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# FOOD SECURITY, CLIMATE CHANGE CONCERNS AND AGRICULTURE COMMODITIES



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**Abstract**

This paper aims to examine the impact of climate change concerns on agricultural commodity prices within the context of food security. We use the Climate Change Concerns Index to proxy climate change risk and agricultural commodities such as cocoa, coffee, sugar, corn, soybean, and wheat commonly traded in financial markets. We employ the quantile-on-quantile connectedness technique from January 3, 2003, to June 28, 2024. Our results show a reciprocal relationship between the news on climate change and the prices of agricultural commodities. While the prices of agricultural commodities affect climate change concerns during the high increases and decreases in agricultural commodity prices, climate change concerns affect the prices of agricultural commodities during more stable periods. Our results provide essential information to policymakers and investors.

**Keywords:** Food security; Climate change; Agricultural commodities; Connectedness

## Introduction

Sustainability and food security are two of our most critical global issues. Sustainability means protecting and using natural resources in a way that meets the needs of future generations. This concept includes not only environmental but also economic and social dimensions. According to the Food and Agriculture Organization (FAO) (2001), food security is a situation that exists when all people constantly have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Sustainable agricultural practices will increase food security by making more efficient use of limited resources such as land and water, creating more resilient agricultural systems that will reduce the effects of climate change, and finding solutions to problems such as poverty and unequal income distribution.

Food security has four pillars: availability, access, utilization, and stability, which are affected by changing climate. Among them, "access" indicates the ability to obtain food, including the

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effects of food prices. Climate change may cause rises in food prices that affect mostly low-income consumers due to a lack of resources to purchase food (Mbow et al., 2019).

Significant increases and fluctuations in food prices have been observed in the last two decades, and three essential food crises have been encountered. The first crises emerged in 2007/2008 due to extreme increases in the prices of cereals, especially rice and wheat. According to FAO, the Food Price Index increased from 53.3 points in 2000 to 117.5 points in 2008. Two main reasons for this crisis are the drought experienced by underdeveloped countries and the increasing domination of multinational companies in international agricultural trade. In addition, the increase in oil-based input and supply costs and financial speculation triggered the crisis. The second crisis occurred at the end of 2010 and the beginning of 2011, and the Food Price Index increased to 131 points in 2011. But this time, the high food prices lasted five years until 2015. This crisis emerged with low yields and stocks caused by bad weather conditions in major grain-producing countries. The periods of these two food crises also coincide with the 2007-08 global financial crisis and the European debt crisis, respectively. The third and, for now, the last food crisis was observed in 2022, and the Food Price Index rose to 143.7 points. Although a decrease was observed in food prices due to uncertainties at the beginning of the COVID-19 pandemic, an increase was observed afterward due to the disruptions created by the pandemic in global supply chains[1]. In addition, the disruptions in the food supply chains caused by the Ukraine-Russia war triggered the crises since these two countries have significant roles in the production and export of agricultural products and fertilizers in the world[2].

As can be seen, significant increases in food prices are related to climate. Therefore, this paper focuses on the climate change factor causing a lack of food and threatening food security. We use the Media Climate Change Concerns (CCC) Index as a representative for climate change risk developed by Ardia et al. (2023), a daily index using news about climate change published by major U.S. newspapers and newswires to capture unexpected increases in climate change concerns and examines its impact on prices of mostly traded agricultural commodities including Cocoa, Coffee, Sugar, Corn, Soybean, and Wheat.

We employ the quantile-on-quantile connectedness technique and use daily data from January 3, 2003, to June 28, 2024. Our period consists of the COVID-19 pandemic and the Russian and Ukraine wars, which may cause high fluctuations in agricultural commodity prices because of distortions in supply chains. This paper contributes to the existing literature regarding its data and methodology. First, despite their strategic importance, the number of studies dealing with agricultural commodities is still insufficient. Second, this is the first paper to consider the media CCC Index as a factor in the prices of agricultural commodities. Our paper provides essential implications for policymakers and investors. The rest of the paper is structured as follows. Section 2 gives a brief literature review. Section 3 presents data and methods, followed by empirical results in Section 4. Finally, Section 5 concludes the paper.

