AN ANALYSIS OF FOOD SECURITY IN MALAYSIA: DOES FERTILITY RATE MATTERS?

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DECLARATION

We hereby declare that:

(1) This undergraduate FYP is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

(2) No portion of this FYP has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

(3) Equal contribution has been made by each group member in completing the FYP.

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LIST OF ABBREVIATIONS

FS	Food Security
CO_2	Carbon Dioxide Emissions
GDP	Gross Domestic Product
FR	Fertility Rate
IDR	Import Dependency Ratio
GHGs	Greenhouse Gases
MARDI	Malaysian Agricultural Research and Development Institute
GFSI	Global Food Security Index
ESP	Economic Sustainability Plan
ARDL	Autoregressive Distributed Lag Model
ADF	Augmented Dickey Fuller
ARCH	Autoregressive conditional heteroscedasticity
VIF	Variance Inflation Test
MAFI	Ministry of Agriculture and Food Industries
DSMN	National Food Security Policy Action Plan
ECM	Error Correction Model
VAR	Vector Autoregression Model
OLS	Ordinary Least Squares
CUSUM	Cumulative sum of recursive residuals test
CDA	Children Development Account
FAO	Food and Agriculture Organization

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PREFACE

After air and water, food is the most important thing for humans to survive. After the world food crisis between 2007 and 2008, every country took account of food security issues, as goal 2 of sustainable development goals is titled “Zero Hunger”. Food security problem is an increasing issue in every country as millions of individuals in the most disadvantaged communities are in danger of losing their lives as a result of the global food crisis. In addition, food insecurity will lead to malnutrition, hunger and poverty as well as mental health issues. Malaysia has remained as a net importer of food for the past forty years. Therefore, Malaysia was not a country with a secure supply of food as the rice production in Malaysia could support only 70% of its demand from local residents.

Since the researchers of this study acknowledge the issue of decreasing food security problem in Malaysia, they are motivated to explore and analyze the determinant variables that are contributing food security problem in Malaysia. In order to determine how each independent variable influences the dependent variable (food security in Malaysia), three independent variables are chosen: Carbon Dioxide Emission, Gross Domestic Product, and Fertility Rate.

Lastly, the researchers hope that this study will help future researchers better understand how these three independent variables influence food security in Malaysia. At the same time, this study also enables governments to make a more effective and advantageous planning and resource distribution within a certain region.

ABSTRACT

Human cultures have battled throughout history to guarantee that everyone has access to adequate food ensuring an active and healthy life. Having access to enough food persists as a pressing issue at the intersection of nature, society, and technology although there is a significant worldwide endeavor in this era. Food security can be defined as a condition that all individuals are capable of accessing enough, nutritious and safe food physically, socially and economically. This paper contributes to the literature related to the independent variable that led to the food security problem in Malaysia from 1990 to 2019. The independent variable included are Carbon Dioxide Emission, Gross Domestic Product, and Fertility Rate as well as food security in Malaysia be the dependent variable in the research. Fertility rate will be our main focus in this study. There are three theories supporting this study: Neo Malthusian Theory, Anthropogenic Global Warming Theory and Keynesian Theory. Several tests such as ADF Test, ARDL Bounds Test, Error Correction Model, ARCH Test, LM Test, CUSUM Test, VIF Test and Normality Test have been used to test the model. This study has proven that all of the independent variables (Carbon Dioxide Emission, Gross Domestic Product, and Fertility Rate) have a significant relationship with the dependent variable (food security in Malaysia) in the long run.

CHAPTER 1: RESEARCH OVERVIEW

1.0 Introduction

After air and water, food is the most important thing for humans to survive. Starvation will definitely lead to death, however, there is no exact research study on how many days of starvation will cause death because it is considered as unethical investigation (Silver, 2019). After the world food crisis between 2007 and 2008, every country took account of food security issues as goal 2 of sustainable development goals，titled “Zero Hunger”. There is evidence that proves the reasons of Malaysia rely heavily on imports. For example, chili is a common dish which is found in most Malaysian cuisines like Nasi Lemak, Rendang chicken, as well as Asam Laksa. Malaysia’s temperature is also suitable to plant chili, but Malaysia has imported almost two-thirds of its chili from Thailand (*Food Security Malaysia*, 2022). According to the Import Dependency Ratio (IDR), Malaysia's food import bill in the year 2020 was RM55.5 billion (Hunter, 2020). This research starts with an overview on the concepts of food security, then moves on to discuss how carbon dioxide emission (CO_2)， gross domestic product (GDP) and fertility rate relate to food security in Malaysia. Next, this study will assess the intensity of the fertility rate that is continually influencing food security with the use of the data currently accessible.

1.1 Overview

According to estimation, consumers are likely to spend up to 70% of their income on food, necessitating a methodical strategy to guarantee that the population's nutritional demands are satisfied. Human cultures have battled throughout history to guarantee that everyone has access to adequate food ensuring an active and healthy life. Having access to enough food persists as a pressing issue at the intersection of nature, society, and technology although there is a significant worldwide endeavor in this era (McDonald, 2010). The idea of food security was developed in the middle of the 1970s. Food security encompasses all the aforementioned factors, as well as a wide range of socioeconomic concerns that have a significant impact on farmers and the underprivileged in particular. It is not only a matter of production or supply. According to FAO (2002), food security can be defined as a condition that all individuals are capable of accessing enough, nutritious and safe food physically, socially and economically. That means, all people can always fulfill and satisfy their nutritional needs and choices.

There are several levels at which food security can be assessed, including the national, family, and individual levels. When the food supply and effective demand can consistently and steadily meet the population’s food needs, a nation is considered to be in a state of food security. The nation’s food needs can be satisfied by domestic food security, availability of food outside of domestic production, or a combination of both. Food needs in a small economy can be fully satisfied by domestic food security. However, in an open economy, the population’s food demands are dependent on the global market to satisfy their calorie requirements. This shows that the interplay of domestic and international forces affects the nation's level of food security. Despite having a middle income, Malaysia has remained as a net importer of food for the past forty years. In essence, the importation of the nation’s staple foods, particularly rice, has increased. Thus, studying the factors that affect food security is crucial in light of these changes because it will enable policymakers to stay informed about the key elements affecting food security in Malaysia (Applanaidu, Abu Bakar & Baharudin, 2014).

1.2 Food Security In Malaysia

The developing countries, especially those located in extremely dry areas are said to face less problems of poverty, starvation, and malnutrition when they are efficient in growing the country's economy. In other words, countries with stable economic growth are more likely to attain food security when compared to those countries with weaker economic growth (Manap & Ismail, 2019).

In the past few years, the rise of greenhouse gases (GHGs) in the atmosphere has caused climate change issues in many countries. Since the Industrial Revolution, anthropogenic carbon dioxide (CO_2) emissions have increased by one third, and they are expected to double within the next 100 years. The rate of change of CO_2 emissions in Malaysia is highly rapid; the variance in growth from 2003 to 2005 is approximately 70% compared from 1994 to 1996 (Al-Amin, Leal, De La Trinxeria, Jaafar & Ghani, 2011). Any nation's agriculture industry is crucial because it gives its citizens access to food and employment possibilities. In 2015, Malaysia had imported total food worth RM45 billion, making food security a pressing issue that requires action. Agriculture activities may drop because of anthropogenic factors such as forest fires for cultivation and industrial carbon emissions. This indicates that Malaysia may need to import more food in the future, particularly rice from neighbouring countries like Vietnam and Thailand, due to the fall in agricultural yield (Lee, Hoe, Viswanathan and Baharuddin, 2019).

According to Siwar, Alam, Murad, and Al-Amin (2009), if the rising temperature exceeds the tolerance limit which is more than 26℃, the overall agricultural yields in Malaysia will be reduced because of photosynthesis, increased respiratory, and shortened vegetationand grain-filling periods. Grain mass decreases by 4.4% under the current climate change scenario for future temperatures above 25℃, and food grain yield may decrease by up to 9.6-10% for every 1℃ increases in temperature. It is obvious that the typical reaction to an increase in the intensity yields of approximately 10 to 15ppm (parts per million) occurs. Thus, the decline in agricultural crops may lead to food security issues in Malaysia (Siwar et al., 2009).

Before the industrial revolution period, the main focus of the economy of Malaysia was on the agriculture sector. From 1975 onwards, the Gross Domestic Product (GDP) contributed by the agriculture field was getting lower and lower. As evidence, Malaysia's agriculture sector contributed only 13.6% of GDP (Alam, Siwar, Jaafar & Talib, 2017). This situation implies that Malaysia is focusing less on the agriculture sector to stimulate the country's economy. In contrast, Malaysia is focusing more on the areas of services and manufacturing. Since the agriculture sector loses its importance to the country's GDP, Malaysia makes use and converts more agricultural lands for establishing houses and industries. As a consequence, Malaysia utilized more lands to grow industrial crops when compared to food crops. As there is less focus on planting food crops, the amount of food crops available in Malaysia has decreased. In order to ensure Malaysia has sufficient food, the Malaysian government imported rice from neighbouring countries such as India, Thailand, Vietnam, Pakistan and Myanmar. However, the good times do not last long. The rice-exporter countries such as Vietnam, Thailand and Cambodia have started to set a limit on the export amount of rice. This export control negatively affects Malaysia and other countries to face limited supply of rice and then lead to food security problems.

The last 30 years have seen the most pronounced decline in fertility rates in Malaysia. The data showing a decline in total fertility rate in Malaysia from 4.9 infants in 1970 to 1.8 births in 2018 (per woman inside the reproductive age) provides proof of this (Jegasothy, Sengupta, Dutta & Jeganathan, 2021). As mentioned earlier, population growth is a serious challenge to food security in emerging nations like Malaysia. Assuming that individuals have both physical and financial access to enough food is a difficult problem. Cross-sector cooperation, creative thinking, and maximizing all possible interventions are necessary to combat it. According to Smith and Smith(2015), United States had implemented family planning which had a significant impact on food security to prevent the population from continuing to increase. Volunteer family planning methods are said could lower a nation's fertility rate by meeting unmet demand, which will then help to lower the rate of population expansion and lessen future strain on the nation's resources. This means that, with the decrease in the fertility rate, population growth will also decrease. As a result, this will not decrease food accessibility and will not lead the country to enter into the food insecurity problem. However, some researchers found that there is a positive relationship between fertility rate and food security as a high fertility rate represents high working members and it will increase food security.

1.3 Problem Statement

According to Nair (2022), Barjoyai said that Malaysia was not a country with a secure supply of food. This is because Malaysia could not satisfy the demand of local residents. For instance, the rice production in Malaysia could support only 70% of its demand from local residents. In other words, this means that Malaysia is still suffering from a lack of 30%. According to the author again, Malaysia was severely impacted when its main rice supplier, Vietnam, declared that rice exports would be suspended. Aside from experiencing a shortage of rice, Malaysia is also confronting the problem of inefficient supply of chicken, eggs, vegetables and cooking oil. When the instabilities of Malaysia’s food supply become more severe such as in 2019, Malaysia produced only 46% of its vegetables, 70% of its rice, 61% of its fruits, 25% of its beef, 11% of its mutton, and 5% of its dairy requirements, it has made the citizens realize the concept of food security and the importance of food security towards a country.

When a person lacks regular access to adequate safe and nourishing food for healthy growth and development as well as an active and fulfilling life, they are considered to be food insecure. This could be brought on by a lack of food or the means to get food (Food and Agriculture Organization, 2022). Millions of individuals in the most disadvantaged communities are in danger of losing their lives as a result of the global food crisis, particularly in the nations where hunger-related deaths, malnutrition, and poverty are on the rise.

The first effect that will result from problems with food security is malnutrition. According to the World Health Organization (2018), children who lack basic nutritional components are more prone to have health issues. For instance, children have higher chances and probability to become underweight. They are not considered "normal" for their BMI, which suggests that their body may not be as healthy as that of a typical child. As a result, kids are more likely to need hospitalization since they are more prone to developing certain chronic disorders including anemia and asthma. Children who are malnourished not only experience health problems, but also have difficulty in school. They might not be able to fully engage in co-curricular activities at school because of their bad health (Rinkesh, 2022). From a different angle, pregnant women who do not have access to enough food run a higher risk of having babies who are underweight and stunting when they give birth. These ladies will have a higher chance of developing anemia. Not only causing the babies to become light in weight, it also will lead to childhood stunting.

The second impact of the food security issues is it will lead to hunger and poverty. Insufficient dietary energy intake results in the unpleasant or painful bodily sense of hunger. Every year, hunger costs billions of dollars, with the US spending around $178.9 billion of that total. Because of this, more money is spent by the government on national food security rather than infrastructure, healthcare, and educational initiatives (Rinkesh, 2022).

In addition, food insecurity and poverty are closely related. This point of view emphasized how directly linked poverty and food insecurity are. Nothing can be accomplished while an individual is hungry. The individual will thus continue to be hungry and destitute (Ahmad, Shahnawaz, Husain, Qamar & Zaid, 2021).

