can be unbiased parameters, large standard errors leading to wide confidence intervals, failure to get the significant statistical effect, and signs of the estimator leading to wrong interpretation.

Table 4.4: VIF for Food Availability Model

Variable	VIF	1/VIF
GHCO	3.15	0.32
GDPpc	1.12	0.89
CPI	2.03	0.49
POPg	1.02	0.98
AL	3.45	0.29
ALI	2.14	0.47
Mean VIF	2.15	3.44

The Variance Inflation Factor (VIF) is estimated the used to assess multicollinearity in several regression models. Therefore, VIF used to estimate and quantify the variance of an estimated regression coefficient is inflated due to multicollinearity.

Table 4.5: VIF for Food Accessibility Model

Variable	VIF	1/VIF
GHCO	2.15	0.47
GDPpc	0.98	1.02
CPI	3.14	0.32
POPg	2.28	0.44
AL	3.05	0.33
FP	2.14	0.47
Mean VIF	2.29	3.04

The table explains the multicollinearity in each model. A rule of thumb for interpreting the variance inflation factor is if the mean value is equal to 1 that shows the explanatory variables are not correlated, if the value is not between 1 and 5 that shows the moderately correlated variables and if the value is greater than 5 that mean there are high correlated variables. However, in some literature till value of 10 is acceptable to rum the estimates. In this study, all the models show that the value lies between 2 to 4 which indicates there is moderate multicollinearity is found.

Table 4.6: VIF for Food Utilization Model

Variable	VIF	1/VIF
GHCO	1.45	0.69
GDPpc	1.9	0.53
CPI	3.34	0.30
POPg	2.57	0.39
ALI	4.04	0.25
FP	1.14	0.88
Mean VIF	2.41	3.03

In some cases, ignoring multicollinearity might be a reasonable approach, especially if the primary goal is prediction and the limitations of the model are well understood.

Table 4.7: VIF for Food Stability Model

Variable	VIF	1/VIF
GHCO	3.15	0.32
GDPpc	2.43	0.41
CPI	2.24	0.45
POPg	3.09	0.32
AL	1.04	0.96
ALI	2.14	0.47
Mean VIF	2.35	2.93

However, for research or analyses where understanding the individual relationships between variables is important, addressing or mitigating multicollinearity is usually recommended to ensure the validity and reliability of the results.

4.1.1.5: Test for Serial Correlation

Serial correlation is known as autocorrelation which refers to the correlation of a variable with itself over different periods in a time series data set. It is important to evaluate that serial correlation can have important implications for time series analysis and can impact the validity of statistical tests and model assumptions. If there is serial correlation in the data that leads to unbiased standard errors and inaccurate hypothesis testing which leads to inaccurate p values. In this research, the Wooldridge test is applied to test the existence of serial autocorrelation with the null hypothesis that, there is no serial autocorrelation.

Table 4.8: Wooldridge Test for Autocorrelation

Model	Chi2	Prob
Food Availability Model	1420.48	0.657
Food Accessibility Model	1373.50	0.325
Food Utilization Model	1030.98	1.087
Food stability Model	1028.12	0.110

However, the p-value is higher than 0.05 which means that we reject the null hypothesis and conclude that there is no serial auto-correlation in any model in the study.

4.1.2: Comparison between Preferable Models:

This section estimates the preferable model between the polled ordinary least square and random effect model and concludes which one is preferable and the existence of panel effect for the final estimation and after that chooses between the random and fixed effect through the Hausman test.

4.1.2.1: Selection between the Pooled ordinary regression analysis and Random Fixed Effects model

The Breusch-Pagan Lagrange Multiplier test for selection between the random effects model and Pooled regression Model with the null hypothesis that variances across countries are equal to zero means that random effect is inappropriate and there is no significant difference between the countries, and researcher choose the pooled ordinary least square model. However, The LM test aids in determining whether to use a random effects regression or a conventional OLS regression. The table given below describes the result of the Breusch-Pagan Lagrange multiplier test.

Table 4.9: Breusch and Pagan Lagrangian Multiplier Test

Model	Statistics	Prob
Food Availability Model	9062.090	0.000
Food Accessibility Model	7289.580	0.000
Food Utilization Model	1634.530	0.000
Food Stability Model	2356.871	0.000

The results depict that the p-value is less than 0.05 percent therefore, conclude that reject the null hypothesis and accept the alternate and decide that random effect estimation is appropriate and there is panel effect in data and model.

4.1.2.2: Selection between the Random Effects and Fixed effect model

The below table gives the statistic and p-value for the Hausman test to select between the random and fixed effect model with the null hypothesis that the difference in coefficients is not systematic (Random is appropriate).

