

Examining the impact of climate change and economic growth on food security: Evidence from the G-7 countries

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Abstract:

The current study aims to analyse how climate change and economic growth influence food security. To this end, this paper utilizes a panel Autoregressive Distributed Lag (ARDL) approach and causality analyses on the G-7 countries from 1970 to 2021.

In the long run, both economic growth and mean temperature have a significant negative impact on food security, while precipitation has a positive but statistically insignificant impact. Whereas, short run analyses, showed that mean temperature has a negative but statistically insignificant impact on food security, mean precipitation has a negative and significant influence on food situation, and economic growth positively influences the food security. Based on these findings, several policy implications are suggested to mitigate the negative effect of climate variation on food situation in the G-7 nations.

Keywords: Mean temperature; Mean precipitation; GDP per capita; Food production index; Panel ARDL.

JEL Classification Codes: O13; Q54; Q15

1. INTRODUCTION

Food security (FS) is a key factor in social and economic sustainability. Scholars have devoted much research to exploring what drives FS, focusing often on climate change (CC) and economic growth (EG). The multiple dimensions of CC related to FS and the difficulty in measuring impacts has meant that this remains a contested issue (Rutten, Van Dijk, Van Rooij, & Hilderink, 2014; Santangelo, 2018; Warsame, Abdukadir Sheik-Ali, Hassan, & Sarkodie, 2024). Over the years, researchers have used temperature, precipitation and carbon emissions as proxies for CC (Adedoyin, Bein, Gyamfi, & Bekun, 2021; Okeke-Ogbuafor, et al., 2024; Oyelami, Edewor, Folorunso, & Abasilim, 2023). Increasing crop losses because of reduced yields; evaporation increases in more arid regions, making water supply scarcer and therefore less predictable; soil degradation wreaks havoc on scores of croplands for which food production is essential; hugely expensive fish protein markets disintegrate into what can only be described as competing circular arguments (Chen, Yao, & Wang, 2023). On the other hand, precipitation within the same region is likely to be an important determinate for food availability. According to (Saleem, et al., 2024) several studies have established that the world is already experiencing CC shifts. The main causes of climate alternation is the emission of greenhouse gases in general.

There is ample evidence that EG as a primary factor for improving FS (Agboola, Bekun, Osundina, & Kirikkaleli, 2022; Kinda & Badolo, 2019). These can increase income and purchasing power, investing in agriculture itself, improving infrastructure for production, environmental services or indirect effects on food safety / quality as well expand social protection programs. Nevertheless, a small number of studies have actually investigated how both exacerbated CC and increased EG may affect FS.

The article herein reviews the dynamics and mainstream areas of research linkages between climate change, EG and FS at global level. To our knowledge, this is the first study that very broadly tackles these problems in 50year period and on G7 countries scale. The research addresses the following question: What is the impact of CC and EG on FS

in the G-7 countries from 1970 to 2021? The importance of this study lies in clarifying to what extent CC is going wrong with respect to EG and FS.

To this end, after conducting data pre-testing-especially given that the G-7 countries are known for their rapidly growing economies-there is a possibility of cross-sectional dependency problems. Since a shock in one country can quickly affect others, it is necessary to apply cross-sectional dependency (CSD) tests. Following this, the study investigates the short- and long-term effects on FS by employing the panel Autoregressive Distributed Lag (ARDL) model, marking the first time this approach has been used in the G-7 countries. Moreover, a causality analysis is performed to further understand the direction of causality. This examination of the interactions in both short and long run can shed light on extant literature as well as be useful for policy making to shape economic policies leading towards better FS situation not only at G-7 countries level but also across globe.

Part two of this research offers a literature review. Data and methodology are presented in part three. Empirical findings and discussion of the main results are presented in part four. Finally, conclusion, policy implications are presented in section five.

2. Literature review

Over the past decades, there has been a growing body of academic literature that examines FS and its interaction with several economic, social, and climatic phenomena across different regions and periods. The purpose of this section is to synthesize the most recent literature the focused on the interaction between climate change, economic growth, and FS. Additionally, it provides an overview on the variables used by scholars to reflect our variables of interest. Finally, we aim to shin the light and identify gaps in the literature that our research can address.