Last but not least, lack of access to sufficient food will cause people that lack access to food to experience mental health issues. There is a strong connection between mental health issues and poverty, which are essentially emotional and psychologicalailments (Griffin, Fuhrer, Stansfeld& Marmot, 2002). Three main conclusions are presented by the study. First, food inadequacy increases the risk of depression and better predicts this risk than measures of low income, the principal source of income, and education after adjusting for traditional socioeconomic and sociodemographic characteristics. Second, despite the fact that social resource gaps greatly lessen the impact, the harmful effects of food scarcity cannot be attributed to them. In general, we have seen that the issue of depression brought on by food insufficiency is more prevalentin women than in men, but our study reveals those single fathers experience sadness at a rate higher than any other group, including single moms from food insecure families (Wu & Schimmele, 2005).

Climate change is an essential element in enhancing a country’s food security. Due to rapid industrialization that releases unchecked carbon dioxide and other greenhouse gasses, Malaysian agriculture is experiencing a reduction in productivity as the climate around the world warms. Ideally, the Kyoto Protocol ought to have lowered carbon dioxide emissions, but the rate of decline is much slower than what the world requires. Environmental alteration brought about by agricultural methods like large-scale rice, rubber and oil palm production led to changing land use patterns throughout Malaysia’s accelerated economic expansion into a middle-income country during the previous few decades. Increased temperatures would lead to more unpredictable and severe storms. The country has yearly average surface temperatures between 26℃ and 28℃. According to 40 years of statistics (1969-2009), it was found that Malaysia’s average surface temperature rose at a pace of 0.6℃ to 1.2℃ per 50 years (Ogundipe, 2020).

Flood, soil degradation and decreased crop yields, particularly for economically significant crops like oil palm, rubber, and rice, have been impacted by climatic variability in Malaysia. A recent survey stated that the main crops of Malaysia, which are rice, could see a 13% to 80% production reduction due to climatic variables. The cultivation of industrial crops, such as oil palm, rubber, and cocoa will decrease between 10% and 30% because of the adverse effects of climate volatility (Siwar, Ahmed & Begum, 2013). According to Chuen Khee, Yet Mee and Chee Keong (2011), the Malaysian Agricultural Research and Development Institute (MARDI)predicted that a 1°C increment in daily average temperature would result in a 10% reduction in rice yield. If prevention strategies do not chane, it is predicted that the minimal level fall in rice yield will be at least 13.5% in the following century.

Anomalies in the world's climate, the COVID-19 epidemic, the Russia-Ukraine War and the ringgit's decline are all to blame that lead to the food price increase which will then exacerbate the condition of food insecurity in Malaysia (Chiong, 2022). It is said that when food security does not occur in Malaysia, some of the citizens will feel hunger and lead to the condition of malnutrition. This will then cause an individual’s physical and cognitive development to become poor. As a consequence, this will directly affect Malaysia's gross domestic product (GDP) because the poor development of the citizen’s physical and cognitive ability will cause an individual’s productivity to become low.

Nowadays, the developing nations including Malaysia are facing food security problems. Upon research, we found that the major culprit of slowing economic growth of Malaysia is due to the dilemma, food insecurity. Based on the Global Food Security Index (GFSI), Malaysia's score is 68.1 and was ranked 40th out of 113 countries in 2018. Malaysia was performing significantly worse than wealthy nations like Singapore, the United Kingdom, Denmark, and Japan. The results show that Singapore has the highest global food security index, with a score of 85.9. Subsequently, it is followed by the United States, Denmark and Japan whose GFSI scores are 85.0, 80.9 and 79.9 respectively (Building resilience in the face of rising food-security risks, 2018).

According to Haini, Musa, Loon and Basir (2022), it is stated that if the fertility rate keeps growing, it may affect food security to decrease; while if the fertility rate keeps declining, it may increase food security. However, Malaysia is experiencing the most pronounced drop in fertility rates over the last 30 years. In fact, the reported average total fertility rate has been below the benchmark of 2.1 since 2013. Besides, research shows a decline in total fertility rates in Malaysia from 4.9 newborns in 1970 to 1.8 babies in 2018. This means that the nation's average number of births per woman is insufficient to produce the necessary number of offspring to replace her and her spouse in the population (Jegasothy et al., 2021). An article mentioned that a low fertility rate will impede economic growth and strain the government budget as today's babies are tomorrow's workers and taxpayers (Murray, 2021). So, a low fertility rate definitely will affect food security in Malaysia. Hence, the effect of the diminishing fertility rate is very vital in testing the stability of food security in Malaysia. Since there is a mixed relationship, in this paper we would like to investigate the actual relationship between the fertility rate and food security in Malaysia.

1.4 Research Questions

1. How does Carbon Dioxide Emission (CO_2) affect food security in Malaysia?
2. How does Gross Domestic Product (GDP) affect food security in

Malaysia?

3. How does fertility rate affect food security in Malaysia?

1.5 Research Objective

The general objective of our research is to identify the factors affecting food security in Malaysia from 1990 to 2019.

The specific objectives are as follows:

-To investigate the relationship between Carbon Dioxide Emission (CO_2) and food security in Malaysia.

-To investigate the relationship between Gross Domestic Product (GDP) and food security in Malaysia.

-To investigate the relationship between fertility rate and food security in Malaysia.

1.6 Significance of Study

Food security issues have been a global trend among the world in recent years. This issue has also gradually spread among Malaysia. Although most Malaysians have the consciousness of this issue, they are not really informed about the actual severity of this issue. The reason we choose Malaysia as our research country is because recently, Malaysia's dependence on imports to sustain its food supply, particularly for rice, has put it in jeopardy in the future. Moreover, the underdevelopment of Malaysia's agricultural potential continues to be a problem with relation to its strategy for ensuring food security. When compared to other food production, industrial yield crops have continued to get disproportionate attention. This condition is very suitable for our research topic.

The primary purpose of our study is to help future researchers better understand how the independent variable, carbon dioxide emissions (CO_2) influence food security in Malaysia. In addition, we have added two variables which are Gross Domestic Product (GDP) and fertility rate into the study due to the scarce research on these variables in Malaysia context. Based on the past studies, we have found the mix result on the effect of fertility rate towards food security in Malaysia and there are limited academic resources on this variable. Moreover, the rising of low fertility rate lead to food security issue in Malaysia. Thus, we have made the fertility rate as our main contribution of this study as we are interested in investigating the actual effect of fertility rate towards food security in Malaysia due to the limited academic resources on this variable.

Our research paper will enable governments to make a more effective and advantageous planning and resource distribution within a certain region. For instance, the government can allocate sufficient resources to stabilize food prices generally in order to promote economic growth as well as stabilize the domestic price that will help to boost the effectiveness of the independent marketing sector when food insecurity is happening (Manap & Ismail, 2019).

University students are required to do assignments, after reading the journal article they will gain an overall idea of the topic. Besides, reading journal articles will boost their reading skills as well as writing skills and this will boost their grades. We believe that it can provide preferable and useful information for university students to serve as a reference in the future. It gives students the tools they need to self-evaluate, improve their own work, and build lifetime abilities in evaluating and giving feedback to others.

Peer review successfully exposes an author's work to the examination of other professionals in the area, and it has since become the cornerstone of the scientific publication system. As a result, it motivates the researchers and specialists to work hard to generate top-notch research that will improve the discipline. Its purpose is to govern the distribution of research data so that unjustified claims, undesirable interpretations, or personal opinions are not publicized without first receiving expert evaluation and to encourage them to uphold the discipline's high standards. The peer review procedure has received a lot of criticism while being extensively used by most journals due to the lengthy time it takes to publish new discoveries and the perception of prejudice among editors and reviewers. Peer review has developed into a crucial part of the academic process of writing in the scientific community. It makes sure that articles that are published in scholarly publications provide meaningful research answers and draw reliable conclusions from well done experiments.

Meanwhile, food security is an important element that can illustrate a country's economic stability and power. Through this study, we hope to provide a clear picture to those policymakers and analysts in comprehending the food security issue in Malaysia. From that, it has delivered beneficial advice in order to let those policymakers and government make an effective decision in improving our country's food security. A well-organized decision can be an efficacious strategy to reinforce a country's economic condition. We have used 30 years of data which is considered as a long-term time series data to generate an accurate foundation regarding the linkage between food security and those variables so it can serve as a reference to the future generation.

1.7 Scope of Study

The purpose of this paper is to study the factors that affecting the food security in Malaysia bases on the yearly data from 1990 to 2019 which will be taken from the World Bank Data. Food security has always been a global concern as the scarce food resources have been gradually increasing in recent years. Therefore, Malaysia as a net food importer, it should place more emphasis on food self-dependency and strategic managements in order to deal with the difficulties with food security. This study will be focusing more on the macroeconomic elements such as Carbon Dioxide Emissions (CO_2), Gross Domestic Product (GDP) and fertility rates. Our research gap variable includes fertility rate. Due to the limited past studies on this variable, it is believed that it will give a wonderful contribution in this study. Lastly, few policies recommendations will also be given in the end of this study to improve on the food security in Malaysia.

1.8 Chapter Layout

In this research, there will consist of a total of five chapters. The first chapter has focused on the relationship between the food security and Carbon Dioxide Emissions (CO_2), Gross Domestic Product (GDP) as well as the fertility rate. Besides that, in this chapter, it has also included some key issues that are happening in Malaysia. While in the second chapter, the literature review conducted by the earlier scholars is described. At the same time, the third chapter describes the data and technique employed continued with the fourth chapter discussing the empirical findings before the fifth chapter draws a conclusion.

CHAPTER 2: LITERATURE REVIEW

2.0 Theoretical Review

2.0.1 Neo Malthusian Theory

The first theory to be applied in this research is the Neo Malthusian Theory. English economist Thomas Robert Malthus was the first to discuss how food security and supply are related. According to Malthus, food security rose in an exponential manner while population grew in a geometric manner. As a result, an increased population due to rising fertility rate moves in a quicker manner compared to food security, eventually outpacing it. He stated that catastrophic occurrences like illnesses,famine, suffering, and warfare would cause a population decline if humanity could restrict reproduction freely via self-control (Dunn, 1998).

In order to inform the populace of the impending tragedies brought on by England's growing population, Thomas R. Malthus, who rose to fame with his dissertation "An Essay on the Principle of Population," authored this book in 1798. The quantity of food per person tends to decline as the population rises, according to Malthus, because of the Law of Reducing Yields (Unat, 2020). According to Malthus again, if fertility rate is not reined in, it will double every twenty-five years because global food security will rise in an arithmetic sequence while population growth will be geometric. In light of this, some Neo-Malthusian academics in the field of social sciences who view population increase as a threat for societal welfare re-examined Malthus' model. This group, which contributed significantly to demographic trends after World War II and had a significant influence on the decisions made by various international organizations like the United Nations, concentrated on the environmental harm high population growth instead of the issues with the global food supply and in contrast to Malthus, they endorsed advanced contraception measures like abortion.

The traditional assertion that population increase will outpace the planet's capacity to sustain life is recycled by neo-Malthusian viewpoints. The greatest immediate challenge to food security in this scenario is limited food supply, which is made worse by issues with access and use of food that are made worse by the growing shortage. The maximum capacity of the world has limits, and as more people put pressure on the ecosystem, those limits are being quickly approached. Neo-Malthusians challenge the idea that the earth's resources are "infinitely substitutable", pointing out the limitations of human ability to adjust to environmental change while urging people to change their current consumption habits (Scanlan, 2001).

Neo-Malthusians theory stated that the increase of fertility will place shortage of land that led to an absolute shortage restriction on food security in particular and imposed falling rates of return on all other variables of production (Scanlan, 2001). However, Merrick (2002) stated has made a contradiction of Neo-Malthusians theory, stating that the low fertility rate may cause to the low food security in a country in his study. The percentage of the population composed of elderly adults who are no longer employed will gradually rise as a result of low fertility. The speed at which decreased fertility sets in determines how strong the age-structure effect will be. To help the enormous pool of potential employees gain skills and find rewarding jobs, it also depends on governments following sensible economic and social policies. When this occurs, as it did in nations like Taiwan and South Korea, a brief surge in the development of human and physical capital helps to accelerate the growth in living standards.

Some red flags are also raised by the research on the consequences of Latin America's rapid fertility drop. Latin America's economic growth has lagged behind that of East Asia in the 1970s in part due to the failure of these nations to engage as much in education, especially for the underprivileged. Additionally, economic policies in these nations were less supportive to the development of productive employment for the people of working age. The possibility that India and Bangladesh, which are currently in the later stages of their transitions to low fertility, may not profit at all from the favorable demographic conditions established by such transitions is raised by similar policy failures in South Asia. Hence, low fertility rates will lead to low employment and low production in the country which will directly lead to low food security.

2.0.2 Anthropogenic Global Warming Theory

The theory to be applied in this research is anthropogenic global warming. According to the concept of climate change, greenhouse gas emissions from humans are primarily carbon dioxide (CO_2), methane, and nitrous oxide. These gases are the main tragedies to blame for the alarming increase in global temperatures. The improved greenhouse effect is the process through which this occurs. This hypothesis is known as "anthropogenic global warming," or simply AGW. Based on the proponents of the AGW theory, the 0.7°C warming during the previous 150 years and the 0.5°C warming over the last 30 years are primarily or entirely due to the greenhouse gases produced by humans. They refute or reject assertions that part or maybe all of the growth may be attributable to Earth's ongoing recovery from the Little Ice Age (1400-1800). By using computer simulations based on physical principles, theories, and assumptions, they project that a doubling of atmospheric CO_2 would result in an additional 3.0℃ increment in global temperature by 2100 (Bast, 2010).