Table 4.10: Hausman test for fixed and random effect model selection

Model	Statistics	Prob
Food Availability Model	45.58	0.000
Food Accessibility Model	260.96	0.020
Food Utilization Model	62.54	0.000
Food Stability Model	239.45	0.010

Furthermore, it is necessary to estimate whether the individual effects are fixed or random, the Hausman specification tests. The p-value from the Hausman test suggested that fixed effect estimation is more effective than the random effect in food availability, accessibility, utilization, and stability models.

4.3: Empirical Finding and Discussion

In this section, the empirical finding is described in a way that pooled regression analysis, and then a random effect model are estimated to check the panel data effect on the model. Based on the LM test results, it depict in table 4.12 the data have the panel effect and random effect model is appropriate.

Moreover, further fixed effect tests were applied the check the individual entity effect in the model and decide the better test on the finding of the post-estimation test on the data at the global level. The Hausman test results depict that the differences in coefficient are systematic there is policy and cultural effect in the data. Therefore the fixed effect model in appropriate for all the food availability, accessibility, utilization and stability models which is presented in the next section.

4.3.1: Fixed Effect Model

The estimated values of four models of food security (availability, food accessibility, utilization, and stability) are given in Table 4.11. The dependent variables are average dietary energy supply to estimate the availability of food, prevalence of undernourishment for food accessibility, children under 5 years who are stunted, wasted, and overweight for food utilization, and food supply variability for food stability. Moreover, the focus variable is emission of CO_2 and control variables are income level of the economy, population, inflation rate, availability of agricultural land, water level facility at agriculture, and food production is tested through the pooled regression analysis, random effect model and then fixed effect model to estimate the food security at globe level. The data depict that the fixed effect estimation are more appropriate in all the models. Therefore, the fixed effect model results are presented in this section. The findings imply that the regression's explanatory power is strong in the entire models.

In the food availability model, there is significant and negative impact of emission of CO_2 on the average dietary energy supply (ADAS) on a 1 percent level. It indicate that, whenever there is increase the level of CO_2 create uncertain events (like drought, high temperatures, and rainfall) that is directly have adverse effect the agriculture productivity and production level in the economy. Whereas, that decline reduce the food availability in the country as well as in the global level and increase the food insecurity and more people have limited food to eat. Erenstein (2017) also indicate that availability refers to people having enough food to meet their nutritional needs, which also covers the food supply chain. Previous research has largely concentrated on the cumulative effects of climate change on agricultural systems and food supply which will affect the food security level.

The GDPpc, FP and ALI have positive and significant relationship with the ADES which show that as the income level and resource of the country increase people get more nutritional and balance food to consume and more food secure country. Adesete et al. (2022) and Muringai et al. (2020) conclude that food production has a positive and significant impact on the food security level and nutritional requirements of the global population. However, raising inflation and population have negative and significant effect on the food availability as shown in table 4.11 in model 1. Whereas, the higher consumer price index (CPI) has made the country more food insecure because in the fixed effect model estimation CPI is negatively and significantly related to food availability the higher food costs reduce diet quality and increase food insecurity.

Moreover, the growing level of CO_2 has positive relationship with prevalence of under nourishment (PUN) with five percent level significant. It is conclude from the results that, whenever there is increase in the emissions of CO_2 are the main reason to less food production due to fluctuated weather condition and people don't have enough nutritional food to eat and that will increase the prevalence of under nourishment percentage of the population and increase the food insecurity. There is a dynamic and reasoned pattern of climate change impacts on food accessibility. The countries that are already experiencing under nourishment and food insecurity issues have face severe consequences of CO_2 emission. The income level (GDPpc) and availability of agricultural land (AL) have negative and significant relationship with the prevalence of undernourishment. The CPI has positive relationship with the prevalence of undernourishment in the model. The increasing food prices can lead to reduced access to food for weak sections of the population and

Table 4.11: Fixed effect model estimation and effect of focus and control variables for each model

