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Food Insecurity in Asia Pacific: Climate Change and Macroeconomic Dynamic

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Abstract

This study analyzes the effect of climate change and macroeconomic factors on food security in Asian Countries with moderate to weak food security ratings. This study finds significant findings using panel data from 14 countries in the Asia Pacific Region from 2012 to 2021. First, climate change variables measured by CO_2 carbon emissions significantly negatively impact food security. Increased carbon emissions can threaten crop production, alter rainfall patterns, and increase vulnerability to natural disasters. Second, macroeconomic variables such as agricultural value added, food price inflation, exports, and GDP per capita also show significant adverse effects. Global crises such as the COVID-19 pandemic, geopolitical conflicts, and U.S. monetary policy have impacted food prices, agricultural production, and per capita income, disrupting supply chains and increasing food security risks. However, the positive findings related to food imports and the Per Capita Production Index suggest that food imports can improve supply diversification, food availability, and food price stability, which are essential strategies for strengthening food security in the Asian Region. This research highlights the importance of carbon emission mitigation, macroeconomic crisis management, increased local food production, and import policies in facing the complex challenges of food security amidst climate change and global economic dynamics.

Keywords

Food insecurity, climate change, agricultural value added, food price inflation, gross production index per capita, agricultural net export.

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Introduction

Food security significantly impacts poverty reduction and is critical to social and economic development. Food security improves health and productivity by ensuring access to sufficient, safe, and nutritious food, helping families escape poverty. In developing countries, many poor people depend on agriculture, benefiting from the increased productivity catalyzed by food security, which directly increases their incomes. Food price stability, an essential component of food security, is significant for poor families who allocate a large proportion of their income to food, allowing them to plan their spending better and avoid food crises. Food security also enables investment in education, which is critical for future generations to fight poverty. In addition, food security increases resilience to economic crises and natural disasters, enabling poor families to survive in difficult conditions. Food security is essential in building national resilience and a fundamental cornerstone of economic development. Secure food production contributes to economic development by reducing poverty and inequality. Food security contributes to agriculture, tourism, and food processing, which is essential in attracting investment and economic growth (Naidanova and Polyanskaya, 2017).

By 2022, an estimated 51 million people are in crisis in Asia's five largest food-insecure countries. This is a significant increase from around 29 million in 2021. This increase is mainly due to the addition of Myanmar and Sri Lanka as countries experiencing major food crises (Food Security Information Network Required citation FSIN & Global Network Against Food Crises, 2023), accounting for more than 21 million people in acute food insecurity in 2022. Afghanistan faces the worst food crisis in Asia, with 39 percent of its regional population experiencing acute food insecurity, followed by Myanmar, Pakistan, Sri Lanka, and the Cox's

Bazar region of Bangladesh. The impact of the food crisis is inseparable from various variables, such as the primary trend of the subject of food crisis, namely global warming and climate change. (Lee, Wang, and Thinh, 2023; Lee, Zeng, and Luo, 2024; Yang and Hamori 2023). Especially in terms of extreme weather (de Amorim et al., 2018; Ledda et al. 2020, 2021) significantly affecting food production, including aspects of quality, price, and supply chain (de Amorim et al. 2018; Jin et al. 2023; Lee, Zeng and Luo, 2024). A broader focus on Food Security in research emphasizes the increase in global food crises and severe food insecurity in 2022, triggered by economic shocks, geopolitical situations, climate change, and extreme weather events. (Amiraslani and Dragovich, 2023; Ceballos, Hernandez and Paz, 2021; Chriest and Niles, 2018; Naidanova and Polyanskaya, 2017; Rice, Einbinder and Calderón, 2023).