Due to their susceptibility to extreme events, agricultural systems are experiencing certain problems as a result of anthropogenic climate change. Forecasts indicate that a rise in world population in the next few years will make the issue worse and raise demand for food worldwide. Regarding the use and availability of natural resources, it will raise serious issues (Smith& Gregory, 2013). One of the anthropogenic activities that will be more impacted in the future is agriculture. The amount of CO_2 in the atmosphere today has risen to levels that haven't been seen in about a million years, and predictions suggest that by 2050, it will reach 500 parts per million(ppm). As agricultural systems are so prone to unfavorable and harsh situations, weather and climatic conditions have a significant impact on them. Water availability, food quality, and security will all suffer due to the changes in temperature, precipitation, and sea level. Rapid climate change threatens plant growth and productivity while also changing the type and quantity of nutrients available to plants. The severity and duration of the stress, the plant genetics, and development stage all affect these consequences. Additionally, modifications in agroecological conditions may have an impact on agricultural product demand, income distribution, and growth.

Forecasts suggest that in the coming ten years, climate change may be to blame for a global drop in food security. There have been some investigated and hypothesized implications of human-induced climate change on agriculture. Most likely, the rise in soil salinity is responsible for the increase in CO_2 concentration, temperature, changes in rainfall, and a reduction in the amount of land that can be used for agriculture. The possible growing season may be extended by rising temperatures, which may potentially reduce maturity times and alter productivity with latitudes. In addition, higher precipitation levels are anticipated at high latitudes and in some tropical regions, while 21st century climate models predict decreases in several subtropical and lower mid-latitude regions. This enables the hypothesis that a change in the local climate could lead to substantial changes in agricultural yield (Del Buono, 2021).

In the study of Ros and Nang (2011), Cambodia's government has been placing agriculture sector as their focal emphasis towards the country development since 1993. In between of 1960 and 2005, Cambodia's average temperature has climbed by 0.8℃; the pace per decade was roughly 0.20℃ to 0.23℃ in the dry period and 0.13℃ to 0.16℃ in the rainy season. According to the projections, the average temperature is expected to have increased by 0.3℃ to 0.6℃ by 2025, 0.7℃ to 2.7℃ by 2060, and 1.4℃ to 4.3℃ by 2090. The predicted warming will be extremely high from December to June. Based on the theory of anthropogenic global warming, following by the increment greenhouse gases and climate change induced by artificial, the agriculture sector in Cambodia has been affected especially rice production. Besides, the poor rural population in Cambodia relies primarily on agriculture for livelihood. All rural and some urban groups experience food insecurity and undernourishment, which are mostly caused by low yields and the consumption of rice and fish as staple foods.

Furthermore, Guiteras (2009) has stated in his study that there is a considerable negative effect on the yields due to increasing temperature by using a panel data collection spanning 40 years and more than 200 Indian districts. Based on the extent and spread of global warming, the medium term (2010-2039) climate change is anticipated to cut yields by 4.5%-9%. The effects of long-term climate change (2070-2099) are even significantly worse which yields are expected to decline by at least 25%. Current figures from developing nations imply that one percentage point of agricultural GDP growth improves the spending of the three weakest quartiles by 4 to 6 percentage points. The unfavorable consequence of climate change on agriculture is expected to have a significant influence on poverty.

2.0.3 Keynesian Theory

Keynesian Economics is also known as Keynesianism was developed by British economist, John Maynard Keynes during the Great Depression of the 1930s, and his ideas were presented in his book The General Theory of Employment, Interest, and Money which was published in the year 1936. In the Keynesian view, the level of aggregate demand or total spending is affected by production, employment, and inflation in the country. As the aggregate demand is extremely unstable: recession when low demand and inflation when the demand is high so Keynesian economists indicate economic fluctuations can be mitigated by using government policy to manage aggregate demand and stabilize the economy.

Precisely, Keynesian Economics is that the government should take accurate fiscal policy actions while the central bank should take appropriate monetary policy actions to stabilize economic output, inflation, and unemployment over the business cycle (Jahan, Mahmud & Papageorgiou, 2014). For example, Keynes proposed that during a recession period the government should implement policies like cutting taxes and spending more money on corporations. In turn, it will lead to reduced unemployment, increase consumer demand as well as activate the economic activity in the country.

According to the Keynesian hypothesis, the level of aggregate demand, or overall economic spending, alone determines the GDP and employment (Gordon, 1991). According to Kpoghul, Okpe and Anjande (2020), the central tenet of the Keynesian theory of aggregate demand management is that, given the available resources, aggregate demand determines the production and employment; unemployment and economic fluctuations are caused by shortage in aggregate demand, which can be corrected through corrective government spending. In the study, during Covid-19, the Nigeria's government had imposed an Economic Sustainability Plan (ESP) to help boosting the country's exports. The rise in crops, fisheries, forestry, and livestock production in agriculture may be responsible for this rise in exports of agricultural products. The policy ramifications of these modest improvements in agricultural production and exports over the Covid-19. In the first place, they would increase the country's access to food. Increases in income, a measurement of the purchase power of food in an economy, would result from the export of agricultural products and the contribution of agriculture to GDP. Additionally, revenue from jobs in agriculture along the agricultural value chain is provided to households, increasing their ability to buy food and hence leading to the increase food security. The theory is appropriate to be used in this research as it can help us to study the relationship.

2.1 Empirical Review

2.1.1 Gross Domestic Product (GDP) and Food Security

First and foremost, we are investigating past studies related to the impact of economic growth on food security. Economic growth is one of the independent variables that we used in our research proposal. In research from Manap and Ismail (2019), food is the main necessity for human beings. It plays an important role in maintaining the health of an individual. According to the authors, the problem of food security will arise when individuals consume insufficient nutritional food. Intake of less nutritional food will cause the individuals to lack some essential nutrients, vitamins and even antibodies. As a consequence, the economic growth of that country will be reduced since the productivity level of labour declines due to lack of healthy bodies.

There are a lot of studies such as FAO (2002) and Timmer (2004) showing that food security will be positively affected by efficiency in economic growth. FAO (2002) stated that there is a positive relationship between economic growth and food security. This statement implies that a particular country with higher production and productivity levels, more job opportunities and higher salaries is believed to be capable of achieving food security. In addition, Timmer (2004) also claimed that there is a significant relationship between economic growth and food security. Improvements in food security have been made as a result of the development of economic systems.

In the study of Sabo, Isah, Chamo and Rabiu (2017), GDP has a positive relationship with the food security in Nigeria.

Agriculture was the most significant economic sector contribution to Nigeria's GDP. It currently provides 70% of employment to Nigeria's citizens and contributes 40% for the nation's GDP with crops contributing for 80%, livestock 13%, forestry 3% and fisheries 4%. In addition, starting from 1970s, the export of petroleum has become one of the major contributors to Nigeria's GDP. The food security in Nigeria is secured if the country's natural resources are being utilized efficiently as the high food security and living standard can give a positive effect on the citizen's ability to access to foods.

Next, Yaseen (2019) has revealed that the GDP could has a positive effect on the food security. BY using the method of ARDL estimation, it is found that if the GDP increase by 1%, on average, the food security will increase by 0.054 units in the developing countries. Pawlak and Kołodziejczak (2020) investigated the positive connection between the GDP in agriculture and the food security in developing countries. The research had included 100 developing countries and use a comparative analysis method to observe their relationship. It is concluded that investment and adoption in farming technologies is important in boosting the nation food security and enhancing food accessibility.

Lastly, in the research of Matkovski, Đokić, Zekić and Jurjević (2020), it is found that the adverse impact of low agriculture GDP on the food security in developed countries by adopting OLS method. As developed countries normally focus more on other sectors such as manufacturing, mining, and services instead of agriculture, it will lead to a lower level of food security.

2.1.2 Carbon Dioxide Emissions (CO_2) and Food Security

We involve the second independent variable, carbon dioxide emissions, CO_2 into our studies to investigate the relationship between food security and carbon dioxide emissions. It is predicted that climate change, which largely manifests as higher temperatures and CO_2 levels, will make otherwise unfavourable places suitable for the development of infections and pests. Numerous regions of the world have forecasted the effects of climate change, which could jeopardize global food supply and safety (Peter Mshelia, Selamat, Iskandar Putra Samsudin, Rafii, Abdul Mutalib, Nordin & Berthiller, 2020). In Malaysia, there are several variables that contribute to household food insecurity. They include matters pertaining to politics, the economy, the environment, society, infrastructure,and health. Household food security may potentially get worse because of climatic changes and associated effects, such as natural disasters. Food security, supply consistency, food accessibility, and food consumption are the four components of food security. Climate change may have an impact on each of them (Alam et al., 2016).

According to Duasa and Mohd-Radzman (2021), based on the ARDL predicted result, the influence of climate change as assessed by carbon dioxide emissions has a minimal short-term impact on rice yield. An additional study utilizing OLS regression with interaction variables reveals that when interaction effects are taken into account in the regression, the negative influence of carbon dioxide emissions on rice yield may be identified. In other past studies, it was stated that there is a negative short-term relationship between the carbon dioxide emissions and agricultural productivity which will indirectly affect the food security in Nigeria (Edoja, Ayec & Abu, 2016).

Next, Kwakwa, Alhassan and Adzawla. (2022) has investigated that carbon dioxide emissions from industrial, transportation and other sectors greatly slow down the agricultural development in the long run of Ghana by using regression analysis. For every 1% increase in the emission rate from the industrial sector, the agricultural products will decrease by 0.35%. A 0.65% decline in agricultural output is correlated with a 1% increment in carbon emissions from the transportation sector. If the carbon emissions from other sectors increase by 1%, agricultural development will follow by a 0.52% of reduction. Amponsah, Kofi Hoggar and Yeboah Asuamah (2015) had also examined a negative relationship between carbon dioxide emissions and cereal yields in both long and short run in Ghana. By using ARDL approach, the findings show that carbon emissions are rising. A 1% increase in CO_2 will result in a 54.67% drop in cereal yields in the long run; while a 1% of increment in CO_2 will reduce approximately 31.03% of cereal crops in short run.

In addition, Firdaus, Tan, Rahmat and Senevi Gunaratne (2020) has investigated a negative relationship between the climate change due to increasing carbon dioxide emissions and the food security in Malaysia. They had observed the relationship by using a 34-year trend of precipitation and temperature of granary areas in Malaysia through Mann–Kendall and Sen’s slope test. It is concluded that the rising CO_2 level from 383ppm to 574ppm had reduced the rice production and indirectly lead to the food inaccessibility and food security since rice is a staple food for Malaysia.

Lastly, a previous study which was Alam et al. (2016) has investigated the negative relationship between the carbon dioxide emission and the indirect effect of reducing crop on food security in Malaysia by using Partial Least Square method. Due to the significant greenhouse gas emissions, a 0.3℃ to 4.5℃ increase in temperature is predicted. The climate variability will make the agricultural system susceptible, diminish crop productivity, induce drought in many locations, and maybe make it impossible to cultivate some crops in the future. According to the study, the present paddy yield decreases by 3.44% for every 1% increase in temperature. Therefore, this theory is suitable to be added into our study to explain how the carbon dioxide emissions affects the food security in Malaysia.

2.1.3 Fertility Rate and Food Security

Natural growth is slowing down and becoming increasingly influenced by population dynamics as individual fertility continues to decrease. There is little chance that the human population will double in four or five centuries, as it did in the latter part of the 20th century. Food demand patterns are being affected more by changes in per capita consumption brought on by income development as population expansion slows (Misselhorn, Aggarwal, Ericksen, Gregory, Horn-Phathanothai, Ingram& Wiebe, 2012).

In the study of DiClemente, Grace, Kershaw, Bosco and Humphries (2021), it is stated that fertility rate has a negative relationship with food security. By using descriptive data and data cleaning method, the fertility preferences and food security level in Tanzania has been detected. Women with high fertility preference or having many young children often face the problem of low food security while women with low fertility preference or avoiding having new born young children are less likely to have food insecurity issue. Furthermore, Thomson, Hadley, Greenough and Castro (2012) have found that the negative relationship between increasing fertility rate and food security in Idjwi Island. Idjwi Island is an island that have the highest fertility rate over the world which is above 8 live births per woman averagely. However, the high population has imposed a severe environmental degradation as well as food insecurity.

Next, Rosegrant and Cline (2003) have also determined a negative relationship between fertility rate and global food security. The rising fertility rate will lead to a high population globally where it is hard to continuously sustain the global food security with the limited food accessibility. A lower fertility rate can have more benefits such as raise the productivity of women and improve the environmental management. According to Szabo (2016), there negative relationship between fertility rate and food security in United States urban areas has been detected in this study. Descriptive statistic and regression analysis have been used and it is tested that the negative association between fertility rate and food security in the urban areas. For those high growth rate urban areas, every 4% increase in human development will be led to an average of 89% increase in the food insecurity risk.

Hossain, Naher and Shahabuddin (2005) has revealed a negative relationship between fertility rate and food security level in Bangladesh. In Bangladesh, the increase in fertility rate as well as total population rate is giving pressure on the scarce land resources. The low food grain productivity and inadequate food accessibility has always been an issue in Bangladesh. The higher the fertility rate, the higher the income inequality and poverty line. It could lead to harsh food security in the country.