## Literature review

This section focuses on how selected agricultural commodities and food security are related to climate change concerns, reflected in media news. Climate change concerns are shaping the beliefs of individuals, investors, and policymakers, ceteris paribus. To present inclusive studies, we dive into literature in two strands. In the first strand, studies investigate the relationship within the commodity markets, including energy, agriculture, metals, etc. The second strand demonstrates the association in the nexus between climate-related uncertainty, agricultural commodities, and food security.

The first strand investigates the commodity market, including its sectors such as agriculture, livestock, energy, and metal. In line with this, agricultural commodities were examined in terms of return and volatility transmissions among themselves (e.g., Lahiani, Nguyen, and Vo, 2013; Hernandez, Ibarra, and Trupkin, 2014; Gardebroek, Hernandez, and Robles, 2016; Umar, Jareño and Escribano, 2022). Hernandez, Ibarra, and Trupkin (2014) found that corn, wheat, and soybeans were strongly interdependent, while corn and wheat were found as volatility drivers by Gardebroek, Hernandez, and Robles (2016). The relationship between agricultural commodities and energy (majorly oil) was investigated (Nazlioglu and Soytas, 2012; Mensi et al., 2014; Cabrera and Schulz, 2016; Yip et al., 2020; Miljkovic and Vatsa, 2023; Ahmadian-Yazdi et al., 2024; Liu and Serletis, 2024). On the other hand, studies considered commodity market instruments altogether, and many of which tried to understand their spillover and connectedness dynamics (Tiwari et al., 2020; Bouri et al., 2021; Adeleke, Awodumi and Adewuyi, 2022; Cui and Maghyereh, 2024; Khan, Mejri and Hammoudeh, 2024). Contrary to the findings of Gardebroek, Hernandez, and Robles (2016) regarding the role of wheat, Bouri et al. (2021) found that among various commodities networks, cocoa, coffee, sugar, and wheat were the net volatility receivers, while soybean and corn were the net transmitters. Furthermore, Khan, Mejri, and Hammoudeh (2024) concluded that sugar was affected by positive and negative geopolitical risk shocks. Most of the studies also highlighted increased connectedness during black swan events.

The second strand gains importance due to climate change's direct and indirect impact on agricultural commodities and food security. In a recent study, Pham and Kamal (2024) studied the CCC index of Ardia et al. (2023) and various commodity markets (energy, agricultural, and precious metals) using conditional autoregressive value-at-risk and time-varying parameter tail risk connectedness. They found that since agricultural commodities were loosely connected and drove a relatively small portion of the overall connectedness within the network, they could be used for diversification and hedging. Another result from their study was corn and wheat act as net transmitters among other agricultural commodities, and clime risk impacts tail connectedness. In line with climate-related risks-agricultural commodities, Khalfaoui et al. (2024) investigated this from bearish to bullish market conditions with three various time horizons (short, medium, and long)

[1] The second goal of the UN Sustainable Development Goals is "Zero Hunger". According to the Sustainable Development Goal Report (2022), the number of people going hungry and suffering from food insecurity gradually rose between 2014 and the onset of the COVID-19 pandemic. (The Sustainable Development Goal Report 2022, available at: https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf, accessed 10 October 2023.

2 Russia is third in wheat, second in sunflower oil production, following Ukraine, and first in raw sugar production in 2019. In addition, Russia is the world leader in wheat export in 2020 (FOA Yearbook 2022, available at: https://www.fao.org/3/cc2211en/cc2211en.pdf, accessed 10 October 2023).

and asymmetrical dependence results showed that agricultural commodities experience loss because of climate change. Moreover, Nam (2021) investigated the effect of climate uncertainty on 63 global commodities employing modified time-varying factor-augmented vector autoregression. As climate uncertainty created some obstacles to supply and demand, it increased the price of agricultural food commodities. Makkonen et al. (2021) examined the impact of temperature anomaly and macroeconomic variables on the returns of future contracts on agricultural commodities by using a quantile regression approach. They concluded that temperature anomaly significantly negatively impacted soybean, corn, cotton, and coffee returns while positively affecting soybean, corn, and cocoa in severe market conditions.