Extreme weather (Aragie et al., 2023; Gebre and Rahut, 2021; Hadebe, Modi and Mabhaudhi, 2017) global supply chain risks such as the COVID-19 pandemic (Devereux, Béné and Hoddinott, 2020; Dietrich et al., 2022; Gerard, Imbert and Orkin, 2020; Sassi and Trital, 2023) and the war in Ukraine (Abay et al., 2023; Bechdol et al., 2022; Glauber and Laborde Debucquet, 2023; Mottaleb, Kruseman and Snapp 2022), as well as the energy crisis in recent years (Byerlee, Falcon and Naylor, 2017; Naylor and Higgins, 2018) rising and volatile agricultural and food prices (Amolegbe et al., 2021; Oluwaseyi, 2018; Shittu et al., 2017), has triggered instability in the agricultural sector. Triggering instability in the agricultural sector and increasing the risk of insecurity, as reported by the Food and Agriculture Organization (2023) and the World Trade Organization (2023), as well as country-level policies, continue to promote agricultural exports to stimulate economic growth in poor countries. However, market failure, infrastructure, investment, and supply chain issues are the main problems in food security issues in developing countries. A study conducted by Rudolf (2019) and Mgomezulu et al. (2023) shows that these investments contribute to poverty alleviation and improved food security.

This is achieved through increased agricultural production and sales, as found by the studies of Mutegi et al. (2024) and Samdrup et al. (2023). Such investments are also associated with increased demand for more diverse and nutritious food, as Sultana and Sadekin (2023) found. However, the influence of increased agricultural production as a significant factor of supply chain development on dietary diversity and food security among rural populations, especially in the Small Island Developing States (SIDS) region, has not been recognized (Santangelo, 2018; Songsermsawas et al., 2023; Syddall, Fisher and Thrush, 2022). Agricultural export policies lead to an increase in consumption and drive food security instability, the findings of several studies show the adverse effects of export policies on food security conditions in Low-Income Countries. The concerns of several researchers found that there is a potential neglect of small subsistence farms, which could result in a slowdown in productivity growth. At the same time, the dynamics of market integration support agricultural exports but there are trade-off effects between domestic food production and domestic markets (Campi, Dueñas and Fagiolo, 2020, 2021).

Agricultural policies significantly increase agricultural production and impact climate change risks. The trade-off between policies in increasing production capacity, such as increasing agricultural production land, agricultural technology, and farmer productivity (Lee, Wang and Thinh, 2023; Lee, Zeng and Luo, 2024; Yang and Hamori, 2023). Several studies have found that the impacts of increasing agricultural production, including greenhouse gas emissions, are often associated with increased fertilizer use, which can result in greenhouse gas emissions that impact climate change. Land use and expansion of agricultural land often means deforestation or other land conversion, which reduces CO_2 sequestration by vegetation, land use, deforestation, and carbon sequestration can show their impact on climate change.

According to Economist Impact (2022), the four main pillars of food security are availability, accessibility, utilization, and stability of the food system. Several studies have examined the relationship between climate change and food security. Some studies found an inverse relationship between climate change and food security, climate change can reduce food availability, especially in Sub-Saharan and South Asian regions where many nutritional problems occur (Affoh et al., 2022; Fuller et al., 2018; Stuch, Alcamo and Schaldach, 2021). Studies analyzed the impact of temperature variations on maize, wheat, and soybean production. The results showed that rising global temperatures adversely affect crop yields, leading to food shortages. Another study revealed that climate change reduces aquatic food production and crop productivity in Asia and Africa (Affoh et al., 2022; Chandio et al., 2023, 2022; Zhao et al., 2017).

Climate change negatively affects food availability, especially in Sub-Saharan Africa and South Asia. Climate change generally disrupts food production in Asia, but its impacts vary across regions. Several studies in the Asian region show the impact of climate change on food crop production in the South (Fahmida, Chaudhary, and Hanif 2022; Yan and Alvi 2022) with the findings that temperature and carbon emissions adversely affect long-term food crop production, while rainfall supports long-term food crop production in the region, climate change decreases cereal production, increases cereal prices, and decreases domestic consumption and income. The study further states that rising temperatures and carbon emissions significantly reduce long-term rice production in Asia. On the other hand, rainfall increases rice production in the Asian region in the long run. (Mumuni and Joseph Aleer 2023; Trnka et al. 2019).