However, several journal articles have indicated that there is a positive relationship between fertility rate and food security. In research from Merrick (2002), food security will decrease as fertility rate decreases. This is because the proportion of older adults who no longer work will gradually increase. As a result, the productivity of the country will decline as a result of the decline in the working population. Additionally, Maharjan and Joshi (2011) also claimed that there is a positive relationship between fertility rate and food security. They found that a high fertility rate could help increase the number of active workforce and thereby contribute to improving the food security of a given country. Last but not least, an increase in fertility rate can result in high food security. An increase in the fertility rate implies an increase in the population and an increase in the labour force in agriculture. Since there are more workers in the agricultural sector, the country is capable of attaining food security (Prosekov & Ivanova, 2018).

2.2 Gap of Literature Review

In this study, the theoretical framework and empirical review have been provided and explained. The main discussion of this research is about the connection between the impact of carbon dioxide emission (CO_2), GDP and fertility rate towards food security. Our gap variable for this study is fertility rate.

There are few studies on Malaysia contexts about how the fertility rates affects the food security in Malaysia. There have been many previous studies of other countries such as the United States, Tanzania and Bangladesh, but research on the Malaysian context is rarely seen. It is because the fertility rate increase will affect food security severely. The changes in fertility rate will affect the demand for food in Malaysia. Thus, it should be discussed furthermore. It is simpler to capture the public's and the government's attention when the issue is narrowly focused. As a result, the government can be more cautious in this issue. Therefore, we will conduct a test on finding the relationship between the food security and these variables in Chapter 3 and results will be observed in Chapter 4.

CHAPTER 3: METHODOLOGY

3.0 Introduction

In this research, our objective is to investigate how the food security in Malaysia will be impacted by the Carbon Dioxide Emission (CO_2), Gross Domestic Product (GDP) and fertility rate. From all the information provided in Chapter 2 of this study, we have obtained sufficient information to step into the new chapter in the research which is to do an econometric model construction. In this chapter, we will discuss the econometric model, empirical testing procedures and the diagnostic checking in more detail.

The autoregressive distributed lag (ARDL) bounds cointegration test technique, popularized by Pesaran, Shinand Smith (2001), was used in the investigation. The ARDL model is regarded to be the best econometric technique compared to others in a case where the variables are stationary to I(0) or incorporated into the I(1) order. The objective of using the approach in this study is to investigate how Malaysia's Carbon Dioxide Emission (CO2), Gross Domestic Product (GDP) and fertility rate will affect food security in the long term. Augmented Dickey Fuller (ADF) test was devised to guarantee that the ARDL methodology without spurious regression problem, serves as an acceptable model for this investigation. Granger Causality test is being used to test for the causal relationship between variables in the short run.

Moreover, in order to avoid bias, inconsistency and inefficiency, we will run the diagnostic checking. Autoregressive conditional heteroscedasticity (ARCH), the Breusch-Godfrey serial correlation LM test, CUSUM test, Variance Inflation (VIF) test and normality test are the tests used for diagnostic checking. Meanwhile, in order for data analysis and reporting to be implemented successfully in this study, we have collected all the annual data needed from the World Bank Data website from 1990-2019. Besides that, by employing this research methodology, the hypotheses that emerged in the prior chapters, which is chapter 2 will be able to be identified. At the same time, relationship between variables over the long term can be found.

3.1 Data Description

Time series analysis is used to investigate the relationship between Carbon Dioxide Emissions (CO_2), Gross Domestic Product (GDP), and fertility rate on food security in Malaysia during 1990 to 2019. Diagram below shows the variable used and source of data:

Table 3.1: Summary of Variables and Source of Data

	Abbreviation	**Variable**	**Source**	**Cite from**
Food Security	lnFOOD	Food production index (2014-2016=100)	World Bank	Bozsik, Cubillos, Stalbek, Vasa & Magda. (2022)
Carbon Dioxide Emission	lnCO2	CO2 emissions (kg per PPP $ of GDP)	World Bank	Duasa & Mohd-Radzman (2021)
Gross Domestic	lnGDP	GDP growth	World Bank	Kavallari, Fellmann

Product (GDP)		(Annual %)		& Gay (2014)
Fertility Rate	lnFR	Fertility rate, total (births per woman)	World Bank	Ajao, Ojofeitimi, Adebayo, Fatusi& Afolabi. (2010)

3.1.1 Definition of Variables

3.1.1.1 Food Security

Every nation must produce food since a scarcity of food will endanger people's lives and security. Also, Food security is also seen as one of the prerequisites for economic growth. To enhance food security in the nation, the Ministry of Agriculture and Food Industries (MAFI) will carry out a number of projects under the National Food Security Policy Action Plan (DSMN) 2021–2025.

3.1.1.2 Gross Domestic Product (GDP)

The Economic Times defines GDP as the total dollar amount of products and services produced inside a nation's borders during a given time period.The rate of GDP growth is a crucial gauge of a nation's economic health (The Economic Times, n.d.). GDP is one of the independent variables for this study. It is because the GDP represents the country’s growth which includes the spending level of the household, the expenditure of the government on country development and foreign investment. According to the theory, when people have enough money, they are willing to spend more on food, boosting the country's food security and people's food security is secured.

3.1.1.3 Carbon Dioxide Emissions

According to the World Bank (2022), the production of cement and the combustion of fossil fuels both produce carbon dioxide emissions. They consist of gas flaring and carbon dioxide created through the utilization of solid, liquid, and gas fuels. It is measured by the kg per PPP $ of GDP.

Based on other research, the increase in carbon dioxide emissions will lead to an increase in severe weather, such as dryness, excessive rainfall, and gusty winds. All these extreme weather events frequently will result in lower food availability and higher food costs due to their negative impact on food supply, preservation, and transportation systems. This will then damage the consumers as the consequences.

3.1.1.4 Fertility Rate

If a woman were to live to the end of her reproductive years and have children in line with the age-specific fertility rates of the given year, the total fertility rate reflects the number of children that would be born to her (World Bank, 2022). A much lower fertility rate has historically been observed in industrialized nations, which is typically connected with higher levels of affluence, education, urbanization, and other variables. Conversely, fertility rates are often greater in underdeveloped nations. When the fertility rate is higher in these countries, the demand for food will increase. As we know, a country is considered to be "underdeveloped" if it has extensive poverty levels and less economic advancement than other countries. Hence,it can be said that this will lead to food insecurity as these countries will not be able to solve this problem due to their poverty levels and the economic condition of the countries when the countries' fertility rate is high.

3.2 Econometrics Model

3.2.1 Basic Model

This study suggests an econometric model that links the Food Security of Malaysia to CO_2 emissions. In our research, we used the Food Production Index of Malaysia to act as the proxy for Food Security. To conduct this research,we used the data from 1990 to 2019.

Food Security = f (CO_2 emissions)

$$lnFOOD = \beta_0 + \beta_1 lnCO2_t + \varepsilon_t$$

Equation 3.1

Where,

lnFOOD = Food production index (2014-2016=100)
β_0 = Intercept of equation 3.1 at time t
$\beta_1 lnCO2_t$ = CO_2 emissions (kg per PPP \$ of GDP) at time t
ε_t = Error term at time t

The model above is our basic model for this study. This model is adopted from Bandara and Cai (2014). The study has investigated the relationship between climate change (CO_2 emissions) and food security in South Asia. In the study, it has been evaluated that there is a significant negative relationship between the variables. The increase in greenhouse gases will lead to a decrease in food productivity as well as food security. CO_2 emissions will be the control variable in our study, and we have extended the model by adding two variables which are GDP and fertility rate.

3.2.2 Extension Model

Gross Domestic Product (GDP) and fertility rate were added as conditional variables into the basic model shown in equation 3.1 to make a comparison. This is to examine the long-run relationship between food security and these two variables.

Food Security = f (CO_2 emissions, GDP, Fertility rate)

$$\ln FOOD = \beta_0 + \beta_1 \ln CO2_t + \beta_2 \ln GDP_t + \beta_3 \ln FR_t + \varepsilon_t$$

Equation 3.2

Where,

lnFOOD=Food production index (2014-2016=100)

β_0=Intercept of equation 3.1 at time t

$\beta_1 \ln CO2_t$= CO_2 emissions (kg per PPP \$ of GDP) at time t

$\beta_2 \ln GDP_t$= GDP growth (Annual %) at time t

$\beta_3 \ln FR_t$= Total (births per woman)

ε_t=error term at time t

With the presence of Gross Domestic product (GDP) and fertility rate will play a vital role to determine what is the relationship and how they will affect the food security in the long run in Malaysia.

3.3 Empirical Testing Procedures

3.3.1 Unit Root Test

In this study, the unit root test was the first test we applied for. Every single time series variable's stationarity and sequence of integration are evaluated using the unit root test. It is very important to ensure the variables are in stationary form because it may cause spurious regression problems which will lead to inaccurate results of the findings. There are three conditions if the result is spurious such as t-distribution is extremely large, the value of R-squared is larger than the Durbin Watson distribution and the relationship between variables does not comply the common sense or theory. To assess our research model, we have selected the Augmented Dickey-Fuller (ADF) Test from among these tests. Two types of models will be used in testing unit root test, constant without trend and constant with linear trend. The equations are shown below:

Constant without trend:

$$\Delta Y_t = \alpha + \gamma Y_{t-1} + \sum_{i=1}^{k} \Delta Y_{t-1} + e_t$$

Constant with linear trend:

$$\Delta Y_t = \propto + \beta_t + Y_{t-1} + \sum_{i=1}^{k} \theta_j \Delta Y_{t-1} + e_t$$

3.3.1.1 Augmented Dickey Fuller Test (ADF)

We use the Augmented Dickey-Fuller (ADF) Test as the first unit root test in our study. This is due to the fact that the ADF test is a helpful and potent tool in checking the stationarity of time series data. Comparatively speaking, it can assist us in handling more complex models better than the Dickey Fuller unit root test (Wiley, 1939). The null hypothesis states that there is unit root in the variables while the alternative hypothesis is the variable does not contain unit root. The hypothesis is as shown below:

H_0: There is a unit root.
H_1: There is no unit root.

For the decision rule, we reject the null hypothesis if the p-value is smaller than the significance level at 1%, 5%, 10%, hence, the variable is stationary. Inversely, we do not reject the null hypothesis if the p-value is larger than the significance level at 1%, 5%, 10% and the variable does not have unit root. The Akaike Info Criterion (AIC) and Schwarz Info Criterion (SIC) will help to determine the number of lags length used (Seddighi, Lawler & Katos, 2000).

3.3.2 Model Estimation

3.3.2.1 Autoregressive Distributed Lag Model (ARDL) Bounds Cointegration Test

In this research, Autoregressive Distributed Lag Model (ARDL) Bounds Cointegration Test by Pesaran and Shin (1999) will be our second test to use in examining the long run relationship between dependent and independent variables from time to time. Examining the possibility of levels of correlations between variables has received a lot of interest in empirical economics during the past ten years. ARDL bounds test cointegration is an econometric type of model used in time series analysis. It is preferred to be used when the variables are integrated in different orders, I(0) or I(1) or the combination of both. ARDL bounds cointegration test is also reliable when there is just one long run relationship between the underlying variables in a small sample size (Nkoro & Uko, 2016). The primary goal of this test is to establish whether the suggested variables have a long-term association by running anF-test on the combined significance of each variable's lag level coefficient.Pesaran (1997) asserted that the ARDL bounds test approach has numerous advantages over the corresponding other measures cointegrating relation. Firstly, ARDL bounds test modelling uses substantial statistics to prove identity cointegrating when the sample size is small, whereas Johansen (1988) cointegrating requires a bigger sample to establish dependability (Odhiambo, 2009). Secondly, in the ARDL bounds test approach, regression variables can withstand varying optimal lags due to the diverse techniques connected with cointegrating demands the variables included in the regression linked with lag as another (Hua, 2016). In this case, since our research sample size is small, it is more suitable to adopt Autoregressive Distributed Lag Model (ARDL) Bounds Cointegration Test.

The hypotheses of bound test are as below:

H_0: There is no cointegration relationship between the dependent and independent variables.

H_1: There is cointegration relationship between the dependent and independent variables.

The decision rule is we reject H0 if the F-statistic is greater than the upper critical value at I(1). Otherwise, we do not reject H0. Nevertheless, if the F-statistic is inside the crucial range, the test is ambiguous and meaningless.