The gap in the literature is that climate-related studies have emerged recently compared to other topics. Therefore, studies have used different variables to represent climate change and various methods such as quantile regression, vector autoregression with time-varying parameters, conditional autoregressive value-at-risk, etc. At this point, our study contributes to the literature using a novel quantile-on-quantile connectedness approach. It allows us to investigate extreme market conditions in a bi-variate setting. In addition, the period covers essential dates such as the global financial crisis, the European debt crisis, the Paris Agreement, the COVID-19 pandemic, Russia, Ukraine, and the Palestinian-Israeli conflicts and uses the novel quantile-quantile connectedness. This study examines the connection of news-based CCC with agricultural commodities.

## Methodology and Data

We use the novel quantile-on-quantile connectedness approach of (Gabauer and Stenfors, 2024) to examine the connectedness of the CCC Index with agricultural commodities. The approach is the generalization of the quantile connectedness approach of (Chatziantoniou, Gabauer, and Stenfors, 2021), essentially combining two frameworks, quantile-on-quantile regression (Sim and Zhou, 2015) and dynamic connectedness (Diebold and Yilmaz, 2012). This approach captures the spillovers across various quantiles, thus relaxing the intrinsic assumption of positive correlation in time series. In addition, it enables the investigation of the interconnectedness of time series even when they are at distinct quantiles. This approach lets us compute dynamic total connectedness indices for directly and reversely related quantiles.

Our sample consists of the Media CCC Index developed by Ardia et al. (2023) and the prices of six commonly traded agricultural commodities: Cocoa, Coffee, Sugar, Corn, Soybean, and Wheat. Our data are at daily frequency covering January 3, 2003 –June 28, 2024. The commodities' prices are collected from Yahoo Finance, and the CCC index is obtained from Ardia et al.'s (2023) Website[1].

We analyze changes in the indices to meet the stationarity condition. The time series are plotted in Figure 1, and their summary statistics are given in Table 1. Cocoa shows the highest variance. JB statistics indicate that none of the indices follow a normal distribution at the 1% significance level. Moreover, the ERS unit root test results demonstrate that the indices exhibit stationarity at the 1% level. While the correlation matrix indicates a positive correlation between the agricultural commodities, the CCC has a negative correlation with them.