Food security does not only depend on agricultural production, but several studies found that macroeconomic variables such as population, per capita income, poverty, exports, and imports have a significant effect on food security (Ceballos, Hernandez, and Paz 2021; Chriest and Niles 2018; Naidanova and Polyanskaya 2017; Rice, Einbinder, and Calderón 2023). In addition, findings from several studies show that population growth has a significant negative impact on food security in the short term and an insignificant negative impact on food security in the long term (Bakari, Mabrouki and Elmakki, 2018; Ceesay and Ndiaye, 2022; Sun and Zhang, 2021). Other macroeconomic indicators related to GDP per capita have varying findings; some studies found that an increase in GDP per capita positively impacts food security, while other studies show that economic growth in the agricultural sector determines food security in Asian and African countries. Other studies show that economic growth does not significantly affect food security in Low-Income Countries (Gnangnon, 2023; Sassi and Trital, 2023).

Materials and methods

This study uses climate change variables (CO_2 Carbon Emissions) and macroeconomic variables, namely (agricultural value added, food Price Inflation, Gross Production Index per capita, Agricultural Export and Import) to model the effect of climate change and macroeconomic variables on food security in Asian countries that have food security ratings categorized as having moderate and weak scores in the world food security index (Economist Impact, 2022). The panel data linear regression model analyzes the impact of climate change and macroeconomic variables on food security in 14 Asia Pacific countries from 2012 to 2021. The countries selected were Indonesia, Thailand, Azerbaijan, Philippines, India, Myanmar, Uzbekistan, Nepal, Tajikistan, Cambodia, Sri Lanka, Bangladesh, Laos, and Pakistan (Economist Impact, 2022). This method is thoroughly analyzed by considering variations between time and between countries. The econometric model specifications are as follows:

$$FS = f(CO2, VA, FPI, GPcap, EX, IMP)$$

Equation (1) is expressed in explicit and econometric form as follows:

$$FS_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 VA_{it} + \beta_3 FPI_{it} + \beta_4 GPCap_{it} + \beta_5 EX_{it} + \beta_6 IMP_{it} + \beta_7 GDPCap_{it} \varepsilon_{it}$$

Where FS = Food Security Index, β_0 = Constant, β_1- β_7 = Regression coefficient, VA = Added Value of Agriculture Sector, FPI = Food price inflation, $GPcap$ = Per capita production index, EX = export, IM = Import and $GDPcap$ = GDP per capita growth rate ε_{it} = error of term, i = 14 Asia Pacific countries, t = 2012-2021 period.

This model was estimated by comparing three approaches, namely the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). CEM assumes no differences between countries, with the same intercept for each country and time. FEM takes into account fixed differences between countries, with a different intercept for each country. REM assumes that differences between countries are random and uncorrelated with independent variables. To select the best model, the Chow test was carried out to compare CEM with FEM, the Hausman test to determine whether FEM or REM was more suitable, and the Lagrange Multiplier (LM) test to evaluate whether REM was better than CEM. If the test results show that differences between countries are fixed and significant, the FEM would be a better choice. On the other hand, if differences between countries are considered random and not correlated with independent variables, then the REM is more appropriate (Greene, 2012).

Several models were considered in the initial stages, including Pooled Mean Group (PMG) and Autoregressive Distributed Lag (ARDL), considering the potential for variables with mixed integration between I(0) and I(1). However, after testing stationarity using the Levin, Lin, and Chu (LLC), Im, Pesaran, and Shin (IPS), and Augmented Dickey-Fuller (ADF) methods, the results showed that all variables were stationary at level [I(0)]. Thus, this study does not apply the ARDL and PMG models, which are generally used for variables with mixed levels of integration. Instead, this research uses three main panel data regression models: the Common Effect Model, Fixed Effect Model, and Random Effect Model. To select the best model among the three models, Chow, Hausman, and Lagrange Multiplier tests were carried out. These models were chosen because they better fit the stationarity of the existing data, thus allowing the analysis of linear relationships between variables without considering long-term cointegration.