The ARDL bounds cointegration test model can be expressed as below:

Basic model:

$$lnFOOD_t = \alpha + \sum_{i=1}^{P} \beta_0 \, lnFOOD_{t-1} + \sum_{i=0}^{q} \beta_1 \, lnCO2_{t-i} + u_t$$

Extension model:

$$lnFOOD_t = \alpha + \sum_{i=1}^{P} \beta_0 \, lnFOOD_{t-1} + \sum_{i=0}^{q} \beta_1 \, lnCO2_{t-i} + \sum_{i=0}^{r} \beta_2 \, lnGDP_{t-i} + \sum_{i=0}^{s} \beta_3 \, lnFR_{t-i} + u_t$$

Where,

lnFOOD=Food production index (2014-2016=100)

β_0=Intercept of equation 3.1 at time t

$\beta_1 lnCO2_t$= CO_2 emissions (kg per PPP $ of GDP) at time t

$\beta_2 lnGDP_t$= GDP growth (Annual %) at time t

$\beta_3 lnFR_t$= Total (births per woman)

u_t=error term at time t

3.3.2.2 Error Correction Model (ECM)

After testing the ARDL Bounds Test, Error Correction Model (ECM) test will be our second test in our model estimation. An ECM is used to examine the relationship of long run and short run dynamics between variables in a time series data. The ECM is frequently employed when the variables are cointegrated, which denotes that they have shared a stable long run relationship over time. In this instance, ECM is included and depicts the process of the variables returning to the long run equilibrium following a short-term deviation from it after a shock (Alogoskoufis & Smith, 1991). The ECM model can be expressed as following:

Basic model:

$$\Delta lnFOOD_t = \beta_0 + \sum_{i=1}^{P} \beta_1 \, \Delta lnFOOD_{t-1} + \sum_{i=0}^{q} \beta_2 \, \Delta lnCO2_{t-i} + \lambda U_{t-1} + e_t$$

Extension model:

$$\Delta lnFOOD_t = \beta_0 + \sum_{i=1}^{P} \beta_1 \, \Delta lnFOOD_{t-1} + \sum_{i=0}^{q} \beta_2 \, \Delta lnCO2_{t-i} + \sum_{i=0}^{r} \beta_3 \, \Delta lnGDP_{t-i} + \sum_{i=0}^{s} \beta_4 \, \Delta lnFR_{t-i} + \lambda U_{t-1} + e_t$$

λU_{t-1} is the error correction term that is added into the equation to form ECM model. It tells us how much of the adjustment to equilibrium takes place each period, or how much of the equilibrium error is corrected following an exogeneous shock (Go,Lau, Yii& Lau, 2019).

3.3.2.3 Granger Causality Test

A statistical technique called the Granger causality test is used to examine if one time series can predict another time series accurately. The test assumes that, if one time series, X, influences another time series Y, then past values of X can forecast Y more accurately other than only using the past values of Y. Granger causality can show the direction of causal effects, such as $\mathcal{X}$ and $\mathcal{Y}$ have a bidirectional causal effect or unidirectional causal effect. In a bidirectional causal effect, X and Y are the causes of one another (eg. X causes Y; Y causes X). Whereas, in a unidirectional causal effect, one of X or Y is the cause of the other (eg. X causes Y).

Unfortunately, Granger causality does not have a positive or negative sign to determine whether the impact is direct or indirect.

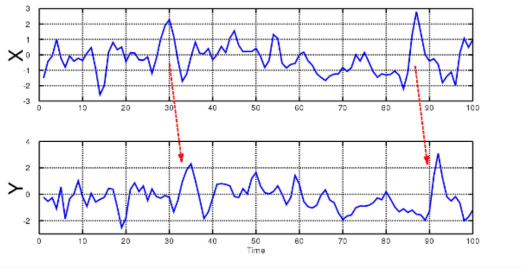


Figure 3.3.2.3: Granger Causality Graph

Two linear regression models are frequently fitted in order to conduct a Granger causality test: one in which Y is regressed on only its own past values, and the other in which Y is regressed on both its own past values and the past values of X. By using statistical tools like F-test or Akaike Information Criterion (AIC) can examine how well the second model forecasts compared to the first model. If the predicting accuracy of the second model, which incorporates historical values of X, is much higher than that of the first model, then X is said to be "Granger cause" Y. Granger causality is a valuable technique for determining potential causal linkages between time series, but it is vital to keep in mind that it does not indicate causation in the strict sense.

Granger causality tests consist of two types: the univariate Granger causality test and the multivariate Granger causality test. The univariate granger causality test is to determine if a time series' past values may be used to predict its upcoming values. The test involves creating a regression model that uses the lag values of time series as predictors, and then assessing if using these lag values improves the model's forecasting accuracy. Besides, the multivariate granger causality test assesses whether the previous values of one time series can be used to predict the future values of another time series after correcting for the impact of other factors. The test involves training a vector autoregression (VAR) model using the lag values of all relevant time series as predictors, and then assessing whether the inclusion of a particular time series' lag values improves the model's forecasting performance.

For a collection of three time series, A, B, and C, the multivariate Granger causality test can indicate whether A Granger-causes B, if B Granger-causes A, whether there is bidirectional Granger causation between A and B, or whether there is no Granger causality between them at all. The findings of the univariate and multivariate Granger causality tests should be taken with care since both contain specific assumptions and restrictions. They do not prove a strict causal link between the time series, but they can provide signs of predictive causality. To prove causation with more certainty, further techniques could be required. According to Damos (2016), the first step to generate Granger causality test is to transform the unrestricted model to restricted model.

Unrestricted model: $Yt = \beta 0 + \beta 1\ Xt + \beta 2\ Xt\text{-}1 + \beta 3\ Xt\text{-}2 + \beta 4\ Xt\text{-}3 + \beta 5\ Xt\text{-}4 + \varepsilon t$

Restricted the model: $Yt = \beta 0 + \beta 1\ Xt + \beta 2\ Xt\text{-}1 + \beta 3\ Xt\text{-}2 + \varepsilon t$.

The second step is run the Granger causality test via Eviews to obtain the Sum of Square Errors (SSE) restricted and SSE unrestricted. Then, insert the data obtained into the formula below to identify the F statistic.

$$F=\frac{(SSERestricted - SSEUnrestricted)/(kUnrestricted - kRestricted)}{(SSEUnrestricted)/(n - kUnrestricted - 1)}$$

The third step is calculating the critical value, Fα.

Fα =(kfull – kreduced), (n-kfull-1)

The fourth step is state the decision rule. Decision rule of Granger causality test is rejecting null hypothesis (H0) when F test statistic is greater than critical value which indicates that $\mathcal{X}$ Granger causes $\mathcal{Y}$. Otherwise, the H0 should not be rejected, it means $\mathcal{X}$ does not Granger causes $\mathcal{Y}$. Lastly, if H0 is not rejected, it indicates $\mathcal{X}$ and $\mathcal{Y}$ are independent and there is no granger causality between the variables. On the other hand, second method to identify Granger causality is through probability value (p-value). P-value will be obtained through Eviews results. The H0 tend to reject when p-value less than significance level (α), it represents $\mathcal{X}$ does not Granger causes $\mathcal{Y}$.

3.4 Diagnostic Checking

Diagnostic checking is a key phase in the time series modelling process which involves running a calibrated model through a number of statistical tests to make sure it accurately captures the observed time series. It is used to check for heteroskedasticity, autocorrelation, incorrect functional form specification and other problems that need to be avoided in the study. In this study, a few diagnostic tests will be carried out, including the Autoregressive Conditional Heteroscedasticity (ARCH) Test, the Breusch-Godfrey Serial Correlation LM Test and the CUSUM Test. All the tests will be performed by EViews 12 to check whether the problems occur or not.

3.4.1 Autoregressive Conditional Heteroscedasticity (ARCH) Test

H_0: There is Homoscedasticity.

H_1: There is Heteroscedasticity.

Before the ARCH test is implemented, the null and alternative hypothesis is set as above. When the standard deviations of a regression model are not constant throughout a range of independent variable values or when they compared to earlier time periods, this is known as heteroscedasticity in statistics. The correlation between food expenditures and earnings is a typical illustration of heteroscedasticity. The amount of money that people with lower salaries may spend on food is frequently limited by their budget. People will consume more food when their salaries rise because they have more alternatives and are not as constrained by their budgets. One issue with econometrics is heteroscedasticity, which arises from the fact that ordinary least squares (OLS) regression presumes that all residuals come from a population with constant variance. ARCH test is used in order to discover whether heteroscedasticity problems exist in the model used in this study. If the p-value for X^2 is less than the criterion for significance at 1%, 5%, or 10%, the H0 will be rejected.

3.4.2 Breusch-Godfrey Serial Correlation LM Test

H_0: There is no serial correlation.

H_1: There is a serial correlation problem.

Before the Breusch-Godfrey Serial Correlation LM Test is implemented, the null and alternative hypothesis is set as above. When mistakes from one time period continue into subsequent time periods, this is known as serial correlation in time-series investigations. An overestimate in one year, for instance, is likely to result in overestimates in subsequent years if we are forecasting the rise of stock dividends. Serial correlation is considered as a problem due to the predicted variances of the regression coefficients will be skewed as a result of serial correlation, which makes verifying the validity of the hypothesis becomes difficult. It will look as though the t-statistics are more important than they actually are. Breusch-Godfrey Serial Correlation LM Test is used in order to discover whether the serial correlation problems exist in the model used in this study. If the p-value for X^2 is less than the criterion for significance at 1%, 5%, or 10%, the H_0 will be rejected.

3.4.3 CUSUM Test

Cumulative sum of recursive residuals test (CUSUM) is to test the stability of ARDL bounds test parameters. CUSUM relies on the type of structural change occurring. The tests disprove the null hypothesis of continuous volatility at the 5% level since the test statistics for both tests cross the critical lines at least once. Thus, it is said that the plot should be within the specific range in order to prove the ARDL bounds test parameters are stable.

3.4.4 Variance Inflation Factor Test (VIF)

A statistical metric called the variance inflation factor (VIF) is used to quantify how the multicollinearity in multiple regression analysis increases the variance of the predicted regression coefficients (Trinidad, 2022). Multicollinearity is when two or more independent variables in a multiple regression model have a high degree of correlation with one another. In these situations, it is possible that the estimated regression coefficients are unreliable since it is impossible to precisely quantify the impact of each predictor on the dependent variable due to the influence of the other predictors.

To get the VIF, the variance of the coefficient estimate in a model with multiple predictors is divided by the variance of the coefficient estimate in a model with a single predictor. The formula of Variance Inflation Factor:

$$VIF_i = \frac{1}{1 - R_i^2}$$

There is no multicollinearity issues if the VIF value falls below 5. According to the past study of Micheal and Abiodun in year 2014, collinearity can be identified in the variable when its Variance Inflation Factor is approximate or higher than 5.

3.4.5 Normality Test

In this research, we used e-views to run the normality tests for each independent variable and dependent variable. Normality test is a statistical procedure that helps in determining whether a given dataset is normally distributed or not. In research from Kwak and Park (2019), there are several ways for performing a normality test. They are Shapiro-wilk test, Anderson-Darling test and Kolmogorov-Smirnov test. These three tests are following the same procedures: state the hypothesis testing, determine the significance level, state the decision rule, calculate the test-statistic or p-value and make conclusions.

The hypotheses of normality test are as below:

H_0: The data is normally distributed.
H_1: The data is not normally distributed.

The decision rule is we reject H0 if the P-value is less than significance level and this mean that the data is not normally distributed. Otherwise, we do not reject H0. Do not reject H0 would imply that the data is normally distributed.

CHAPTER 4: EMPIRICAL RESULTS

4.0 Introduction

In this chapter, we will run the diagnostic checking and examine the relationship between the food security and all the independent variables by using E-views 12. This chapter will include a summary of all the results while the appendices will display the outputs. Each model's complete outputs, which are listed in the appendices, are listed below with their respective numbers.

4.1 Unit Root Test

All independent variables have undergone both an interaction-free and interaction-based unit root test. The sustainability of the research's variables will be assessed using the ADF test. Table 4.1.1 presents the findings of all variables without interaction. Each variable can move on to the next stage for more research, such as ARDL, to examine the long-term link between the dependent variable and independent factors after it reaches stationary behavior in the first difference. Otherwise, it will produce a biased and invalid result.

Table 4.1.1: Results of Augmented Dickey Fuller Test

Augmented Dickey Fuller Test				
Variables	**Constant Level (p-value)**	**First Difference (p-value)**	**Constant Level (p-value)**	**First Difference (p-value)**
	Intercept without trend		**Intercept with trend**	
ln FOOD	0.565 (0.9861)	-3.947** (0.0054)	-1.180 (0.8961)	-3.975** (0.0218)
ln CO2	0.494 (0.9835)	-6.322** (0.0000)	-1.554 (0.7859)	-6.330** (0.0001)
ln GDP	-3.934** (0.0056)	-7.980** (0.0000)	-4.054** (0.0183)	-7.873** (0.0000)
ln FR	-3.359** (0.0219)	-1.744 (0.3984)	0.265 (0.9973)	-6.573** (0.0001)

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Based on the above Augmented Dickey Fuller (ADF) test result, GDP achieved stationary at both level form and first difference form (intercept with trend and without trend). Food Production Index ~~and CO_2~~ achieved stationary at level form and first difference form as their p-value is smaller than alpha (intercept with trend and without trend). Lastly, FR achieved stationary at level form and first differences form (intercept with trend and without trend). As mentioned earlier in our previous chapter, we reject null hypothesis if the p-value is smaller than the significance level of 5%. Otherwise, we do not reject the null hypothesis. Hence, we can conclude that the food production index, CO_2, GDP and FR are achieving stationary at different form of levels.

4.2 Model Estimation

4.2.1 ARDL Cointegration Bounds Test

The ARDL Cointegration Bounds Test has been used as the first test in model estimation to examine the long run relationship between the dependent and independent variables. The value of F-statistics will be used to compare with the critical value at I(0) and I(1) to see if there is any cointegration between variables.