2.1 Climate change and food security

FS has four aspects namely availability, accessibility, utilization, and stability, which all of them are venerable for CC fluctuations. Availability denotes the physical disposal of sufficient amount of food through local production, importation, or food aid programs (Edoja, Aye, & Abu, 2016). This aspect emphasizes the supply side. Accessibility stands for the

capability of individuals to secure necessary quantities of food, either through purchase, exchanging, or other ways. This aspect is impacted by income, food price, and market situation. Utilization involves the appropriate utilization of food, including its nutritional content and the body's capacity to metabolize it (Hadley, Talbott, Reddy, & Wheat, 2023). Stability stands for consistency of the pervious factors over time and not being disrupted by any climate, social, or economic challenges (Bouteska, Sharif, Bhuiyan, & Abedin, 2024).

It is established over the last years that CC has a significant effect on FS. For instance, (Van Oort & Zwart, 2018) found that rising temperature negatively influences the FS in Africa. The increasing temperature observed in the last decades caused food insecurity through several mechanisms, including crop yields reduction, increased water vaporization, soil degradation, livestock stress, and food supply chain disruption. Additionally, (Kinda & Badolo, 2019) estimated the effect of rainfall variability on FS for 71 developing countries and found that such variability has a negative effect on FS, especially in countries that depend on rain-fed agricultural. While precipitation enhance food availability, precipitation variability hinder food situation.

In the same vein, (Warsame, Abdukadir Sheik-Ali, Hassan, & Sarkodie, 2024) examined the impact of CC of FS by the means of ARDL approach and causality analyses. The findings showed that, in the long run, temperature has a negative significant impact, whereas precipitation has a positive and insignificant effect on food availability. In the short run, both CC variables were statistically in significant. Furthermore, the time-varying Granger causality test suggested that temperature and precipitation were responsible for two episodes of causality, the first one occurred between 1990 and 1992 and again between 2011 and 2012.

As aforementioned, CC variables, such as high temperature, can hinder the FS by crop yields reduction, increased water vaporization, soil degradation, livestock stress, and food supply chain disruption. On the other hand, precipitation variability is expected to enhance food availability.

2.2 Economic growth and food security

Recent scholarly research has focused on exploring the interaction

between EG and FS. As an illustration, (Agboola, Bekun, Osundina, & Kirikkaleli, 2022) employed several different econometric methods to investigate the interrelationship between EG and agricultural sector as a primary source of FS in Nigeria. a positive significant impact of crop production on EG is found. Moreover, Granger causality analyses suggested the presence of a unidirectional causality from crop production to economic growth. These findings are supported by (Santangelo, 2018) and (Lv, et al., 2022) in the case of China.

Furthermore, (Ntiamoah, et al., 2023) examined the impact of CO₂ emissions, economic growth, trade openness, agricultural employment, and population growth on FS in East Africa between 1990 and 2020. The authors used GDP growth as a measure of EG and the food production index as a proxy for FS. The FMOLS results indicated that EG has a positive long-term impact on FS; however, causality analysis revealed no causal relationship between these two variables. In contrast, (Alsaleh & Abdul-Rahim, 2023) assessed the impact of geothermal energy on FS, measured by food supply levels, in selected European countries. Their model also included variables such as economic growth, institutional quality, and population density. Using the ARDL model, they found that EG has a significant positive effect on FS in the long run, though it is insignificant in the short run.

Economic growth, as shown previously, can be a source of enhancing FS in nations. This positive effect can transfer through several mechanism such as, increased income and purchasing power of individuals, Investment in Agriculture, Improved Infrastructure, Enhanced Food Safety and Quality, and Social Safety Nets and Programs.

2.3 The interaction between climate change, economic growth, and food security

When conducting a literature review, especially empirical studies we found that relatively few have examined the simultaneous effect of CC and EG on FS. Among these studies, (Kinda, 2021), having analyzed the impact of various macroeconomic variables on FS, specifically focusing on food availability and the proportion of undernourished people in Sub-Saharan Africa. Utilizing a two-step Generalized Method of Moments (GMM)

model, the study considered CC and economic growth, represented by precipitation and GDP growth per capita, respectively. The findings indicate that both variables have a positive impact on food availability.

In the same vein, (Ceessay & Ndiaye, 2022) analyzed the impact of CC peroxide by the average annual rainfall, agricultural sector size reflected by the Agriculture valued added of agriculture, and EG measured by GDP per capita on the food situation in Gambia. The authors employed several methods such as ARDL, Error Correction Approach (ECM), Vector Autoregressive Approach (VAR) and Granger causality analyses to get detailed insights on the long and short run relationship in addition to the direct and indirect effect between the model variables.