The panel data regression approach is very appropriate to apply in this research because panel data allows a more in-depth analysis by combining dimensions across time (time-series) and across units (cross-sectional) so that it can accommodate heterogeneity between units that cannot be observed through classical linear regression (Baltagi, 2005; Wooldridge, 2010). The CEM assumes no heterogeneity between units, so each unit is treated equally. The FEM, on the other hand, considers individual variation between units by including a specific intercept for each unit, so this model is used when specific differences between units can influence the dependent variable (Hsiao, 2003). The REM assumes that differences between units are random and uncorrelated with independent variables, making it more efficient if this assumption is valid (Baltagi, 2005; Greene, 2012).

To select the best model, statistical tests such as the Chow Test are used to compare CEM and FEM, the Hausman Test to differentiate between FEM and REM, and the Lagrange Multiplier Test to compare CEM and REM. Selecting the suitable model ensures that the model used accurately reflects the characteristics of the data. The use of panel data regression is based on its superiority in analyzing inter-unit heterogeneity and variable dynamics in the time dimension. Therefore, although the Compound Linear Regression Model (LRM) was considered, the panel nature of the data encouraged the use of the CEM, FEM, and REM models, which follow the econometric theory outlined by Baltagi, 2005; Wooldridge, 2010; Hsiao, 2003.

This study uses panel data from 14 countries in the Asia Pacific region, with the selection of countries based on the Global Food Security Index (GFSI) which calculates a country's food security score. This index assesses food security based on availability, accessibility, quality, and sustainability. The countries selected for analysis had a food security score ≥ 60, indicating the moderate to weak category according to the GFSI classification. In more detail, countries with a score of 60 to 69 are categorized as moderate, while countries below 60 are considered to have weak food security. The countries included in this study, such as Indonesia, Thailand, the Philippines, India, and Bangladesh, are in the moderate category. In contrast, countries such as Myanmar, Nepal, Laos, and Tajikistan tend to be in the weaker category. These countries face significant challenges related to food access and distribution, although they do not fall into the lowest category in terms of food security. The selection of countries with a score ≥ 60 focuses on countries that are in food security, which requires specific policies to increase food accessibility, improve distribution infrastructure, and increase resilience to climate change and economic crises.

Thus, climate change data (proxied by CO_2 carbon emissions from agricultural land use) in the Food and Agriculture Organization. While macroeconomic indicators (proxied by data on agricultural value added, food price inflation, per capita production index, Export and Import Index, and per capita GDP growth rate measured in percent) in the World Bank. Food security is measured using the World Food Security Index based on the four main pillars of food security: availability, accessibility, utilization, and stability of the food system (Economist Impact, 2022). Table 1 summarizes the variables described by symbol and measurement as follows:

Variables	Symbol	Measurement	Source	Scale
Food security	FS	Food Security is an index of global food security measured based on 4 pillars: availability, accessibility, utilization, and stability of the food system.	Economist Impact	Ratio
Carbon emissions	CO_2	Carbon Emissions is the percentage of carbon emissions resulting from agricultural production	Food and Agriculture Organization	Ratio
Value added in the agriculture sector	VA	Value Added is the distribution of agricultural production measured by the percentage of value added in the agricultural sector.	World Bank	Ratio
Food price inflation	FPI	Food price inflation is the rate of food price inflation as measured by percentage.	World Bank	Ratio
Per capita production index	GPCap	Agricultural Production is measured based on the index of agricultural production per capita	World Bank	Ratio
Export	EX	Agricultural sector exports are the total value of goods and services sold abroad, calculated using the ratio method to show the contribution of exports to the economy quantitatively	World Bank	Ratio
Import	IMP	Agricultural sector imports are the total value of goods and services purchased from abroad, measured accurately using a ratio scale to reflect the influence of imports on the agricultural sector economy.	World Bank	Ratio
GDP per capita growth rate	GDPCap	The GDP per capita growth rate is measured as the annual percentage change in GDP per capita, directly indicating the country's economic growth rate in the context of increasing output per capita.	World Bank	Ratio

Source: Own processing

Table 1: Definition and measurement of variables.