Table 4.2.1.1: Results of ARDL Bounds Test for Extension Model

TEST STATISTICS	VALUE	SIGNIFICANCE LEVEL	I(0)	I(1)
F-STATISTIC	7.7108**	1%	3.65	4.66
K	3	5%	2.79	3.67
		10%	2.37	3.2
CONCLUSION	Cointegrated			

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

From Table 4.2.1.1 above, the value of F-statistic is 4.9890 which is greater than the upper critical value of 4.66, 3.67 and 3.2 at the significance level of 5%. Based on the hypothesis of ARDL Cointegration Bounds Test we mentioned in Chapter 3, we reject the null hypothesis, H0 if the F-statistic is greater than the upper critical value at I(1). Therefore, we can conclude that the variables are cointegrated and the CO_2, FR and GDP do exist long run effect on food security.

Table 4.2.1.2: Results of Long Run Coefficient for Extension Model

Variables	Coefficient	T-Statistic	P-Value	Standard Error
ln CO2	-0.7664	-3.9486	0.0055**	0.1941
ln GDP	0.2159	4.2045	0.0040**	0.0513
ln FR	-0.4912	-2.9821	0.0205**	0.1647

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Based on the Table 4.2.1.2 result shown above, the p-value of CO_2 is 0. 0055 which means it is significant at the significance level of 5%. Hence, there is sufficient evidence to conclude that there is a relationship between food security and CO_2 in the long run. If CO2 increase by 1%, on average, the food security will decrease by 0.7664% in the long run. When the CO_2 produced is too high, it will reduce food security, especially agricultural products. This negative relationships between these two variables can be supported by the several studies such as Alam et al. (2016), Duasa and Mohd-Radzman (2021), Kwakwa, Alhassan and Adzawla (2022) and Amponsah, Kofi Hoggar and Yeboah Asuamah (2015) and Edoja, Ayec and Abu (2016), Peter Mshelia et al (2020) also stated in his studies that the higher temperature will make the unfavourable place suitable for the development of infections and pests which jeopardize food security. To conclude, CO_2 can have a negative impact on food security which will affect food security in the meanwhile.

Secondly, the P-value for GDP is 0.0040 which is statistically significant at the significance level of 5%. Hence, we can conclude that there is a significant relationship between GDP and food security in the long run. When the GDP increases by 1%, on average, food security will increase by 0.2159% in the long run. The positive relationship between GDP and food security can be supported by the study of FAO (2002) and Timmer (2004). When the GDP of Malaysia increase, it means that there are more foods imported and produced in the country which will ensure every citizen have the accessibility to get food. Hence, it will lead to food security. The result is also supported by Sabo et al. (2017), Yaseen (2019), Pawlak and Kołodziejczak (2020) and Matkovski et al. (2020).

Thirdly, the p-value for fertility rate is 0.0205 which is statistically significant at the significance level of 5%. It indicates that there is a significant negative relationship between fertility rate and food security in the long run. When the fertility rate increases by 1%, on average, food security will decrease by 0.4912% in the long run. The is supported by the study of DiClemente, Grace, Kershaw, Bosco and Humphries (2021) which mentions that the low fertility preferences will lead to the increase in food security. Hossain, Naher and Shahabuddin (2005) also stated that the increase in fertility rate will place pressure on the limited land resources for cultivation which will reduce the food crops and availability. This result can also be supported by Thomson et al. (2012), Rosegrant and Cline (2003), Szabo (2016).

4.2.2 Error Correction Model

Table 4.2.2.1: Results of ECM for Extension Model

Extension Model	
Variables	CO_2, GDP and Fertility Rate
ECT Coefficient	-1.7228
P-Value	0.0001**
T-Statistics	-7.7836**
Standard Error	0.2213

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Based on the ECM table above, we can observe that there is a cointegration for the extension model as the p-value is statistically significant at the 5% of significance level. The ECT coefficient for the extension model is -1.7228 which has fallen out of the range of 0 and -1. It means that there is an overcorrection of 72% error in each time period of error correction process on Malaysia's food security (Yiew, Kalimuthu, Lee, Cheah& Foo, 2018). In other words, it also implies that the error correction process varies about the long-run value in a dampening way rather than monotonically converging to the equilibrium path straightly. Nevertheless, the convergence to the equilibrium path will eventually be rapid once the process is complete (Narayan & Smyth, 2006).

4.2.3 Granger Causality Test

Table 4.2.3.1: Results of Granger Causality for Extension Model

		Variables			
		ln FOOD	ln CO2	ln GDP	ln FR
Variables	ln FOOD		7.5307**	0.2447	8.6987**
	ln CO2	0.4983		0.1468	12.9285**
	ln GDP	0.0105	0.2628		0.7896
	ln FR	3.8250**	3.7772**	3.8619**	

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Table 4.2.3.1 shows the result of granger causality for each variable with food security. Firstly, food security will granger cause CO2 at the significance level of 5%, while the CO2 will not granger cause food security. Secondly, food security does not granger cause GDP and GDP does not granger cause food security at the significance level of 5%. Thirdly, fertility rate will granger cause food security at the significance level at 5% and food security will granger cause fertility rate at significance level of 5%. To conclude, fertility rate is the most important contribution in this study as it may granger cause food security in the short run. High demand for food can be brought by the high fertility rate which will directly put pressure on the food availability (Grote, 2014). Especially the newborn infants that need a lot of nutrients may require more food crops to develop a healthy body. In this case, it jeopardizes the food security in Malaysia as the food accessibility is low now (Ala & Ridwan, 2020).

4.3 Diagnostic Checking

4.3.1 ARCH Test and LM Test

Table 4.3.1.1: Results of LM Test and ARCH Test

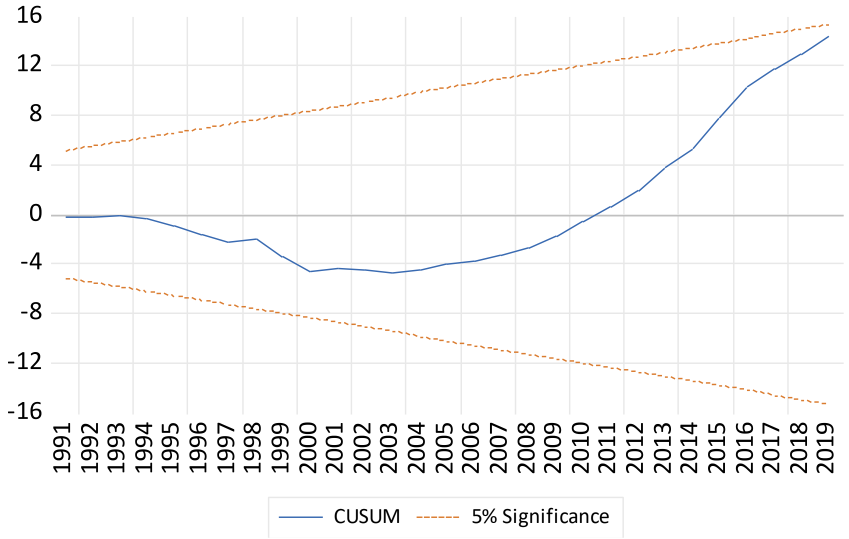
Diagnostic Testing	Chi-Square/ P-value	Conclusion
<u>Extension Model</u>		
Serial Correlation LM Test	0.1321**	No serial correlation
ARCH Test	0.1164**	No Heteroskedasticity

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Based on the result from Table 4.3.1.1, the extension model is free from any econometric problem at all significant levels. The p-value of serial correlation LM test is 0.1321 and ARCH test is 0.1164 where both are larger than significance level at 5%. Conclusion, we do not reject the null hypothesis and there is no autocorrelation and no heteroscedasticity problem in the model.

4.3.2 CUSUM Test

Figure 4.3.2.1: Extension Model



A CUSUM test determines if a series of values can be described as random by using the cumulative sum of a quantity. The CUSUM technique is simple to apply and effective for locating change points. In research from Oh and Lee (2019), this CUSUM technique is employed to find abrupt shifts in time series models. Based on the E-views output, it shows that the CUSUM statistics fall within the range at 5% significance level of critical bounds. Thus, we do not reject the null hypothesis as the parameter is stable.

4.3.3 Variance Inflation Factor (VIF)

Table 4.3.3.1: Results of Variance Inflation Factor

Extension Model	Multicollinearity	
	VIF	Yes/No
ln CO2	3.1983	No

ln GDP	1.1332	No
ln FR	3.4230	No

According to Alin (2010), multicollinearity is the linear relationship between two or more factors. It also refers to the absence of directionality between the variables. As a result, it can be challenging to ascertain the precise impacts of each predictor variable on the outcome variable, which can lead to issues with the model. When there is the existence of multicollinearity, estimating the precise impact of each variable on the result variable becomes challenging and this may lead to less accurate coefficient estimations as well as broader confidence ranges.

In this study, we have used the variance inflation factor (VIF) to test whether there is the problem of multicollinearity. The variance inflation factor (VIF), which is used historically to diagnose the potential presence of multicollinearity, may not necessarily indicate that the presence of multicollinearity would have a detrimental impact on the statistical study (Gómez, García & García, 2020). The VIF assesses the extent to which multicollinearity has inflated the variance of the calculated coefficients. According to Micheal and Abiodun (2014), there is collinearity associated with a variable if the VIF for that variable is close to or more than 5. This means that, if the value is not around or greater than 5, there is no multicollinearity problem exits in the model.

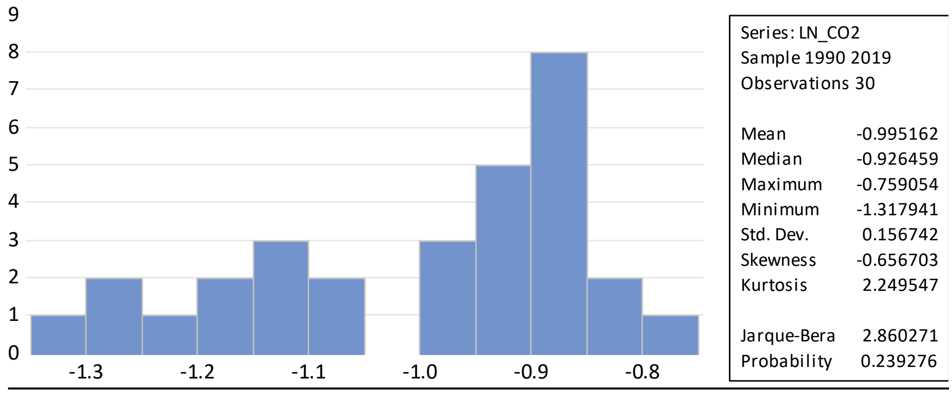
From the results shown in table 4.3.3.1, the VIF for all the variables in the extension model is almost close to 1. This also proved that there is no multicollinearity problem in the model. As a consequence, this regression model which lacks multicollinearity is typically viewed favourably since it produces more precise and trustworthy findings for our research.

4.3.4 Normality Test

Variable 1: Carbon Dioxide Emissions

Output for Normality Test

Figure 4.3.4.1: Normality test for Variable 1

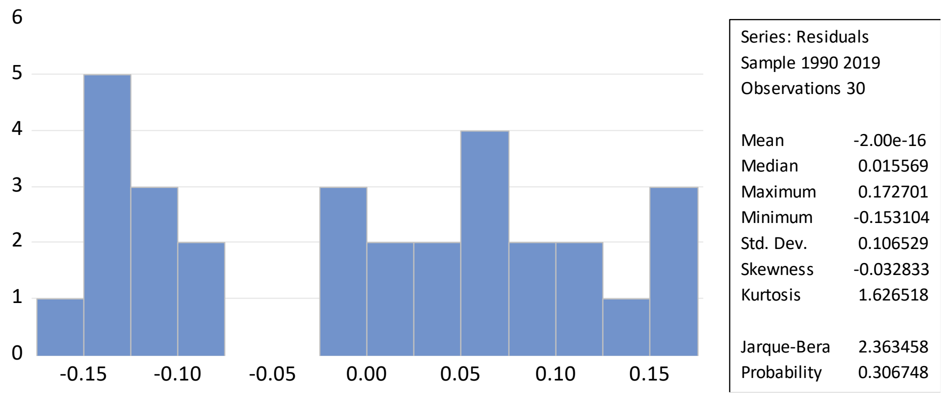


The result of normality test for model 1 shows that it will not reject the H0 since its p-value (0.2393) is greater than the significant level (0.05). Hence, we can conclude that the data is normally distributed.

<u>Variable 2: Fertility Rate</u>

<u>Output for Normality Test</u>

Figure 4.3.4.2: Normality test for Variable 2

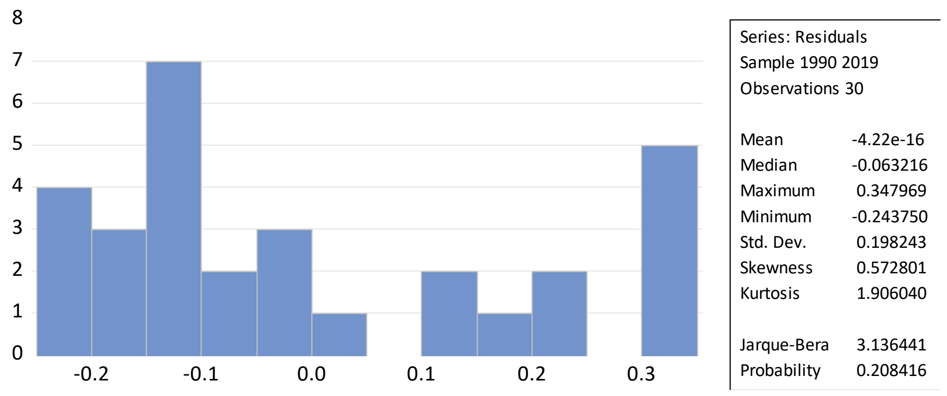


The result of normality test for model 2 shows that it will not reject the H0 since its p-value (0.3067) is greater than the significant level (0.05). Hence, we can conclude that the data is normally distributed.

