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Assessing the Causality Relationship between the Geopolitical Risk Index and the Agricultural Commodity Markets

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Abstract: The aim of this study was to investigate the Granger causality between geopolitical risk (GPR) sub-indices in order to examine the implications of geopolitical risk on ten agricultural commodities classified as softs or grains. The Granger causality test was used to determine the causal relationship between the daily GPR sub-indices and the future prices of ten essential agricultural commodities from 31 March 2000 to 31 March 2022. We discovered that the GPR Threat and Act sub-indices Granger-caused changes in the wheat and oat commodity prices. These findings were also connected to the ongoing Russian–Ukrainian conflict, which has had an impact on agricultural commodity prices because both countries are major agricultural producers. The empirical results also showed how the GPR Threat sub-index Granger-affected the future prices of soybean oil, coffee, wheat, and oats. On the other hand, the GPR Act sub-index only Granger-affected the future price of oats. The findings of this study should provide useful information to both policymakers and governments to help them acknowledge the importance of geopolitical risk when setting their national policies related to food security.

Keywords: geopolitical risk; geopolitical risk index; agricultural commodity markets; causality

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1. Introduction

Over the years, non-financial events, such as the large-scale terrorist attacks of 11 September 2001, the rise of the Arab Spring, the annexation of Crimea from Ukraine, and the implications of Brexit, have left their mark on the globalized world. A common contributory factor to these events is the concept of geopolitics, and the world is constantly in a state of volatility in relation to both the global economy and geopolitics (Bouoiyour et al. 2019). Since geopolitical tensions have risen around the world, governments and international businesses must effectively manage geopolitical risk. Geopolitical risk monitoring and mitigation cannot be accomplished without ongoing research in this field.

Over the years, several academics conducted studies on the implications of geopolitical risk on commodity markets. Such studies focused on crude oil and precious metals, which are considered to be the most important commodities in the world (Su et al. 2021; Das et al. 2019; Qin et al. 2020; Bouoiyour et al. 2019; Cunado et al. 2020). However, there are few studies related to the various types of agricultural commodities (Tiwari et al. 2021) in order to assess the importance of food security and the supply of raw materials. As a result, a gap in the literature was identified because most academics focus on the causality relationship between geopolitical risk and the two most researched commodity markets, namely, precious metals and energy. Hence, there is a gap in the literature concerning the subject of agricultural commodity markets within a geopolitical context.

The aim of this study was to investigate the Granger causality between geopolitical risk (GPR) sub-indices in order to investigate the implications of geopolitical risk on ten agricultural commodities classified as softs or grains. These sub-indices were GPR Act and GPR Threat, where the GPR Act index represents terrorist attacks and war-related attacks, while the GPR Threat index represents tensions between countries, such as nuclear and military tensions. The Granger causality test was used to determine the causal relationship between the daily GPR sub-indices and the future prices of ten essential agricultural commodities from 31 March 2000 to 31 March 2022. The Granger causality analysis revealed that, in tandem, the GPR sub-indices influenced the prices of certain grain commodities, including wheat and oats. On the other hand, when each respective GPR sub-index was considered separately, it was noted that GPR Threat had further implications when compared with GPR Act.

This study's findings make several contributions to the existing literature. First, this is the first study to look into the Granger causality relationship between the GPR sub-indices (GPR Threat and GPR Act) and agricultural commodities (softs and grains). Second, this study contributed to a better understanding of how geopolitical acts and geopolitical threats affect agricultural commodity prices. Third, this empirical study supports the notion that certain agricultural commodities, specifically grains, were more vulnerable to geopolitical events between 2000 and 2022 than softs.

Geopolitical risk is present and constantly changing, and it has direct implications for several economic actors, such as national governments, businesses, institutional investors, and ordinary citizens. Essentially, national governments are the main actors responsible for managing and mitigating such risks; however, as the world has become more globalized and interconnected, other economic actors, such as institutional investors and corporate entities, are urged to implement risk management principles in order to effectively manage geopolitical risks. This research should be beneficial to international businesses because it will help them to gain a better understanding of the dynamics of geopolitical risks. As a result, international businesses will be able to undertake effective and informed decisions. Furthermore, this study could also assist professional investors, as they can use it as a guide to adequately plan their strategies and diversify their investment portfolios in view of the increase in geopolitical risk.