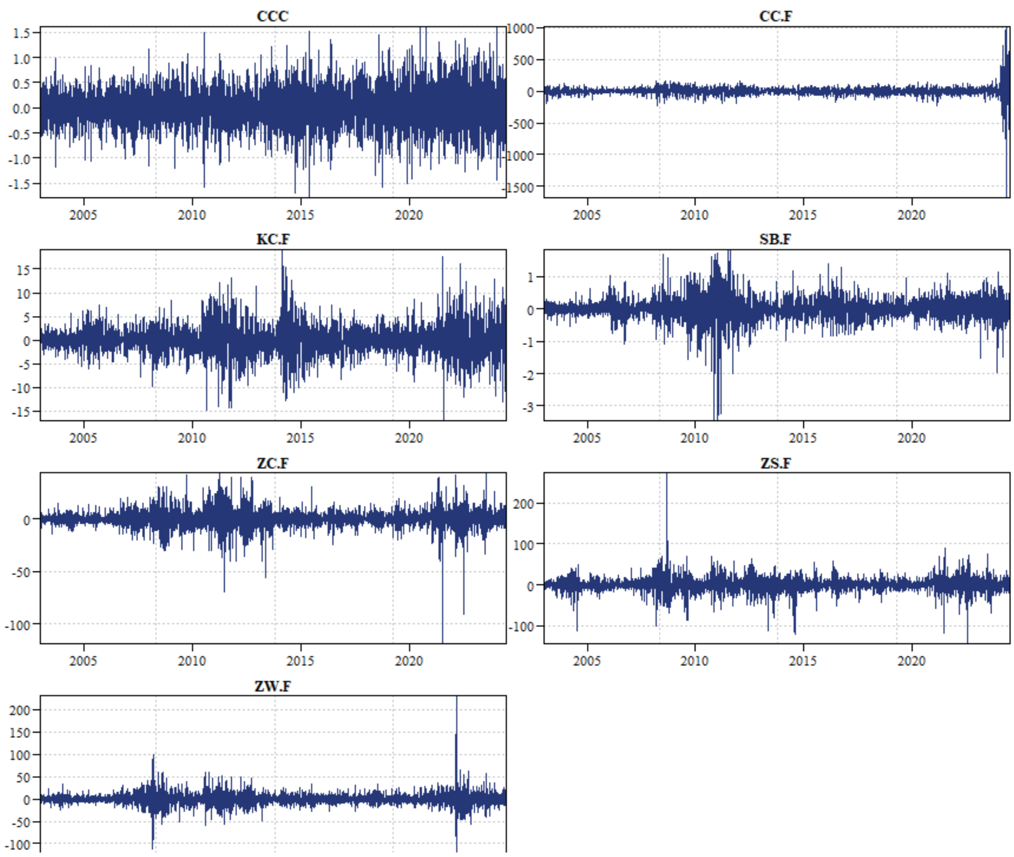



**Figure 1:** First-Differenced Data

**Note:** The daily series is from January 3, 2003, to June 28, 2024.

[1] Media CCC: https://sentometrics-research.com

**Table 1: Summary Statistics**

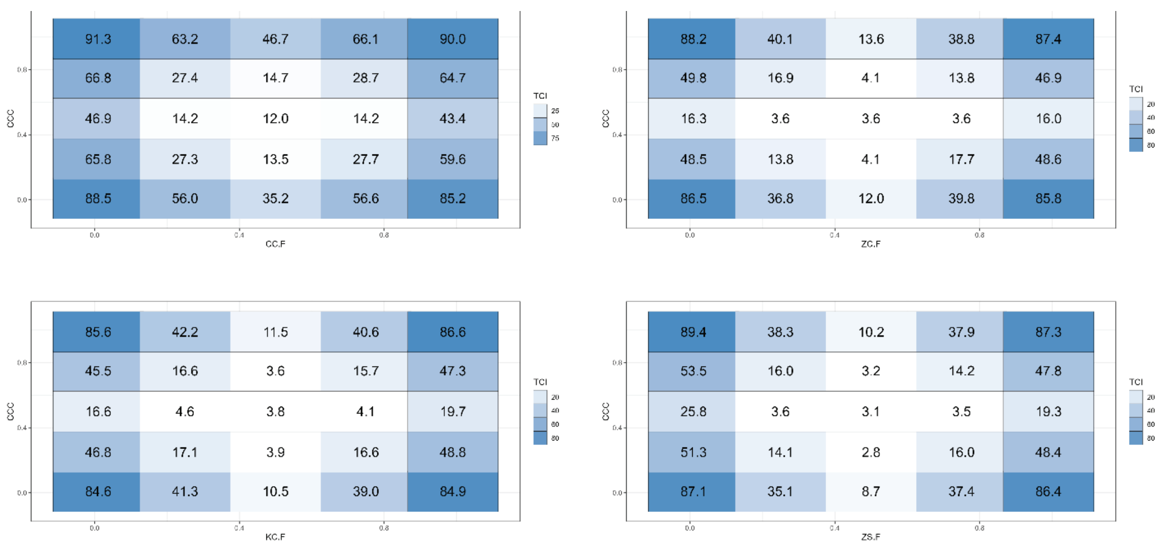
| | CCC | CC.F | KC.F | SB.F | ZC.F | ZS.F | ZW.F |
|---|---|---|---|---|---|---|---|
| Mean | 0.012** | 2.248** | 0.027 | 0.002 | 0.030 | 0.402 | 0.005 |
| Variance | 0.155 | 5191.926 | 9.358 | 0.131 | 75.188 | 301.764 | 193.987 |
| Skewness | -0.075** | -1.948*** | 0.129*** | -0.904*** | -1.084*** | 0.293*** | 0.533*** |
| Ex.Kurtosis | 0.964*** | 113.276*** | 3.453*** | 11.676*** | 15.631*** | 19.957*** | 28.262*** |
| JB | 167.8*** | 2263156.6*** | 2112.5*** | 24591.7*** | 43868.8*** | 70224.6*** | 140909.5*** |
| ERS | -22.1*** | -17.2*** | -27.1*** | -13.8*** | -28.1*** | -28.0*** | -28.7*** |
| Q(20) | 423.4*** | 253.5*** | 15.0 | 37.9*** | 7.6 | 14.2 | 59.3*** |
| Q2(20) | 405.6*** | 2091.7*** | 917.1*** | 1318.6*** | 268.3*** | 105.1*** | 2052.8*** |
| **Correlation** | CCC | CC.F | KC.F | SB.F | ZC.F | ZS.F | ZW.F |
| CCC | 1.000*** | -0.012 | -0.006 | -0.017 | -0.015 | -0.008 | -0.018 |
| CC.F | -0.012 | 1.000*** | 0.118*** | 0.072*** | 0.039*** | 0.050*** | 0.050*** |
| KC.F | -0.006 | 0.118*** | 1.000*** | 0.148*** | 0.110*** | 0.112*** | 0.105*** |
| SB.F | -0.017 | 0.072*** | 0.148*** | 1.000*** | 0.132*** | 0.119*** | 0.117*** |
| ZC.F | -0.015 | 0.039*** | 0.110*** | 0.132*** | 1.000*** | 0.384*** | 0.425*** |
| ZS.F | -0.008 | 0.050*** | 0.112*** | 0.119*** | 0.384*** | 1.000*** | 0.264*** |
| ZW.F | -0.018 | 0.050*** | 0.105*** | 0.117*** | 0.425*** | 0.264*** | 1.000*** |