<u>Variable 3: GDP</u>

<u>Output for Normality Test</u>

Figure 4.3.4.3: Normality test for Variable 3



The result of normality test for model 3 shows that it will not reject the H0 since its p-value (0.2084) is greater than the significant level (0.05). Hence, we can conclude that the data is normally distributed.

4.4 Chapter Summary

In this chapter, several tests have been conducted to test for the long run relationship between Food Security, Carbon Dioxide Emissions (CO2), Gross Domestic Products (GDP) and Fertility Rate in Malaysia from the year 1990 to 2019. Unit root test is the first test we have been used in examining the stationarity of the variables. We have used the Augmented Dickey Fuller (ADF) Test to determine the stationarity of each variable. It is shown that GDP is stationary at both level form and first difference form (intercept with trend and without trend). Food Production Index and CO2 achieved stationary at level form and first difference form as their p-value is smaller than alpha (intercept with trend and without trend). Fertility rate achieved stationary at level form and first differences form (intercept with trend and without trend). As the variables are all stationary, therefore we can proceed to the next step.

Next, ARDL Cointegration Bounds Test, Error Correction Model (ECM) and Granger Causality Test have been used to determine the long run relationship between the variables. First, ARDL test has shown the CO_2, GDP and fertility rate have long run relationship on food security. The ECM result has also indicated that the cointegration between variables. Lastly, the Granger Causality test has revealed the causal relationship between food security and fertility rate. After having all these tests, we can conclude that the model has a long run relationship and hence, we can proceed to the diagnostic tests.

Last but not least, diagnostic checking is the test to check for multicollinearity, normality, heteroscedasticity. Variance Inflation Factor (VIF) is for multicollinearity checking and it has been tested that no multicollinearity exists between the variables as the VIF value is less than 5. Next, ARCH test and LM test have been used in testing the heteroscedasticity. The result shows that there is no serial correlation problem in the model. Furthermore, the normality test for each variable also proved that they are normally distributed. Lastly, the CUSUM test shows the model consists of structural stability in this research as the CUSUM statistic falls between the range at significance level of 5%.

CHAPTER 5: DISCUSSION, CONCLUSION AND IMPLICATIONS

5.0 Chapter Summary

The implications, conclusions, limits, and suggestions of this study are covered in this chapter before the conclusion is reached. All the results that are provided as evidence that the study's goals and posed hypotheses are being met. This chapter will also include an implication which is the inference that can be drawn from the data of the research that explores potential solutions to the issue as well as strategies to build on key discoveries to achieve the study's goal through workable policies with positive externalities. There were a few flaws in this study's methodology, which will be covered in more in this section. Finally, some suggestions for upcoming researchers who will carry out similar studies will be discussed too.

5.1 Summary of Major Findings

The main objective of this research paper is to identify the factors such as CO_2, GDP, and fertility rate affecting food security in Malaysia from 1990 to 2019. Firstly, the study found that Carbon Dioxide Emissions (CO_2) is consistent with the Anthropogenic Global Warming Theory as CO_2 has a negative impact on the food security in Malaysia. One of the interrelated elements that affects food security is climate change (Gregory, Ingram & Brklacich, 2005). It is predicted that the temperature in Asia Pacific region will have risen by 2℃ in 2030 to 2.7℃ in 2070 (Kovats, Bouma, Hajat, Worrall & Haines, 2003). If no specific mitigation plans are taken on reducing carbon dioxide emissions to a lower level, the agricultural productivity in developing nations such as Malaysia and Thailand could decline by 10-25% by 2080 (Al-Amin & Ahmed, 2016). In the study of Affoh, Zheng, Dangui and Dissani (2022), the increase in CO_2 which led to the rise of temperature has negatively influenced the crops production and food availability in Sub-Saharan Africa by using the panel data analysis. Lee et al (2019) has also investigated a detrimental impact of the increasing greenhouse gases on the rice production in Malaysia as it will reduce the rainfall amount. Therefore, the first objective of this study has achieved which we have determined the adverse relationship between food security in Malaysia and CO_2.

Secondly, the study has achieved the second objective which proved that the Gross Domestic Product (GDP) has positively affected the food security in Malaysia which is consistent with the Keynesian Theory. Sillah (2013) mentioned that the productivity in agriculture and livestock is the important key development to the country's economic growth. When the supply has been fulfilled, it will boost the country's average income per capita and personal standard living. Meanwhile, food security can be secured in a positive way. According to Liefert (2004), starting from 1999, the macroeconomics condition of Russia has been consistently improving which led to an upsurge in their national GDP and personal income. Consequently, the number of households that face food unsecure and the percentage of people living in poverty has significantly decreased, falling to roughly 15% by 2003. There is a positive relationship showing annual GDP can affect the food security in Gambia (Ceesay & Ndiaye, 2022). Food security grows by 0.0704% for every 100% increase in the agriculture sector.

Lastly, we have achieved our third objective which fertility rate is consistent with the Neo Malthusian Theory, it has a negative relationship between food security in Malaysia. In tandem with the expanding fertility rate, food insecurity is increasing. A slower pace of fertility rate increase may benefit the economy of developing countries (Kelley, 1998). As an illustration, Nigerian women have an average fertility rate of 5.3 children, and the country is projected to become the third most populous country by 2050. This can be attributed to the fact that only 12% of married women in Nigeria use modern contraception methods while approximately 60% of Nigeria's population experiences moderate to severe food insecurity (Chen Cui, Vitousek, Cassman, Matson, Bai, Meng, Hou, Yue, Römheld & Zhang, 2011). Data from the Early Childhood Longitudinal Study indicates that children raised by parents who report unwanted childbearing in two-parent households are more likely to experience food insecurity and related stressors (Patel & Surkan, 2016). In the study of Molotoks, Smith and Dawson (2021), it is found that the increasing fertility rate has an adverse impact on the food security on global food security. Countries with declining population growth are often having economic benefits and reducing country poverty level. Rising incomes per capita leads to the food secured in the nation.

5.2 Implications of Study

5.2.1 Baby Bonus Scheme

Baby Bonus Scheme is a component of a recurring set of family assistance programs that purport to aid private families with the costs of raising children while encouraging a rise in the country's fertility rate. This is a policy used by many governments in different nations such as Australia and Singapore to boost their country fertility level. In most affluent nations, fertility fell after the post-war baby boom. For instance, the total fertility rate in Australia has decreased virtually constantly from peaking at 3.5 children per woman in 1961, falling below replacement levels in 1976, and eventually achieving a 1.75 level of fertility in 2003. Due to the negative effects of a declining workforce and an elderly workforce, there are many concerns in many developed nations if the fertility rate is below the replacement level.

By implementing Baby Bonus Scheme, many advantages can be obtained by parents which indirectly encourage them in contributing to higher birth rate. Parents with low financial ability can get financial support through the scheme. As we know, the cost of raising a child is not expensive. Expenses such as educational fees, supplements, food and household items and more all needed to be prepared. The Baby Bonus Scheme can lessen the cost of raising a kid by giving parents financial assistance when they give birth to a new child. Hence, couples may find it easier to have a child, especially those who might be worried about the high expenditures (Chua, 2009). Next, the Baby Bonus Scheme may help in incentivizing parenthood. This program acts as an incentive in fostering couples to have children. For people who are possibly hesitant about having children, the one-time financial incentive and other advantages might make the thought of having a kid more appealing and attainable (Guest, 2007).

The Australia government had imposed a Baby Bonus Scheme to help rising the country's fertility rate. The main function of this original policy was a straightforward lump-sum cash payment of a $3,000 made to families once a baby was born or adopted, up until the age of two. The bonus was paid to the family within 26 weeks once they start to claim for the application without looking into the household's income or mother's employment status. Besides, the amount was also excluded from taxable income. Worries about young parents led to a 2007 revision to spread the incentive over 13 biweekly installments for mothers under the age of 18 was changed to available for all mothers in 2009. It does reflect a positive effect on the Australia's fertility rate as the country's birth rate has increased afterwards (Drago, Sawyer, Shreffler, Warren & Wooden, 2009).

Moreover, Singapore's government had also imposed Baby Bonus Scheme to drive up the country's fertility rate. The total fertility rate in Singapore has decreased from 1.96 in 1998 to 1,4 in 2001. The Baby Bonus Program, which went into effect on April 1, 2001 has provided a first tier of benefits of $9,000 for the second child and $18,000 for the third child. In addition, the Children Development Account (CDA), which offered additional payment tiers, allowed the government to match funds saved into a kid's account dollar-for-dollar up to a limit of $6,000 for a second child and $12,000 for a third child, respectively. The funds in the CDA might be utilized to pay a portion of the tuition at institutions covered by the plan and for all of the family's children. The Baby Bonus Scheme had given out $11 million by 2002 (Wong & Yeoh, 2003).

To conclude, Baby Bonus Scheme can be adopted by Malaysian government in boosting the fertility rate if the fertility is below the replacement level. Replacement level is a level where the overall fertility rate is needed to maintain current population levels. However, the policy should not be taken if the fertility rate has exceeded the replacement level because a high fertility rate may harm the food security in Malaysia. 62% of the countries that are having low fertility rate have sought policies in enhancing the fertility such as baby bonuses, family allowances, tax incentives and parental leave (United Nations, Department of Economic and Social Affairs, Population Division, 2016).

5.2.2 Policy Reform and Land Tenure Security

In simple words, market regulation reform involved lowering trade barriers in the hopes that trade would encourage economic growth, lower prices, and broaden access to food. Results have been extremely positive when a progressive market reform is combined with help for farmers, the expansion of local markets, or greater land security. This was true for both rice and cotton in Vietnam and Burkina Faso. By lowering the cost of imported inputs and equipment, trade reform has lowered production costs. As an illustration, millions of farmers in Bangladesh are benefited from the purchase of cheap Chinese irrigation pumps. Reduced trade barriers and private food imports are the best ways to address acute food security deficiencies. As evidence, Bangladesh rebounded from the 1998 floods significantly better than it did from the 1974 floods, when private import was restricted.

Most African governments have prioritized market opening in the hopes that their citizens will derive benefit from it (Mwaniki, 2006). Governments should reduce the trade barriers and encourage free trade so that their country can attain positive economic growth and achieve food security. By reducing trade barriers, this means that each nation can increase its exports to other countries. Exporting food commodities to other nations could help to generate income source and stimulate the economic growth of a country. From another perspective, countries also can import food products from their neighboring countries or other developing countries at a lower cost when trade barriers are reduced. Food prices and malnutrition rate will decrease when the trade barriers are removed from market access. This happens because consumers will have more purchasing power and might not feel it burden of obtaining food. Customers are consequently less apt to experience food insecurity and hunger. Contrarily, consumers and importers can benefit from consuming a variety of products in large quantities and at a lower cost (Friel, Schram & Townsend, 2020). Their standard of living can be improved too. Low trade barriers also contributed to boosting healthy rivalry between the domestic and foreign food industries. Both of them will compete to create food commodities of a higher quality using their creativity and technologies.

In addition, land tenure security should be provided to the farmers. A study from Deininger and Feder (2009) shows that many individuals in developing countries do not have access to secure land titles. The small-scale farmers have greater incentives to invest in land. Increase in investment in land could generate higher agricultural productivities, efficiencies and food security. The most impressive outcomes were attained in China and Vietnam. The shift from collective to family agriculture greatly increased output in China and Vietnam. The broader shift from a planned to a market economy, which made a significant contribution to growth in these two nations as well as global advancements in food security in the 1980s and 1990s, cannot be separated from the effects of land reform. Efficiency improvements in agriculture made labour much more motivated to work. The poverty rate in China decreased from 53% in 1981 to 8% in 2001 while Vietnam's poverty rate reduced from 58% in 1993 to 16% in 2006. The formalization of illegitimate land rights through land use certificates in Ethiopia or land titles in Peru inspired farmers to engage in agriculture even though there was no access to funding.

Hence, the Malaysian government should reform the market regulation to reduce trade barriers through lower tax imposition, reduce import quotas and encourage international trades. By doing so, the Malaysian citizens will have access to a variety of foods at a lower cost. Besides that, the businesses and firms have access to a broader market. They can easily export their food products to other nations. From another perspective, Malaysian consumers can purchase food commodities at a lower price because the cost of importing goods has been reduced. As a result, the problem of food security problem can be alleviated as everyone can access the market freely and obtain food commodities easily. Farmers should be assured of title through providing secured land tenure by government so that they can obtain land to engage in agricultural activities. Thus, agricultural productivity can be increased and food security can be improved.