The short and long run relationship outcomes established several important results. In the short run, an alteration in the FS variable on its own lag is negative and significant, CC has a positive insignificant impact, and EG had negative significant effect on FS at one lag. In the long run, both CC and EG have a positive nonsignificant impact on food situation. Furthermore, based on the VAR results, CC and EG have a negative significant impact on FS at one lag. Moreover, the Granger causality test revealed a bi-directional relationship between CC and FS, and a unidirectional relationship between FS and economic growth.

(Suryanto, Trinugroho, Susilowati, Aboyitungiye, & Hapsari, 2023) study aimed to analyze the interaction between CC terms of rainfall and rainy days, EG in terms of GDP, and population growth on food situation in for 22 cities in Central Java Indonesia from 2018 to 2020. The outcomes of the study suggested that the CC in terms of rainy days has a positive significant effect on FS while EG had a positive insignificant impact on FS. More recently, (Łacka, Suproń, & Szczepaniak, 2024) employed Feasible Generalized Least Squares (FGLS) approach with robust standard errors and a Quantile Regression (QR) approach on dataset of European Union countries. The authors analyzed the impact of CC reflected by average annual temperature and average annual precipitation and EG measured by constant GDP per capita on cereal production per hectare as a FS index. The empirical outcomes supported the findings found by the previous researchers.

2.4. Literature gap

Based on the literature review, it is evident that the impacts of CC and EG on FS are varied and complex. However, existing studies have not sufficiently explored this relationship using symmetric analyses, particularly in the context of long- and short-run dynamics. Therefore, the current study proposes the adoption of a panel ARDL approach to gain deeper insights into the nature of these relationships in both the long and short run relationship. This study focuses on the G-7 countries, as, to the best of our knowledge; no researcher has yet examined this relationship in these nations. Furthermore, the availability of 50 years of data provides a unique opportunity for robust analysis. Additionally, we will employ causality analyses to offer a more detailed understanding of the interconnections between climate change, economic growth, and FS in these countries.

3. Methodology

3.1 Data and variables

Using yearly observations data, the current study examined how the G-7 countries FS (food production index) situation was affected between 1970 and 2021 by CC factors (mean annual temperature and mean annual precipitation) and EG (constant GDP per capita). Mean annual Temperature (MT) and Mean annual Precipitation (MP) are gathered from Climate Change Knowledge Portal (CCKP), where the food production index and GDP per capita are from the World Development Indicators (WDI). Table 1 offers a more detailed description of the chosen variables, unit of measurement, their assigned abbreviations, and their data source.

Table 1. Variables description

Variables	Description	Unit of measurement	Source
FS	Food Security	food production index (2014–2016 = 100)	WDI
MT	Mean annual Temperature	°C	CCKP
MP	Mean annual Precipitation	mm	CCKP
GDP	Gross Domestic Product	GDP per capita in constant 2015US\$	WDI

Source: Authors' own construction

3.2 Theoretical framework

The purpose of this study is to explore the impact of CC and EG on FS in G-7 countries for 1970 to 2021 period. Following the previous empirical literature review on FS (Benmehaia, 2023; Kinda & Badolo, 2019), we employ the following equation:

$$LFS_{nt} = \alpha_0 + \alpha_1 LMT_{nt} + \alpha_2 LMP_{nt} + \alpha_3 LGDP_{nt} + \varepsilon_{nt} \quad (1)$$

Where LFS_{nt} denotes the log of FS, LMT_{nt} is the log of mean annual temperature, LMP_{nt} is the log of mean annual precipitation, $LGDP_{nt}$ is the log of GDP per capita, and ε_{nt} is the error term.

In this study we measure FS with food production index following the work of (Ceesay & Ndiaye, 2022) due to the availability in a long time period, which give us more insights on the interaction between FS and explanatory variables.

Secondly, primarily CC is reflected in several variables such as temperature, perception, and carbon emissions (Kumar, 2021). In this exercise, we proxy the CC with mean annual temperature and mean annual perception following by this the work of (Niles & Mueller, 2016) and (Benmehaia, 2023). Finally, the economic situation in the G-7 countries in our model is reflected by the GDP per capita in constant US\$ as it argued by (Yaqoob, et al., 2023).