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. JB stands for the normality test (Jarque and Bera, 1980) with the null hypothesis that a series has a normal distribution. ERS stands for the (Elliott, Rothenberg, and Stock, 1996) unit root test, testing the null hypothesis that a series has a unit root; Q(20) and $Q^2(20)$ are the (Fisher and Gallagher, 2012) weighted portmanteau tests.

## Empirical Results

We estimate 200-day rolling window quantile vector autoregression (QVAR) models with a 100-step ahead forecast horizon for each pair (i.e., bi-variate cases), comprising the CCC index and one agricultural commodity index. The lag length for each model is determined by the Schwarz Information Criterion (BIC)[1].

Figure 2 depicts the averaged dynamic total connectedness indices for each pair across 25 quantiles, namely 1%, 25%, 50%, 75%, and 99%. The darker blue shades represent the more vital interconnectedness, whereas lighter blue colors turning white visualize weaker connectedness between the pairs. We determine the highest average total connectedness (91.3%) for the CCI-CC.F (Cocoa) pair at one of the reversely related quantiles. It is followed by CCC-ZS.F (Soybean) (89.4%) and CCC- ZC.F (Corn) (88.2%), respectively. We can also say that the total connectedness indices achieve their highest values at this same extreme quantile other than ZW.F (Wheat).




[1] We also conduct estimations for robustness using various combinations of window sizes (150- and 200-day), forecast horizons, and lag lengths determined by the Hannan-Quinn Information Criterion. The empirical findings obtained from these different settings exhibit qualitative similarity; therefore, we present below the results from the initial model specifications.