Section 2 looks at what has already been written about geopolitical risk, how it is measured, and how it affects commodity markets. Section 3 provides a brief overview of the data and methods used. Section 4 presents the empirical analysis findings, and Section 5 discusses the Granger causality analysis findings. Section 6 concludes with some final thoughts.

2. Review of the Literature

2.1. Geopolitical Risk and Its Measurement

Various prominent international organizations, intelligence agencies, and think tanks acknowledge that the topic of geopolitical risk is a key concern in today's globalized world (Suárez-de Vivero and Rodríguez Mateos 2017). One such international organization is the World Economic Forum (WEF), which actively monitors five categories of large-scale risks on a global level and publishes a yearly report entitled the Global Risk Report. Apart from geopolitical risk, the WEF monitors economic risk, environmental risk, societal risk, and technological risk. In their 2021 report, the WEF noted that the world's top geopolitical risks are interstate relations fracture, the proliferation of weapons of mass destruction, and large-scale terrorist attacks, amongst others. Interstate conflicts and the proliferation of weapons of mass destruction were assigned as having a higher likelihood and a higher impact, respectively (WEF 2021). However, a slight variation in geopolitical risks was noted from previous reports (2016–2019); the 2021 WEF report also highlighted the failure of national governance and state collapse/crisis, which have intensified in recent years.

Geopolitical risk is deemed to be unique in nature as it is distinct from any kind of political risk (Bremmer and Keat 2010). Undoubtedly, measuring geopolitical risk proved to be a challenging task, and as such, it used to be measured intuitively or else using crude macroeconomic data, resulting in a subjective approach (Pyo 2021). As geopolitical events have intensified over the last decade, academics have sought to develop a proxy to measure geopolitical risk (Caldara and Iacoviello 2018).

The seminal study carried out by Caldara and Iacoviello (2018) offers an effective method of measuring geopolitical risk by accounting for the frequency of articles related to geopolitical risk. Within a short period, Caldara and Iacoviello's (2018) prominent work spawned a considerable geopolitical risk literature, as similar studies were conducted in relation to different economic sectors. Caldara and Iacoviello (2018) computed a monthly index based on several geopolitical risk articles published by prominent newspapers in Canada, the United Kingdom, and the US. The index covers the period from 1985 to date; however, it also includes a historical index dating back to the beginning of the 20th century, basing the data on three newspapers published in the US. The historical geopolitical risk (GPR) index illustrated a significant spike only during the World War I and II periods; however, the beginning of the 21st century was a major turning point, as several significant spikes were noted.

Caldara and Iacoviello (2018) revealed that the highest spike in geopolitical risk occurred during the US–Iraq war, followed by the spike following the 9/11 large-scale terrorist attacks and one noted during the Gulf War at the beginning of the 1990s. Other notable spikes were noted following the terrorist attacks that occurred in various European cities over the years. Conversely, during the 2008 global financial crisis, the index did not register a significant spike when compared with the other outlined geopolitical events. Caldara and Iacoviello's (2018) seminal work distinguished between the direct impact of geopolitical events (the GPR Act index) and the impact of geopolitical risks (the GPR Threat index). In addition to this, Caldara and Iacoviello (2018) computed the GPR indices concerning 17 emerging markets in Asia, Latin America, and Africa. The GPR index is computed both on a monthly and daily basis in order to quantify geopolitical risk. The daily index is indeed crucial as it illustrates how a single event occurring on a particular day eventually leads to a significant spike in the GPR index. Since the year 2000, the GPR index was normalized to an average value of 100 from the year 2000 onwards for the rest of the sample, which is still being computed to this day (Caldara and Iacoviello 2018).