Results and discussion

The state of food security in the Asia Pacific region

Food security scores in the Asia Pacific region reflect challenges and successes that vary depending on the country and its context. Food security is measured based on several critical factors, including food availability, access to food, food utilization, and stability of food supply. Table 2 shows significant differences in food security among countries in the Asia Pacific region. The highest ranking of countries with a scoring category of "Good", countries such as Japan, New Zealand, Australia, China, Singapore, Kazakhstan, and South Korea show strong food security. Japan, with a score of 79.5, showed remarkable stability with no change from the previous year. New Zealand and Australia, with scores of 77.8 and 75.4, respectively, recorded improvements, especially in Australia, with a significant increase of 4.7 points. China and Singapore also increased their rankings. In the "Moderate" category, countries such as Malaysia, Vietnam, Indonesia, Thailand, Malaysia, and Vietnam. On the other hand, Indonesia and Thailand showed stable scores but signaled the need to continue improving food access and quality. India also recorded an improvement in its ranking.

Country	GOOD (Score 70-79.9)	Δ
Japan	79.5	0
New Zealand	77.8	0.4
Australia	75.4	4.7
China	74.2	3.6
Singapore	73.1	0.3
Kazakhstan	72.1	1.4
South Korea	70.2	1.3
MODERATE (SCORE 55-69.9)		
Malaysia	69.9	-1.6
Vietnam	67.9	+5.2
Indonesia	60.2	+0.4
Thailand	60.1	-2.0
Azerbaijan	59.8	-1.0
Philippines	59.3	-0.3
India	58.9	+0.5
Myanmar	57.6	-0.7
Uzbekistan	57.5	+3.0
Nepal	56.9	+1.8
Tajikistan	56.7	+2.3
Cambodia	55.7	+0.7
Sri Lanka	55.2	-0.3
WEAK (Score 40- 54.9)		
Bangladesh	54.0	+0.4
Laos	53.1	+4.1
Pakistan	52.2	+2.2

Source: Economist Impact, 2022

Table 2: scoring of food security in the Asia Pacific region.

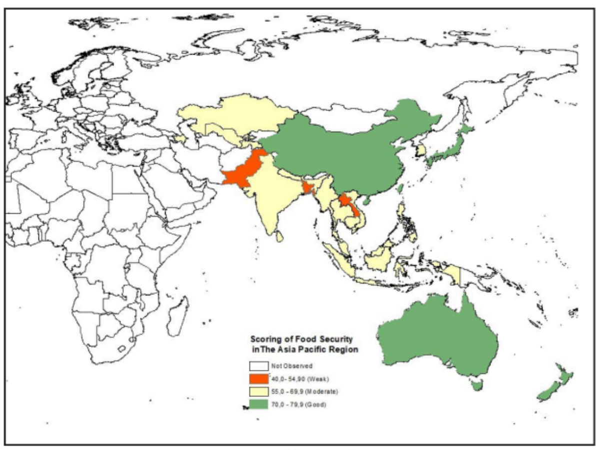
Changes in food security scores (Δ) in Asia Pacific show significant shifts in various countries. Australia recorded the largest increase with a 4.7 point increase, followed by Vietnam with a 5.2 point increase and Laos with a 4.1 point increase. Uzbekistan also experienced a significant increase of 3.0 points, while China increased 3.6. Several other countries, such as Kazakhstan and South Korea, showed moderate increases of 1.4 and 1.3 points, respectively. On the other hand, Malaysia experienced the most significant decline, with a decline of 1.6 points, followed by Thailand, which fell 2.0 points, and Azerbaijan, with a decline of 1.0 points. Slight declines also occurred in Myanmar and the Philippines, with 0.7 and 0.3 points respectively.

Although some countries are showing improvements in food security, others are still facing declines. Countries with "Weak" scores, such as Bangladesh (54.0), Laos (53.1), and Pakistan (52.2), face severe challenges in food security. Although Laos recorded an increase of 4.1 points and Pakistan rose 2.2 points, they remained below a score of 60, indicating a state of low food security and the need for further action to improve food access and stability. Food security scores are measured based on the Food Security Index, with a good score category symbolized by green, a moderate score category categorized by light gold, and a weak score category symbolized by orange (see Figure 1).