5.2.3 Carbon Tax Policy

Carbon tax policy is an effective policy that implemented for the objective to reduce the greenhouse gas emissions that contribute to climate change. Theoretically, monitoring all emissions and levying a consistent tax on them would be the ideal approach to charge a fee for carbon dioxide. With this strategy, families and emitters would have a continuous and all-encompassing incentive to switch to less carbon-intensive manufacturing and consumption (Marron & Toder, 2014). According to Harinderan (2022), Malaysia does not currently have a carbon tax in effect, but it is thinking about implementing one in the future to increase domestic income.

Carbon taxes can reduce energy use, boost energy efficiency, and support the growth of renewable energy sources all at once.

Additionally, the Norwegian carbon taxes raise the cost of fossil fuels, which both directly and indirectly affects the emissions of greenhouse gases. According to a study conducted last year by economists at Duke University and the University of Ottawa, the tax reduced emissions by 5 to 15 percent with "negligible effects on aggregate economic performance" as it increased from 10 Canadian dollars per tons of carbon dioxide in 2008 to 30 dollars by 2012, the equivalent of roughly $22.20 in current US dollars (Porter, 2016).

Taxes serve two purposes: first, they reveal the price of a healthy "environment". Secondly, they encourage the development of innovative technical techniques that boost productivity and energy conservation. Thirdly, they provide companies with the option of where pollution reduction measures must be deployed, helping to lessen environmental harm at the least expensive possible price. Lastly, taxes generate additional cash that might be utilized to support environmental technology innovation.

All in all, the introduction of the carbon tax policy will raise the environmental consciousness as well as the severe impact of the climate change and most of the companies or factory may now reduce the release of CO2 more effectively or try to use any technology that will release less CO2 to the atmosphere. When CO2 emissions are reduced, it means the effects of climate change will be mitigated too. When the rainfall patterns and temperatures become normal and stable, rarely happening of any natural disaster such as flood, the yield of food grains will increase. Hence food security will be increased and stabilized. This means that the food security in the country will be increased.

In conclusion, these three policies are strongly suggested to the government to improve the food security of the country. It is because if the government implemented these policies, firstly, carbon tax policy will help to reduce the CO2 emission to the atmosphere. This not only will improve food security, but also helps to protect the environment so that the quality of the people's lives will be improved tremendously. Secondly, Baby Bonus Scheme will help to increase the fertility rate in Malaysia as the fertility rate of the nation is in a decreasing form. However, this policy will only be adopted if the fertility rate is below the nation's replacement level. The policy will stop being implemented once the fertility rate reach the replacement level to prevent any exceeded fertility rate as it will harm our country food security in the long run. Thirdly, market regulation reform should be taken into consideration by the government to encourage free trade, increase economic growth and food security of a country. Last but not least, farmers need to have secure access to their land so they can plant crops and boost food security. Overall, there may be more policies that could address all the difficulties mentioned, but this study has indicated that these 3 policies are primarily because of their function and affects are more beneficial to the nation and are also capable of achieving the research's goals.

5.3 Limitations

Throughout our study, we have encountered one limitation. This limitation should be improved and applied for future studies. The obstacle we encountered was that Malaysia was the only nation that our research was focused on. According to the Food and Agriculture Organization (FAO) of the United Nations' 2021 Global Report on Food Crises, 155 million people in 55 nations suffered from severe food insecurity in 2020. Yemen and Northern Uganda are some of the nations with the greatest levels of food insecurity (World Health Organization, 2021). However, Dureab, Al-Falahi, Ismail, Al-Marhali, Jawaldeh, Nuri, Safary and Jahn (2019) claimed that there were challenges to obtain reliable and trustworthy data in Yemen. Additionally, the study from Pietrelli, D'Errico and Dassesse (2021) also stated that there is limited evidence that the personal traits of interviewers might influence the results of the food security survey in Northern Uganda. Consequently, the accuracy and dependability of study findings can be significantly impacted by a lack of data. Researchers might have to estimate values or make assumptions when there is a lack of data, which can lead to analysis mistakes or biases. Without taking into account a variety of data, researchers run the risk of missing significant trends. This may make it more difficult to spot widespread trends or new problems connected to the food security being studied. Lack of data might also cause researchers to overlook significant contextual elements that could have an impact on the food security's study. This may result in a skewed or insufficient knowledge of the phenomena studied which is the food security problem. This may make it more difficult to draw judgements about how various variables may be related to the event under research.

5.4 Recommendations

First and foremost, government should promote collaborations governments between researchers and governmental or non-governmental organisations in order to address the problem mentioned above. Researchers may access current data sources and networks by collaborating with these institutions, and they can also interact with specialists that have specialised knowledge or skill in a certain field. In the meantime, government should also provide incentives to future researchers as a reward for motivating them to do research on this topic. Governments may encourage academics to prioritise data quality and dependability and can promote the advancement of new data sources and methodologies by supporting data collecting and analysis.

As a condition of getting money or publishing their findings, governments and other sponsors may demand that researchers make their data available to other researchers and the general public. By encouraging openness and enabling independent results verification, this can aid in enhancing the quality and trustworthiness of data. Moreover, other researchers will be able to conduct further analyses or repeat the investigation using identical information if the data are shared. This can produce fresh ideas, aid to confirm the initial findings, and help to spot any flaws or biases. Lastly, by removing the demand for researchers to gather fresh data for each study, publishing data can also increase research productivity. Researchers may build on prior research and provide fresh perspectives more quickly and affordably by making previously collected information available.

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Appendices

Appendix 1: Augmented Dickey Fuller Test (ADF)

Level Form: Intercept without Trend

Null Hypothesis: IN FOOD PRODUCTION INDEX has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.565199	0.9861
Test critical values:	1% level	-3.679322	
	5% level	-2.967767	
	10% level	-2.622989	

Null Hypothesis: LN_CO2 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.494496	0.9835
Test critical values:	1% level	-3.679322	
	5% level	-2.967767	
	10% level	-2.622989	

Null Hypothesis: IN FERTILITY RATE has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.358641	0.0219
Test critical values:	1% level	-3.699871	
	5% level	-2.976263	
	10% level	-2.627420	

Null Hypothesis: IN GDP_GROWTH has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.933999	0.0056
Test critical values:	1% level	-3.689194	
	5% level	-2.971853	
	10% level	-2.625121	

First Difference: Intercept without Trend

Null Hypothesis: D(IN_FOOD_PRODUCTION_INDEX) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.947191	0.0054
Test critical values:	1% level	-3.689194	
	5% level	-2.971853	
	10% level	-2.625121	

Null Hypothesis: D(LN_CO2) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.321886	0.0000
Test critical values:	1% level	-3.689194	
	5% level	-2.971853	
	10% level	-2.625121	

Null Hypothesis: D(IN_FERTILITY_RATE) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.744069	0.3984
Test critical values:	1% level	-3.711457	
	5% level	-2.981038	
	10% level	-2.629906	

Null Hypothesis: D(IN_GDP_GROWTH) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.979928	0.0000
Test critical values:	1% level	-3.699871	
	5% level	-2.976263	
	10% level	-2.627420	

Level form: Intercept with Trend

Null Hypothesis: IN_FOOD_PRODUCTION_INDEX has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.179567	0.8961
Test critical values:	1% level	-4.309824	
	5% level	-3.574244	
	10% level	-3.221728	

Null Hypothesis: LN_CO2 has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.554902	0.7859
Test critical values:	1% level	-4.309824	
	5% level	-3.574244	
	10% level	-3.221728	

Null Hypothesis: IN_FERTILITY RATE has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.264848	0.9973
Test critical values:	1% level	-4.339330	
	5% level	-3.587527	
	10% level	-3.229230	

Null Hypothesis: IN GDP GROWTH has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.053986	0.0183
Test critical values:	1% level	-4.323979	
	5% level	-3.580622	
	10% level	-3.225334	

First Difference: Intercept with Trend

Null Hypothesis: D(IN FOOD PRODUCTION INDEX) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.974572	0.0218
Test critical values:	1% level	-4.323979	
	5% level	-3.580622	
	10% level	-3.225334	

Null Hypothesis: D(LN_CO2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.329915	0.0001
Test critical values:	1% level	-4.323979	
	5% level	-3.580622	
	10% level	-3.225334	

Null Hypothesis: D(IN_FERTILITY_RATE) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.573042	0.0001
Test critical values:	1% level	-4.339330	
	5% level	-3.587527	
	10% level	-3.229230	

Null Hypothesis: D(IN_GDP_GROWTH) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.873086	0.0000
Test critical values:	1% level	-4.339330	
	5% level	-3.587527	
	10% level	-3.229230	

Appendix 2: ARDL Cointegration Bounds Test

Extension Model

ARDL Long Run Form and Bounds Test
Dependent Variable: D(IN_FOOD_PRODUCTION_INDEX)
Selected Model: ARDL(2, 3, 5, 4)
Case 2: Restricted Constant and No Trend
Date: 04/10/23 Time: 15:02
Sample: 1990 2019
Included observations: 25

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_CO2	-0.766422	0.194098	-3.948642	0.0055
IN_GDP_GROWTH	0.215860	0.051340	4.204500	0.0040
IN_FERTILITY_RATE	-0.491240	0.164732	-2.982055	0.0205
C	3.716643	0.272970	13.61556	0.0000

EC = IN_FOOD_PRODUCTION_INDEX - (-0.7664*LN_CO2 + 0.2159 *IN_GDP_GROWTH -0.4912*IN_FERTILITY_RATE + 3.7166)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	7.710795	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	25		Finite Sample: n=30	
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Appendix 3: Error Correction Model

ARDL Error Correction Regression
Dependent Variable: D(IN_FOOD_PRODUCTION_INDEX)
Selected Model: ARDL(2, 3, 5, 4)
Case 2: Restricted Constant and No Trend
Date: 04/10/23 Time: 15:04
Sample: 1990 2019
Included observations: 25

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IN_FOOD_PRODUCT...	1.407903	0.182576	7.711307	0.0001
D(LN_CO2)	-0.442233	0.132376	-3.340731	0.0124
D(LN_CO2(-1))	0.762342	0.145112	5.253489	0.0012
D(LN_CO2(-2))	0.517784	0.112400	4.606608	0.0025
D(IN_GDP_GROWTH)	0.032436	0.006241	5.197017	0.0013
D(IN_GDP_GROWTH(-1))	-0.291202	0.037707	-7.722680	0.0001
D(IN_GDP_GROWTH(-2))	-0.219660	0.028828	-7.619653	0.0001
D(IN_GDP_GROWTH(-3))	-0.136646	0.017293	-7.901813	0.0001
D(IN_GDP_GROWTH(-4))	-0.066012	0.008513	-7.754555	0.0001
D(IN_FERTILITY_RATE)	32.97954	5.956819	5.536435	0.0009
D(IN_FERTILITY_RATE(...	-18.31601	13.03636	-1.404994	0.2028
D(IN_FERTILITY_RATE(...	-53.04630	15.67640	-3.383832	0.0117
D(IN_FERTILITY_RATE(...	44.50016	8.157166	5.455345	0.0010
CointEq(-1)*	-1.722798	0.221336	-7.783625	0.0001

Appendix 4: Granger Causality Test

Pairwise Granger Causality Tests
Date: 04/10/23 Time: 15:05
Sample: 1990 2019
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
LN_CO2 does not Granger Cause IN_FOOD_PRODUCTION_INDEX	28	0.49833	0.6140
IN_FOOD_PRODUCTION_INDEX does not Granger Cause LN_CO2		7.53073	0.0030
IN_GDP_GROWTH does not Granger Cause IN_FOOD_PRODUCTION_INDEX	28	0.01050	0.9896
IN_FOOD_PRODUCTION_INDEX does not Granger Cause IN_GDP_GROWTH		0.24468	0.7850
IN_FERTILITY_RATE does not Granger Cause IN_FOOD_PRODUCTION_INDEX	28	3.82504	0.0368
IN_FOOD_PRODUCTION_INDEX does not Granger Cause IN_FERTILITY_RATE		8.69874	0.0015
IN_GDP_GROWTH does not Granger Cause LN_CO2	28	0.26279	0.7712
LN_CO2 does not Granger Cause IN_GDP_GROWTH		0.14684	0.8642
IN_FERTILITY_RATE does not Granger Cause LN_CO2	28	3.77721	0.0382
LN_CO2 does not Granger Cause IN_FERTILITY_RATE		12.9285	0.0002
IN_FERTILITY_RATE does not Granger Cause IN_GDP_GROWTH	28	3.86192	0.0358
IN_GDP_GROWTH does not Granger Cause IN_FERTILITY_RATE		0.78955	0.4660

Appendix 5: Variance Inflation Factor (VIF)

Variance Inflation Factors
Date: 04/10/23 Time: 15:38
Sample: 1990 2019
Included observations: 30

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
LN_CO2	0.008806	136.5697	3.198331
IN_GDP_GROWTH	0.000158	7.814278	1.133186
IN_FERTILITY_RATE	0.005358	73.95657	3.422980
C	0.022591	345.4908	NA

Appendix 6: LM Test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.872013	Prob. F(2,24)	0.1756
Obs*R-squared	4.048467	Prob. Chi-Square(2)	0.1321

Appendix 7: ARCH Test

Heteroskedasticity Test: ARCH

F-statistic	2.268840	Prob. F(2,25)	0.1243
Obs*R-squared	4.301456	Prob. Chi-Square(2)	0.1164