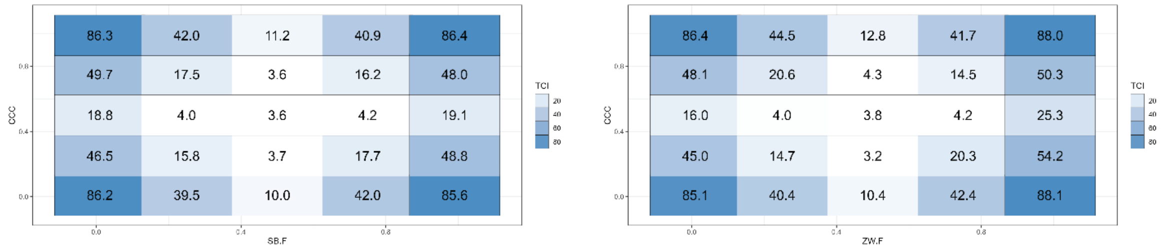



**Figure 2:** Quantile-on-Quantile Total Connectedness Indices
**Note:** The averaged dynamic total connectedness indices are based on a 200-day QVAR model. The quantiles are 0.01, 0.25, 0.50, 0.75, and 0.99.

Figure 3 shows the net directional connectedness across quantiles. The figure features a three-color gradient, incorporating blue for higher (positive) values, white for moderate values (around zero), and red for the lowest (negative) values. According to this figure, a reciprocal interaction in different quantiles, the CCC affects and is also affected. The positive values within the quantiles suggest that the CCC acts as a net transmitter, whereas negative values indicate that it acts as a net receiver in those quantiles. In general, agricultural commodities affect CCC in the lowest 1% and highest quantiles of 99%. In other market conditions, namely in quantiles of 0.25, 0.50, and 0.75, the situation is the opposite; CCC affects commodities.