Caldara and Iacoviello (2022) recently enhanced their robust methodological approach by adopting a dictionary-based method. This method is based on a selection of words related to geopolitical risk, which are frequently used by journalists when writing about geopolitical events and threats. This methodological approach superseded the previously established methodology introduced in 2018. Caldara and Iacoviello (2022) also adopted a broader definition of geopolitical risk by taking into consideration the geopolitical tensions emanating from both nation-states and political actors. National governments are undoubtedly the most influential political actors; however, other political actors, including supranational and international institutions, such as the EU and the United Nations, are exerting significant power in today's globalized world (Rice and Zegart 2018). Furthermore, due to the fact that the GPR index covers a long period, it was important for Caldara and Iacoviello (2022) to acknowledge that language evolves; indeed, they deemed it crucial that the GPR index covers the process of neologism to ensure an effective geopolitical risk measure.

2.2. Geopolitical Risks and the Commodity Markets

Any geopolitical tension between nations might have potential adverse implications, which could, in turn, affect both the macroeconomic and financial cycle of a nation (Olasehinde-Williams and Balcilar 2022). Several academic researchers undertook empirical research to assess the implications of geopolitical risk in relation to various sectors, such as tourism (Balli et al. 2019), banking (Phan et al. 2022), and the financial markets (Yang et al. 2021; Hoque and Zaidi 2020; Rupeika-Apoga and Wendt 2022). Additionally, since various nations are exerting both economic and political power to exploit numerous valuable resources, the commodities industry has gained particular attention within a geopolitical context, especially due to the increase in demand for the consumption of certain commodities, as well as the impact of climate change across the sectors within the industry (Rupeika-Apoga and Petrovska 2022). Recently, the commodities industry has also gained particular attention within a geopolitical context. It is common knowledge that various nations exert both their economic and political power to exploit different natural resources.

For decades, the crude oil industry has been the most relevant commodity for the global economy (Cunado et al. 2020). Su et al. (2019) argued that the presence of geopolitical events does impact the commodity markets, especially crude oil prices. In their empirical study, Su et al. (2019) employed a wavelet approach in order to investigate the causality relationship between geopolitical risk, oil prices, and financial liquidity in terms of time and frequency. Monthly observations were noted for a sample period of 20 years (1998–2018), focusing on Saudi Arabia, which is one of the largest oil-exporting countries. Su et al. (2019) concluded that an increase in geopolitical risk affects both oil prices and financial liquidity. Furthermore, causality correlations were observed both in the short term and medium term when considering the frequency domain. This implies that oil prices are highly dependent on geopolitical risk, which would ultimately affect the financial liquidity of a country. Similarly, Abdel-Latif and El-Gamal (2019) undertook a vector autoregressive analysis in order to investigate the dynamics of three crucial variables, namely, oil prices, financial liquidity, and geopolitical risk on a global scale. Abdel-Latif and El-Gamal (2019) postulate that low oil prices subsequently lead to an increase in geopolitical risk while making reference to the low prices in the late 1980s, which led to the first Iraq War at the beginning of the 1990s.

Tiwari et al. (2021) drew our attention to the distinctive relationship between the energy and agricultural markets; however, they investigated the implications of geopolitical risks on crude oil and primary agricultural commodities, namely, corn, soybean, wheat, and oats. For the purpose of their empirical investigation, Tiwari et al. (2021) employed a copula approach to analyze co-movements between the energy and agricultural commodity markets over a large sample period of 28 years, as well as the dependence between both the energy and commodity markets using Caldara and Iacoviello's (2018) GPR index. In view of an increase in geopolitical risk, which has become prevalent in today's interconnected markets, a strong co-movement was noted between the energy market and the four aforementioned agricultural commodity markets. Furthermore, the empirical investigation conducted by Tiwari et al. (2021) reaffirmed the findings obtained by Cunado et al. (2020) through their time-varying analysis of crude oil prices in relation to geopolitical risk.

Qin et al. (2020) questioned whether gold should be stored in chaotic eras, especially in view of the recent increase in geopolitical events. A full and sub-sample bootstrap causality test was employed to examine the causal relationship between geopolitical risk and gold prices over the period January 1979 to December 2018. In the empirical analysis conducted by the authors, both positive and negative periods were noted. The results suggest that during positive periods, gold should be held, but it was revealed that during negative periods, holding only gold is not sufficient. In their pioneering study, Das et al. (2019) analyzed the impact of geopolitical risk on precious metals. A quantile regression analysis was used to study the sample period from January 1985 to December 2017. Das et al. (2019) noted a positive relationship based on the studied sample period; when geopolitical risk increased, gold return increased by 0.0029%. Furthermore, higher gold returns were registered when considering Caldara and Iacoviello's (2018) sub-index, namely, in terms of geopolitical threats (Das et al. 2019). In contrast, a negative relationship was noted concerning the remaining precious metals, these being silver, platinum, and palladium; indeed, the latter tends to be vulnerable to geopolitical risk (Das et al. 2019).