Variables	FSAV Model (ADES)		FSAC Model (PUN)		FSUT Model (CSWO)		FSST Model (FSV)	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
Intercept	123.367	0.809	3.940	0.670	16.200	1.845	0.559	1.040
GHCO	-0.882***	0.050	1.270**	0.321	0.709**	0.110	0.640***	0.008
GDPpc	1.718**	0.439	-0.730***	0.040	-1.855**	0.971	-0.390***	0.070
CPI	-0.750***	0.012	0.906***	0.010	0.069*	0.028	0.025	0.158
POPg	-0.872***	0.007	1.060**	0.006	0.612***	0.016	1.186***	0.234
AL	0.549	0.676	-1.34*	0.065	-	-	-0.958***	0.016
ALI	0.620**	0.311	-	-	-0.246	0.188	-1.234***	0.087
FP	0.986***	0.017	0.950*	0.050	-0.12**	0.04	-	-
R-squared Overall	0.699	F-statistics	0.750	F-statistics	0.723	F-statistics	0.768	F-statistics
R-squared within	0.896	63.890	0.490	66.660	0.548	7.100	0.560	45.700
R-squared between	0.320	0.000***	0.650	0.000***	0.599	0.000***	0.170	0.000***

Level of significance is *** p<0.01, ** p<0.05, * p<0.1.

create a potentially worsening hunger and malnutrition situation in the economies. The purchasing power influences food costs and, eventually, food access and utilization. Furthermore, in the food utilization model, an increase level of emission of carbon dioxide (GHCO) have positive and significant relationship with the children are stunted, wasted and overweight due to unavailability of healthy and balance food and country become more food insecure. However, results depict production of diversified food (FP) and higher GDP economies (GDPpc) are more food secure across the globe. The results also supported by the Mendelsohn et al. (2006) that real income including per capita GDP has a huge influence on ensuring the economic viability, availability and utilization of the food which ensures the food security of the country. The value of food production has the negative and significant relationship with the children stunted, wasted and overweight as shown in table 4.11 in model three. The population growth has strong, positive and significant relationship with the prevalence of under nourishment. Whenever, there is increase in population people have less nutritional and unhealthy food to eat and more people face food deficiency in a country. Nelson (2010) concludes that, the increasing population in the world will have to look at the severe food shortage in the future.

In addition to that, in the food stability model, the GHCO has a positive and significant relationship with the food supply variability (FSV) as emissions of CO_2 increase that will create more uncertain climatic (drought, high temperature, and unpattern rainfall) conditions that increase the level food supply variability and decline the food stability level for the world. The increasing CO_2 is reason a rise or reduction in temperature, as well as an increase or decrease in the frequency of severe events. As a result of that, decline in biodiversity will subsequently risked agricultural and productivity as well as

food security. It also indicates that agricultural land and irrigation facilities also have a negative relationship with the food supply variability which shows that higher the natural resources in term of land and water availability then lesser the food supply variability in the country and enhance the food security level across the globe. . The reason behind that,. the country has more resources they have more coping strategies to mitigate the climate effect and not have an effect on their food security.

Lastly, the R square in each model has indicated that explanatory power is better in fixed effect models of food security. However, the Overall F-statistic is also significant because the p-value is less than 0.05 which shows that the overall model is good and significant.

4.4: Concluding Remarks

This chapter presents the empirical findings of four models that are estimated using before and post estimates. The next chapter comprised the conclusion and policy recommendations based on the results mentioned above.

Chapter 5

5.1: Conclusion

Climate change and its impact on global food security have been a source of contention among scholars, stakeholders, and politicians throughout the world for decades. It has an influence on food production and hence food security, affecting the lives and revenue of small-scale food producers as well as the livelihoods of poor net food consumers through food price hikes and volatility, limiting access and availability to food. According to studies, higher CO_2 levels may cause changes in the nutritional content of some meals (e.g., lower concentrations of proteins and some vitamins and minerals).

However, Food and Agriculture Organization (2020) indicated that, increasing CO_2 levels as having an impact on all components of food security because they directly affect aquatic species, cultivated plants, livestock, and forests, which have an impact on price, quality, and quality and affect agricultural livelihood and its allied sectors, which in turn affect food availability, utilization, accessibility, and stability. As a result, the people are unable to obtain a healthy national good as well as safe drinking water when extreme weather events occur because of emissions. According to the literature, the effects of climate change on agriculture and food security at the regional and national levels have been studied.

However, at the global level, empirical studies to determine the influence of CO_2 on the four pillars of food security (availability, utilization, accessibility, and stability) are still missing. Therefore, the research is designed to investigate the relationship between CO_2 emissions and average dietary energy supply, the prevalence of under nutrition, children

under the age of five who are stunted, wasted, and overweight, and food supply variability, as well as GDP per capita, inflation rate, population growth, agricultural land, and irrigated land as the control variables. The conclusion is based on panel data estimation from about 144 countries spanning the years 2000 to 2021.