3.3 Econometric framework

This study aims to analyze the impact of CC and EG on FS in the G-7 countries. The panel ARDL approach and causality analyses are employed to get insights on the relationship between the latter variables. Given that the G-7 countries are known to have the fastest growing economies globally, there is the possibility of cross-sectional dependency problem.

Since the presence of a shock in one country can rapidly affects others, necessitating the application of CSD tests. To this end, the (Pesaran, Shin, & Smith, 2021) and (Pesaran, 2007) CSD test is applied to the data. This test gives accurate results in both cases, whether N is greater than T or T is greater than N. The next step will be the application of slope homogeneity test, which is an important step when dealing with panel data. we employ the slope homogeneity test proposed by (Pesaran & Yamagata,

2008) sometimes referred to as “Delta test”.

Thirdly, after the results of CSD and slope homogeneity are verified we will apply either the first generation unit root tests or the second-generation unit root tests. To assess the stationarity characteristics of our time series under investigation, we can employ panel unit root tests such as the Im, Pesaran, and Shin test proposed by (Im, Pesaran, & Shin, 2003) or Levin, Lin, and Chu (LLC) developed by (Levin, Lin, & Chu, 2002) or several others commonly known by the first generation tests. Moreover, we can adopt the Augmented Im, Pesaran, and Shin (CIPS), which is an augmented version of Im, Pesaran, and Shin test, and Cross-sectionally Augmented Dickey-Fuller (CADF) developed by (Pesaran, 2007). The main difference between the previous two generations tests is that the second-generation unit root tests demonstrate greater power and robustness in the presence of CSD problem and slope heterogeneity.

Fourth, after confirming the outcomes of CSD tests and determining the order of time series integration, appropriate tests will be applied to assess the presence of cointegration between the time series. Several cointegration can be applied to test the long run relationship between panel time series. In this study we employ one of the commonly used panel cointegration test by econometricians, which is (Westerlund & Edgerton, 2007) test.

Fifth, to explore the relationship in the long and short run between time series variables we employ the ARDL bound test approach. This approach was first proposed by (Pesaran, 2007) and later developed by (Pesaran, 2015) as an effective approach to explore the long and short run relationship between times series. In this study, we adopt the ARDL approach to investigate the impact of CC and EG on FS situation in G-7 countries. One of the strong features of panel ARDL that it allows for heterogeneity across units thus allowing for the capture of economic and technological differences between seven countries in our sample.

In contrast to the other panel data approaches, panel ARDL permits different lag structure for each variable, thereby making it possible to capture the unique temporal dynamics for each country. Such flexibility is key to understand the effect of CC and EG on FS across our sample.

Additionally, panel ARDL is capable of accommodating variables of different integration orders (I (0) and I (1)) and endogeneity issues. Furthermore, the error correction model in the ARDL approach give robust estimation on the speed of adjustment towards long run equilibrium, providing valuable policy insights on how effectively G-7 countries can tackle FS challenges. As shown in equation below, the long run ARDL estimate is calculated as follows:

$$LFS = \alpha_0 + \alpha_1 LFS_{t-1} + \alpha_2 LMT_{t-1} + \alpha_3 LMP_{t-1} + \alpha_4 LGDP_{t-1} + \sum_{i=1}^m \beta_1 \Delta LFS_{t-i} + \sum_{i=1}^m \beta_2 \Delta LMT_{t-i} + \sum_{i=1}^m \beta_3 \Delta LMP_{t-i} + i=1m\beta_4\Delta LGDP_{t-i} + \varepsilon_t \quad (2)$$

The presence of cointegration, as suggested by the alternative hypothesis, is evaluated against the null hypothesis that assumes no cointegration. The null hypothesis, which states that all β_i are equal, is rejected if the F-statistic is greater than the upper and lower bounds.

The error correction model (ECM), proposed by (Engle & Granger, 1987), is employed to assess the error correction term and short run coefficients. The panel ARDL estimate employing error correction representation represents the short run interactions between the model variables in the following equation:

$$LFS = \beta_0 + \sum_{i=1}^m \beta_1 \Delta LFS_{t-i} + \sum_{i=1}^m \beta_2 \Delta LMT_{t-i} + i=1m\beta_3\Delta LMP_{t-i} + i=1m\beta_4\Delta LGDP_{t-i} + \vartheta ECT_{t-1} + \varepsilon_t \quad (3)$$

Where ϑ is the change rate.