Econometric analysis

The test begins with stationarity testing of LLC, IPS, and ADF. The results of the Root Test show that Food Security, Carbon Emissions, Agricultural Value Added, Food Price inflation, Per capita Production Index, and Export are stationary at the level, so they are integrated at order zero [i.e., i.e./I(0)]. However, GDP per capita is not stationary at the first level, indicating that imports and GDP per capita growth rate are integrated in order one [i.e. I/(1)]. However, based on IPS and ADF tests show that all variables are stationary at the level integrated at zero order [i.e., i.e.,/I(0)] see Table 3, so based on these results, linear regression testing is carried out without applying ARDL.

After testing to determine the appropriate model between Multiple Linear Regression or Pooled Mean Group (PMG) and Autoregressive Distributed Lag (ARDL), the results in Table 1 show that ARDL cannot be used because all variables are stationary at the first level of difference (first difference) and integrated at zero order [I(0)]. The ARDL model is designed to estimate long-term relationships in data with a mixture of integration between I(0) and I(1), so it is inappropriate if all variables are stationary at the same level. Therefore, ARDL is unsuitable because it cannot accommodate long-term relationships with the variable I(0). In contrast, PMG and Multiple Linear Regression



Source: Data Economist Impact (2022), processed by the author

Figure 1: Map of food security classification in Asia Pacific.

Variables	Levin, Lin and Chu (LLC)	Im-Pesaran Shin (Social Studies)	Augmented Dickey-Fuller ADF)
FS	-2.89683***	-3.6687***	-4.53709***
CO_2	-7.3061***	-4.3995***	-4.24821***
FPI	-2.87622***	-3.28848***	-4.2477***
GpCap	-5.30612***	-3.23627***	-4.13324***
EX	-1.88558**	-3.02443***	-3.68188***
IM	0.3022	-1.96888**	-3.0649***
GDPcap	5.31898	-2.87735***	-2.47953**

Note: ****, **, and * indicate significance levels of 1%, 5%, and 10%, respectively
Source: Processed by the authors

Table 3: Panel Unit Root Test results.

models are considered because they are more suitable for panel data with stationary variables at the same level. PMG allows analysis that considers interunit heterogeneity in long-term and short-term dynamics. In contrast, Multiple Linear Regression focuses on estimating linear relationships without considering cointegration, making it more appropriate to use in this study. Testing was carried out by comparing three-panel data regression models, namely the CEM, FEM, and REM, using statistical tests such as the Chow Test, Hausman Test, and Lagrange Multiplier Test to determine the most appropriate model (see Table 3).

Although PMG and ARDL models were initially considered in the methodology, these models were not implemented because all variables were proven to be stationary at the [I(0)] level, so CEM, FEM, and REM were preferred adequately applied. ARDL and PMG are more appropriate to use when there are variables with a mixed level of integration between I(0) and I(1), which was not found in this study. The Common Effect Model estimation results show that the variables VA (Value Added), GPCAP (Gross Production Per Capita), EX (Exports), and GDPCAP (GDP per Capita) are statistically significant at the conventional significance level (p-value close to 0), indicating that These variables have a significant influence on the dependent variable, namely food safety. On the other hand, the CO_2 and IM (Import) variables are not statistically significant because they have a probability value greater than the significance level used. Adjusted R^2 of 0.659 indicates that this model can explain around 65.9% of the variation in the dependent variable.