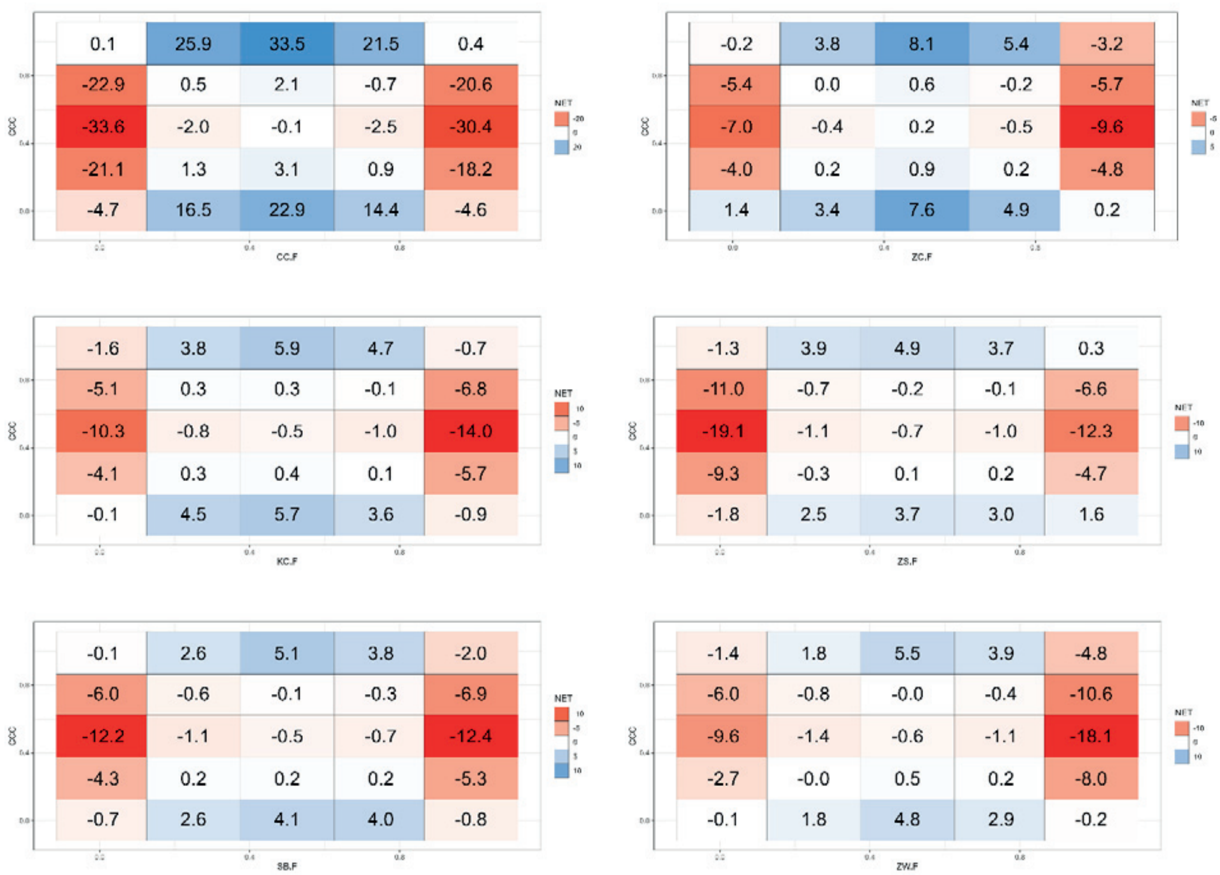



**Figure 3:** Quantile-on-Quantile Net Directional Spillovers
**Note:** The net directional spillover measures across quantiles are based on a 200-day QVAR model. The quantiles are 0.01, 0.25, 0.50, 0.75, and 0.99.

Figure 4 exhibits the directly- and reversely related dynamic total connectedness indices and their differences (ΔTCI) for pairs to capture the parallel and counter-directional shifts in interconnectedness among pairs over time. The times where the reverse TCI (red lines) surpass the direct TCI (green lines) indicate a pronounced negative correlation. The reverse TCI surpassing the direct TCI suggests a robust negative correlation between the series.

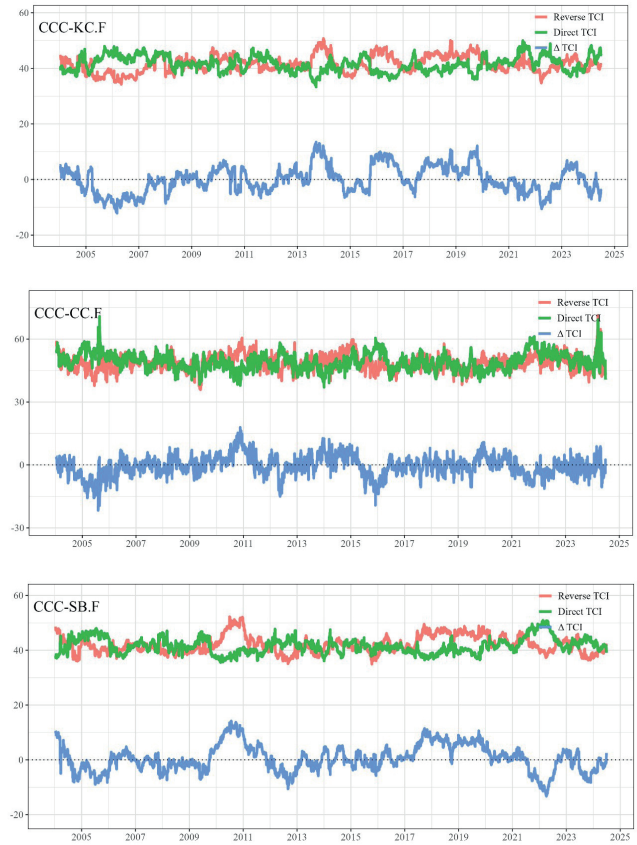



**Figure 4:** Dynamic Quantile-on-Quantile Direct and Reverse Total Connectedness Indices

**Note:** The dynamic directly- and reversely related quantiles total connectedness indices are based on a 200-day QVAR model.