Lastly, we will test the causality direction between the dependent and independent variables. For this reason, we employ causality test developed by (Dumitrescu & Hurlin, 2012) to explore the existence and direction of causality, primarily focusing on the causality between dependent variable and independent variables in our model. This test is more robust than panel Granger causality test in case of CSD between the G-7 countries.

4. Results and discussion

4.1 Descriptive statistics

Table 2 shows the main descriptive unidimensional statistics of the dependent and independent variables. Based on the central tendency and dispersion indicators, the FS variable has a mean of 91.25 with a standard

deviation of 16.7. CC variables mean temperature and precipitation averages are 8.43°C and 1023.65 mm with a standard deviation of 5.34°C and 349.98 mm, respectively. Economic growth's variables average is 31987.92 and a standard deviation of 9405.379 constant US dollars. Furthermore, measures of asymmetry are provided.

Table 2. Descriptive statistics

	FS	MT	MP	GDP
Mean	91.25448	8.438489	1023.650	31987.92
Median	96.13500	9.830000	931.3750	31260.21
Maximum	120.0900	13.86000	2342.530	61330.65
Minimum	41.83000	-6.830000	611.9500	14114.32
Std. Dev.	16.69791	5.340232	349.9844	9405.379
Skewness	-1.108960	-1.750293	1.498961	0.548709
Kurtosis	3.615881	4.633733	4.550412	3.204557
Observations	364	364	364	364

Source: Authors' own construction

4.2 Cross-sectional dependency tests

Before any further statistical analyses, it is necessary to test the presence of cross-sectional dependency. Three main cross-sectional dependency are employed in this study namely Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD. The main hypothesis tested is the absence of cross-sectional dependency. The results showed in table 3 all calculated p-values for the three tests are less than 0.05% this result confirms the existence of cross-sectional dependency problem between the countries dues to the strong evidence against the null hypothesis.

Table 3. Cross-sectional dependency results

Test	Statistic	d.f.	p-value
Breusch-Pagan LM	368.1472	21	0.0000
Pesaran scaled LM	53.56598		0.0000
Pesaran CD	5.528968		0.0000

Source: Authors' own construction

4.3 Slop homogeneity test

Following the cross-sectional dependency tests, it is important to test the slop homogeneity. This statistical test is used to investigate if the slope

coefficients in different regressions are equal across the countries and in our study across the G-7 countries. Table 4 shows the results of (Pesaran & Yamagata, 2008) test, which test the null hypothesis of homogeneity of slopes, according to the results there is strong evidence that the slopes are heterogeneous across the G-7 countries over the study period.

Table 4. Slop homogeneity results

Delta	p-value
24.339	0.000
25.601	0.000

Source: Authors' own construction

4.4 Unit root tests

Since there is a cross-sectional dependency problem in the data, the first-generation tests of unit root tests are not compatible with the data characteristics and it can lead to a false result. Hence, we must employ second-generation unit root tests that encounter for the cross-sectional dependency between variables. The CIPS unit root test, as shown in table 5, indicates that none of the study variables is integrated of the second order. Moreover, the results indicates that the variables have a missed integrated order, with the FS variable Integrated of the first order. Meaning that the application of panel ARDL is possible.

Table 5. Panel unit root tests results

	I(0)		I(1)		Decision
	cnt	Cnt & trend	cnt	Cnt & trend	
FS	-1.438	-3.609	-6.190***	-6.420***	I(1)
MT	-5.819***	-6.349***	-6.190***	-6.420***	I(0)
MP	-5.781***	-6.064***	-6.190***	-6.420***	I(0)
GDP	-1.287	-2.215	-4.763***	-4.840***	I(1)

Note: ***, **, and * stands for 10%, 5%, and 1% significance level respectively.

Source: Authors' own construction

4.5 panel cointegration tests

As aforementioned, the presence of cross-sectional dependency between variables also impacts the results of traditional cointegration tests, therefore it is best to employ more developed tests. Table 6 presents the results of (Westerlund & Edgerton, 2007) test for cointegration, which takes

in account the presence of cross-sectional dependency between variables. We tested the presence of cointegration for some panels and for all the panels and found that there is cointegration. In other words, the series have a long run relationship between them.