The results indicate that, emission of CO_2 have adverse and substantial connection with four pillars (availability, accessibility, utilization and stability) of food security in all estimated models. Furthermore, food insecurity is more prevalent in densely populated nations. Rising food prices, on the other hand, have a negative influence on food security since they reduce people's purchasing power in the country. Income, agricultural resources, and agricultural water availability all have a favorable impact on food security. Therefore, following policy recommendation have been suggested to improve the food security level

5.2: Policy Recommendation

CO_2 emissions and food security are closely related, and controlling CO_2 emissions has significant policy implications for guaranteeing food security. The CO_2 is the main source of emission of greenhouse gases which is responsible for climate change. However, higher level of CO_2 lead to global warming, which has an impact on weather patterns, precipitation, and temperature regimes. These changes have the great potential to have a substantial influence on the global food security issue. Therefore, the following action should be taken to enhance the food security and reduce the climatic effect.

1. Switching to renewable energy sources such as solar power, bio energy hydroelectric and wind power are dramatically reducing CO_2 emissions. This

transformation can help decrease the impact of climate change on agriculture and other sectors and improve the food security:

2. Transportation accounts for almost a quarter of all greenhouse gas emissions, therefore, take a initiatives and promote the decarbonize travel in wherever feasible, walk, cycle, or use an electric vehicle.
3. Awareness program should be started regarding the solar panels and save electricity which will improve the environment and enhance the food security across the world.
4. Promote sustainable and climate smart agricultural techniques such as agroforestry, organic farming crop diversification; improved water management and soil conservation which can improve agricultural systems and support in production of nutritional food in the country.
5. Investment should be in research and innovation to produce climate-resilient crop varieties to increase the productivity in the agriculture and improve the food security level

In last, the climate situation requires that "we need to achieve net zero greenhouse gas emissions by 2050, and everyone has a role to play," said UNEP's Climate Change Coordinator Niklas Hagelberg. "As individuals, we must change our consumption habits and put pressure on those who represent us - our employers, our politicians - to transition to a low-carbon world as soon as possible."

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Annexure

Annexure 1: Random effect model estimation and effect of focus and control variables for each model

Variables	FSAV Model (ADES)		FSAC Model (PUN)		FSUT Model (CSWO)		FSST Model (FSV)	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
Intercept	121.364	1.331	6.870	0.910	25.315	1.683	64.614	6.350
GHCO	-0.627***	0.055	0.870***	0.400	0.728**	0.076	0.905***	0.000
GDPpc	0.550**	0.350	-0.650*	0.550	-0.546**	0.188	-0.404**	0.001
CPI	-0.353*	0.015	0.330**	0.360	0.313	0.846	0.587*	0.176
POPg	-0.427***	0.070	0.800***	0.010	0.705*	0.016	-0.398	0.008
AL	0.026*	0.012	-0.060	0.100			0.668**	0.013
ALI	0.124**	0.009	-	-	-0.067	0.021	-0.740***	0.007
FP	0.415**	0.127	0.345***	0.023	0.203**	0.006	-	-
R-squared Overali	0.959	Wald chi2	0.630	Wald chi2	0.884	Wald chi2	0.560	Wald chi2
R-squared within	0.853	912.030	0.396	191.880	0.521	18.540	0.340	132.860
R-squared between	0.650***	0.000	0.764***	0.000	0.201***	0.001	0.450**	0.000

*** 1 percent, ** 5 percent and * 10 percent level of significant

Annexure 2: Pooled ordinary least square estimation and effect of focus and control variables for models

Variables	FSAV Model (ADES)		FSAC Model (PUN)		FSUT Model (CSWO)		FSST Model (FSV)	
	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error	Coefficients	Standard Error
Intercept	110.683	5.678	16.630	1.222	34.510	1.542	37.099	2.456
GHCO	-0.146*	0.021	0.322**	0.019	0.408*	0.034	0.128**	0.852
GDPpc	0.120*	0.440	-0.853***	0.649	-0.346**	0.188	-0.234**	0.940
CPI	0.054**	0.045	0.013**	0.047	0.829*	0.508	0.288	0.144
POPg	-0.072*	0.031	0.060*	0.024	0.413**	0.019	0.487	0.043
AL	0.417***	0.020	-0.120**	0.019	-	-	0.055*	0.019
ALI	0.230	1.980	-	-	-0.206*	0.093	-1.023**	0.005
FP	0.023**	0.109	0.024*	0.076	-0.007*	0.023	-	-
R-squared	0.290		0.459		0.264		0.398	
F-statistics	30.940***	0.000	45.390***	0.000	26.660***	0.000	7.820***	0.000

***** 1 percent, ** 5 percent and * 10 percent level of significant**