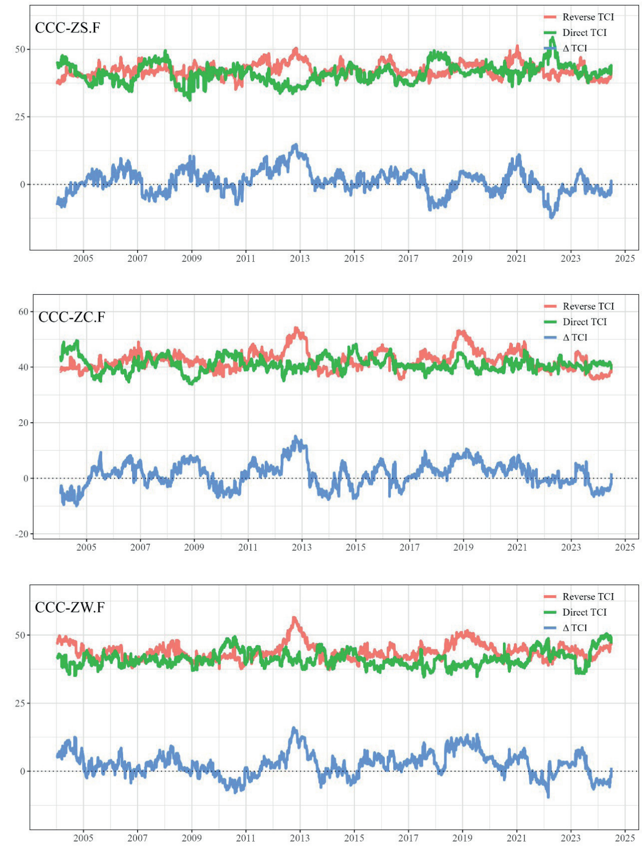



**Figure 4:** Dynamic Quantile-on-Quantile Direct and Reverse Total Connectedness Indices (cont.)

**Note:** See the notes for Figure 4.

## Conclusion

This paper examines the relationship between climate change concerns and agricultural commodities by employing a novel technique, quantile-on-quantile connectedness approach for the period from January 3, 2003, to June 28, 2024, including major global events such as COVID-19 pandemic and the Russian-Ukraine conflict.

Our results indicate that when there are very high decreases and increases in agricultural commodity prices, concerns about climate change increase. The CCC index is affected when the news reflects this situation. On the other hand, when fluctuations in agricultural commodity prices are more limited, news about climate change concerns affects agricultural commodity prices. In other words, concerns about climate change are always on the agenda and affect commodity prices. Increased climate change expectations can cause inflationary pressure on food prices, increasing the food security risk.

However, the large fluctuations experienced during and after the COVID-19 period increase concerns even more, and these realizations in prices create the expectation that the climate crisis will deepen. Although there is a mutual interaction, news about climate change concerns is written more after major price realizations, and this then gives investors and consumers the motivation to change their behavior, thus affecting prices again. A supply-demand imbalance, a significant risk within the scope of food security, can also cause sudden price changes. Necessary cautions should be taken to address the supply-demand imbalance and ensure food security to reduce climate change concerns.

As a result, this paper has important implications for policyholders. Climate change impacts agricultural production negatively by causing extreme weather events, droughts, and floods. Policymakers should develop sustainable agricultural practices to increase food security by creating agricultural systems that are more resilient to the effects of climate change. Governments can improve food security by developing policies that support sustainable agriculture and providing financial support to farmers. In addition, it offers important implications for investors and portfolio managers interested in investing in agricultural commodities. They should care about the impact of climate change news on the prices of agricultural commodities during the more stable market conditions.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

The authors confirm being the sole contributor of this work and have approved it for publication.

## Peer-review

Externally peer-reviewed.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## Conflict of interest

No potential conflict of interest was reported by the author(s).

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