Table 6. Cointegration results

Co-integrating vector	Test	Stat.	p-value	Decision
Some panels are co-integrated	Variance ratio	4.48	0.000	The series are co-integrated
All panels are co-integrated	Variance ratio	3.78	0.001	

Source: Authors' own construction

4.6 Estimation of panel ARDL

Table 7 displays the estimated results for both short- and long-run outcomes. The results indicate that while mean temperature has a negative but statistically insignificant effect on FS in the short run, it shows a significant negative impact in the long run. Specifically, a 1% increase in mean temperature is associated with a 6.32-unit decrease in FS. (Warsame, Abdukadir Sheik-Ali, Hassan, & Sarkodie, 2024) suggests that higher temperatures hinder FS by reducing crop yields, increasing water evaporation, degrading soil quality, stressing livestock, and disrupting food supply chains. Contrarily, (Chandio, Jiang, Rehman, & Rauf, 2020) found that in Turkey, rising temperatures improved the food situation in both the short and long term. Similarly, (Senapati, 2022) reported comparable findings for East India. These findings imply that elevated temperatures exacerbate food insecurity in G-7 countries more significantly over the long term than in the short term. This suggests that short-term policies aimed at mitigating the impact of temperature on FS may be effective in the near term but are insufficient in the long run.

The results also indicate that while the precipitation variable has a negative and significant effect on FS in the short run, it shows a positive but statistically insignificant impact in the long run. Specifically, a 1% increase in precipitation reduces FS by 0.006 units in the short term. These short-run findings align with those of (Chandio, Jiang, Rehman, & Rauf, 2020) for China and (Nasrullah, et al., 2021) for South Korea, where both authors suggest that the negative association is due to extreme rainfall events, such as heavy rain days or prolonged periods of precipitation, particularly

outside of normal seasons. In contrast, the positive relationship observed in the long run is consistent with the findings of (Chandio, Jiang, Rehman, & Rauf, 2020) and (Zouabi, 2022), who used the ARDL approach. This indicates that the negative impact of precipitation has been effectively managed over time, as reflected in the low coefficient estimated by the ARDL results. In addition, the estimated positive and insignificant effect in the long run suggests that G-7 countries have developed a resilient agricultural sector that is not severely impacted by variations in precipitation.

The estimations suggested that while EG has a positive effect on the food situation in the short run, it exhibits a negative influence in the long run. Specifically, a 1% rise in EG enhance the food situation by 0.000848 units in the short run. However, in the long run, this impact reverses, with a 1% increase leading to a -0.003 unit decline in FS in the G-7 countries. These results are statistically significant in both short and long terms. The results of the short run relationship align with those of (Agboola, Bekun, Osundina, & Kirikkaleli, 2022), who found the same effect in Nigeria, as well as studies by (Santangelo, 2018) and (Lv, et al., 2022) in the case of China. In contrary, the long run results are contrast with the previous studies. Notably, (Ceesay & Ndiaye, 2022) found a similar negative impact in Gambia. This may be due to fact that sustained EG often accompanies high carbon emission and shifts in consumption habits that can ultimately increase food insecurity. Finally, the error correction term is negative and statistically significant at 1% level and it suggests that the correction time takes about 0.13 unit.

Table 7. Short and long run panel ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Panel A: Long Run Equation				
MT	-6.316906	2.805065	-2.251964	0.0251
MP	0.018335	0.013899	1.319148	0.1882
GDP	-0.003332	0.001108	-3.007234	0.0029
Panel B: Short Run Equation				
COINTEQ01	-0.131654	0.043727	-3.010854	0.0028
D(FD(-1))	-0.381161	0.095461	-3.992868	0.0001

D(FD(-2))	-0.333877	0.082460	-4.048960	0.0001
D(FD(-3))	-0.194768	0.082940	-2.348305	0.0195
D(FD(-4))	-0.145012	0.053422	-2.714445	0.0070
D(MT)	-0.470248	0.415624	-1.131427	0.2588
D(MP)	-0.006392	0.001765	-3.621186	0.0003
D(GDP)	0.000848	0.000274	3.090856	0.0022
C	26.16552	8.391222	3.118202	0.0020
TREND	0.262944	0.100486	2.616738	0.0093