Comparison of panel data regression results are analyzed in detail, namely (1) The results of the CEM: variables VA, GPCAP, EX, and GDPCAP show high levels of statistical significance (probability values close to 0,0000). This indicates that these variables strongly and significantly influence the food security variable. CO_2 and IM are not statistically significant in this model, characterized by probability values more incredible than the significant level. The Adj R_2 in the CEM shows a value of 0.659 indicating that this model can explain about 65.9% of the variation in the dependent variable, which is quite good but not optimal. (2) The results of the FEM show that the variables CO_2, VA, GPCAP, EX, IM, and GDPCAP show a high level of statistical significance (probability value close to 0,0000), while the FPI variable shows an insignificant effect with a probability greater than α. With a value of 0.8712, this model shows a better explanation (87.12%) of the variation in the dependent variable compared to the CEM, indicating that this model is more optimal in explaining the data. (3) The results of the REM test show that the variables VA, FPI, GPCAP, and GDPCAP are statistically significant with an ADJ R-value of 0.4505 lower than the FEM, indicating a lower explanation of the variability in explaining the food security variable. Based on the Chow Test results with a Prob value of 0.000 indicates a significant difference between the CEM and other models, so the FEM is more suitable. Based on the Hausman Test shows a Prob value of 1,000, which explains why the REM is more suitable. There is a difference in the test results so the last test is the LM test with the Breusch Pagan Test results, therefore the model chosen is the REM. The best selection in the panel data regression model is based on three tests: Chow, Hausman, and LM. However, statistical reviews such as the significance level of the t-statistic, F-statistic, and coefficient of determination are needed to determine the model's implications (Gujarati, 2004; Greene, 2012). Based on most variables' high adjusted R-squared value and statistical significance, the fixed effect model is the most suitable for theoretical implications.

Variables	Common Effect Model		Fixed Effect Model		Random Effect Model		Best Model Selection		
	Coefficient	Prob	Coefficient	Prob	Coefficient	Prob	Chow Test	Hausman Test	Breusch Pagan Test
CO_2	0.002109	0.7383	-0.064501	0.0138**	-0.01131	0.5008	0.000***	1	0.000***
VA	-0.239144	0.000***	-0.708028	0.000***	-0.47633	0.000***			
FPI	-0.070479	0.1101	-0.061181	0.223	-0.10467	0.001***			
GPCAP	0.100555	0.000***	0.07211	0.0007***	0.078341	0.021**			
EX	0.782864	0.000***	-2.726399	0.000***	-0.50586	0.2991			
IM	0.082492	0.7324	3.58967	0.0011***	1.517663	0.0345**			
GDPCAP	-0.220819	0.0008***	-0.132829	0.0031***	-0.16103	0.01480**			
C	37.308	0.000***	48.06736	0.0049****	41.0669	0.000**			
AdJ R^2	0.659		0.8712		0.4505				
Prob-F	0.000***		0.0000***		0.00000***				

Note: ****, **, and * indicate significance levels of 1%, 5%, and 10%, respectively
Source: Processed by the authors

Table 4: Model comparison results and best model selection.

Discussions

The results of the model selection show that the Fixed Effect Model was chosen as the model analyzed for the empirical discussion of the influence of climate change and macroeconomics on food security in the Asia Pacific Region. The results show that the climate change variable proxied by carbon emissions significantly negatively influences food security. In line with several findings, increasing CO_2 emissions and their impact on climate change have the potential to significantly impact food security in the Asian region. Rising global temperatures can threaten crop production, change rainfall patterns, and increase vulnerability to natural disasters that can potentially reduce food supplies. From the perspective of macroeconomic theory, this can be explained through the negative externality mechanism caused by carbon emissions, where an increase in carbon emissions functions as a negative supply shock which directly reduces the productivity of the agricultural sector. The Solow-Swan model with externalities demonstrates how climate change reduces total factor productivity (TFP), resulting in a decline in agricultural output and threats to food security. Another approach, namely the DSGE (Dynamic Stochastic General Equilibrium) model, integrates climate change into real sector equations and shows that climate change causes significant food disruptions in production through a decrease in the quality of production factors such as land and air, which directly reduces supply (de Amorim et al., 2018; Ledda et al., 2020, 2021; Lee, Zeng, and Luo, 2024; Lee, Wang and Thinh, 2023; Yang and Hamori, 2023).

Meanwhile, based on macroeconomic indicators, the variables of value added in the agricultural sector, food price inflation, exports, and GDP per capita statistically show a negative and significant influence on food security. This explanation aligns with the Phillips Curve theory, which states a negative relationship between inflation and unemployment. In this context, rising food price inflation, especially in developing countries, causes an increase in the cost of living which suppresses people's purchasing power and reduces aggregate demand, which in turn slows down economic growth. High inflation creates more significant economic uncertainty, reduces market confidence, and ultimately affects economic stability, directly impacting the food sector and food security.