Source: Authors' own construction

4.7 Causality analyses

As a final step to conclude our empirical investigation and after establishing a long and short relationship between our dependent and independent variables, we proceed to causality analyses. The D-H causality test, as shown in table 8, outputs revealed that there is a significant unidirectional causality between FS and mean temperature at the 1% level. Similarly, a unidirectional causality is established between FS and precipitation at the 1% level. In other words, the study confirmed the existence of a unidirectional causality between FS and CC in the G-7 countries over the last 50 years. Although these results may appear counterintuitive, similar findings have been reported by (Ceesay & Ndiaye, 2022). This causal relationship can be attributed to the replacement of agricultural land with urbanized areas can negatively impact CC by increasing greenhouse gas emissions (Sun & Zhang, 2021), contributing to biodiversity (Hadji-Lazaro, et al., 2024), and exacerbating the urban heat island effect (Taha, 2015). Additionally, there is no significant causality between FS and economic growth. Interestingly there is a unidirectional causality between EG and mean temperature, which can be explain by the environmental degradation in the G-7 countries over the last half century. This finding is aligned with (Orhan, Adebayo, Genç, & Kirikkaleli, 2021).

Table 8. D-H causality results

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
$MT \Rightarrow FS$	4.68265	0.38245	0.7021
$FS \Rightarrow MT$	7.54053	2.72574	0.0064
$MP \Rightarrow FS$	4.32119	0.08608	0.9314
$FS \Rightarrow MP$	7.44330	2.64603	0.0081

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<i>GDP</i> $\Rightarrow$ <i>FS</i>	3.01570	-0.98436	0.3249
<i>FS</i> $\Rightarrow$ <i>GDP</i>	5.39846	0.96937	0.3324
<i>MP</i> $\Rightarrow$ <i>MT</i>	3.64724	-0.46652	0.6408
<i>MT</i> $\Rightarrow$ <i>MP</i>	3.61588	-0.49224	0.6225
<i>GDP</i> $\Rightarrow$ <i>MT</i>	13.5566	7.65860	2.E-14
<i>MT</i> $\Rightarrow$ <i>GDP</i>	2.82213	-1.14307	0.2530
<i>GDP</i> $\Rightarrow$ <i>MP</i>	5.41558	0.98341	0.3254
<i>MP</i> $\Rightarrow$ <i>GDP</i>	4.33336	0.09605	0.9235

Note: $\Rightarrow$ is the direction of causality.

Source: Authors' own construction

5. CONCLUSION

This research investigates the effect of two dimensions of CC variables mean annual temperature and mean precipitation and EG on FS in the G-7 nations from 1970 to 2021. After finishing the pre-tests on the data, the research employed Panel Autoregressive Distributed Lag (ARDL) approach to investigate both short and long run effects. The results indicate that while mean temperature has a negative but statistically insignificant effect on FS in the short run, it shows a significant negative impact in the long run. While the precipitation variable has a negative and significant effect on FS in the short run, it shows a positive but statistically insignificant impact in the long run. EG has a positive influence on the food situation in the short run, it exhibits a negative effect in the long run. Finally, the causality direction between the variables was examined using the D-H causality test. According to the outcomes of this test, there is a unidirectional causality from FS to CC and no causality between EG and FS.

As policy implications, after establishing that temperature has a negative but statistically insignificant effect on FS in the short run, it shows a significant negative impact in the long run. This suggests that short-term policies aimed at mitigating the effect of temperature on FS may be effective in the near term but are insufficient in the long run. Policymakers must therefore reassess and strengthen these policies, considering that over the past 50 years, temperature variables have had the most significant impact on FS in G-7 countries.

For precipitation variable, it is found that it has negative and significant effect on FS in the short run, it shows a positive but statistically insignificant impact in the long run. This indicates that the negative impact of precipitation has been effectively managed over time, as reflected in the low coefficient estimated. In addition, the estimated positive and insignificant effect in the long run suggests that G-7 nations have developed a resilient agricultural sector that is not severely impacted by variations in precipitation. In other words, the G-7 countries have improved their water management practices, developed irrigation system, enhanced drought resistant crops, and diversified food supply chains.

Finally for the EG variable, while it has a positive influence on the food situation in the short run, it exhibits a negative effect in the long run. This may be due to fact that sustained EG often accompanies high carbon emission and shifts in consumption habits that can ultimately increase food insecurity. Therefore, policy makers should keep working on the transition emission free economy to reduce the impact on the environment.

Although this research provides several significant insights into the relationship among climate change, economic growth, and FS, it is important to acknowledge its limitations. This research uses only two variables reflect CC variable, though a more comprehensive approach could involve constructing variable that encompasses different dimensions of CC to better measure its impact on FS. Additionally, the econometric model does not include structural changes that occurred between 1970 and 2021, potentially omitting valuable insights. Future studies should consider incorporating other exogenous variables that may influence the relationship between our main variables.

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