The open IS-LM model explains how US interest rate policy, especially in the context of Quantitative Tightening (QT), causes capital outflows from Asian countries, which weakens their exchange rates. Exchange rate depreciation increases the cost of importing food and agricultural inputs, which ultimately reduces GDP per capita and reduces added value in the agricultural sector. This condition is explained by the health crisis conditions, namely COVID-19 19, the Ukraine-Russia war, and the Quantitative Tightening (QT) policy of the US central bank due to soaring inflation rates in the United States by increasing interest rates which led to weakening exchange rates in the Asian region which caused supply chains to be hampered, especially in food production. This crisis could not be contained by most countries in the Asian Region, especially Income Countries, so there was a surge in food prices which resulted in a decrease in the added value of the agricultural sector which reduced domestic food production and decreased GDP per capita. As described in several studies related to global supply chain risks such as the COVID-19 pandemic (Devereux, Béné and Hoddinott, 2020; Dietrich et al., 2022; Gerard, Imbert and Orkin, 2020; Sassi and Trital, 2023) and the war in Ukraine (Abay et al., 2023; Bechdol et al., 2022; Glauber and Laborde Debucquet, 2023; Mottaleb, Kruseman and Snapp, 2022), as well as the energy crisis in recent years (Byerlee, Falcon and Naylor, 2017; Naylor and Higgins, 2018) rising and volatile agricultural and food prices (Amolegbe et al., 2021; Oluwaseyi, 2018; Shittu et al., 2017), has triggered instability in the agricultural sector.

Triggering instability in the agricultural sector and increasing the risk of food crises. Hindered supply chains also lead to increased agricultural exports to meet the needs of other countries, resulting in trade-off effects that drive food security instability, the findings of several studies show the negative effects of export policies on food security conditions in Low-Income Countries findings show the potential neglect of small subsistence agriculture, which can result in slowing productivity growth, market integration supports agricultural exports, but there are trade-off effects between domestic food production and domestic foreign markets (Campi, Dueñas, and Fagiolo 2020, 2021). Food imports and per capita production index statistically positively influence food security in Asian countries by increasing supply diversification, sufficient food availability, and maintaining food price stability. When local production is insufficient to meet the community's food needs to encourage production balance and increase production, import policies are needed to encourage the per capita production index in the Asian region. This is in line with the findings of the increasing influence of agricultural production and imports as a significant factor of supply chain development on food diversity and food security among rural populations, especially in the Small Island Developing States (SIDS) region (Santangelo, 2018; Songsermsawas et al., 2023; Syddall, Fisher and Thrush, 2022).

Conclusion

The results of this study reveal some significant findings regarding the influence of climate change and macroeconomics on food security in the Asia Pacific Region. Climate change variables measured by carbon emissions significantly negatively impact food security. Increased carbon dioxide (CO2) emissions and climate change impacts can threaten crop production, change rainfall patterns, and increase vulnerability to natural disasters. Furthermore, macroeconomic aspects also have a significant influence on food security. Variables such as agricultural value added, food price inflation, exports, and GDP per capita show a significant negative influence. Global crises such as the COVID-19 pandemic conflicts such as the war in Ukraine, and monetary policies such as Quantitative Tightening (QT) in the United States impact food prices, agricultural production, and income per capita. This disrupts supply chains and increases food security risks. Empirical studies show that when the exchange rate weakens, countries that depend on food imports experience sharp increases in domestic food prices. This is because depreciation increases imported food prices, exacerbating price instability and threatening food security (Reboredo and Ugando, 2014). Thus, the QT policy in the US indirectly affects food prices in the Asian region through exchange rate transmission and increases in import costs.

Positive findings related to food imports and per capita production index. Food imports positively influence food security by increasing supply diversification, sufficient food availability, and maintaining food price stability. The research underscores the importance of reducing carbon emissions to address the impacts of climate change on food security and the importance of policies to improve food security in the face of macroeconomic crises. Increased local food production and optimized import policies are needed to ensure regional food security. Regional cooperation can also strengthen efforts to address food security issues amid the complexities of climate change and global economic dynamics.

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