In the same vein, Baur and Smales (2020) undertook an econometric analysis to test whether various precious metals can act as a hedging mechanism in view of geopolitical risk. The sample period ranged from January 1985 to October 2018 and included the spot prices of four main precious metals, namely, gold, palladium, platinum, and silver, due to their distinctive characteristics. An adjustment to Caldara and Iacoviello's (2018) GPR index was made to take into consideration the time lag of when such geopolitical events are published. Furthermore, Baur and Smales (2020) included an analysis of the 10 geopolitical events registering the largest geopolitical shocks. Similar to the findings obtained by Das et al. (2019), Baur and Smales (2020) noted that the return of precious metals is positively related to geopolitical risk; in particular, a stronger relationship was found when considering geopolitical threats. Additionally, both gold and silver illustrated a positive relationship to geopolitical risk. Baur and Smales (2020) also considered Caldara and Iacoviello's (2018) GPR sub-indices and noted that commodity returns are affected by geopolitical threats but not by geopolitical acts.

In another comprehensive study on precious metals, Yilanci and Kilci (2021) employed Hacker and Hatemi-J's bootstrap causality test, as well as a time-varying bootstrap test, to investigate the role of geopolitical risk in predicting the prices of precious metals for the period from January 1995 to August 2020. In contrast to other empirical studies, such as Das et al. (2019) and Baur and Smales (2020), Yilanci and Kilci (2021) took into consideration five precious metals, namely, gold, palladium, platinum, silver, and rhodium, in order to detect any instabilities in the causality relationship. Yilanci and Kilci (2021) found that throughout the entire period, there appeared to be no causality relationship between geopolitical risk and the prices of metals. However, a causality relationship was present in some periods of the total sample period.

An increasing corpus of literature emphasizes the significance of considering geopolitical risk in the financial markets. However, empirical research that investigated how geopolitical risk affects the agricultural commodity market is very limited. Generally, such studies only focused on the single most important commodity—crude oil. Other available empirical studies considered the precious metals and the spillover effect from crude oil to agricultural commodities.

This paper contributes to the burgeoning literature described above by considering the causal link between geopolitical risk and commodity market futures prices. We investigated this relationship by considering a wide spectrum of commodities within the agricultural sector, focusing on the futures market, while also disaggregating the GPR index into its component sub-indices (GPR Act and GPR Threat) in order to obtain a more nuanced picture of the flow of causality and understand what drove the results.

3. Materials and Methods

3.1. Data Collection and Sample Characteristics

Time-series data on both geopolitical risk and commodity prices were obtained to assess the causality relationship. The primary data for both the daily GPR index and the GPR sub-indices were obtained from Caldara and Iacoviello's website, Geopolitical Risk Index (GPR Index 2023), for the period 31 March 2000 to 31 March 2022. Tiwari et al. (2021) suggested that the inclusion of the daily GPR sub-indices is crucial to understanding the dynamics of the agricultural markets. Similarly, Baur and Smales (2020) acknowledged that the monthly GPR index data is an average of the geopolitical news occurring in that particular month. The agricultural commodity prices were obtained as daily future commodity prices from the CME Group (Chicago Mercantile Exchange) (CME Group 2023). The rationale for selecting the daily prices was to ensure that such agricultural future commodities captured the respective price movements throughout the sample period.

With respect to the sample period selected, we accounted for both the annual US holidays/events and the weekend, as highlighted on Bloomberg L.P. Since future commodities do not trade on such days, the respective daily GPR index and GPR sub-indices were adjusted to account for any US holidays/events and the weekends throughout that particular year. Using the homogeneous sampling technique, we selected ten future commodities related to grain and soft commodities that were top-traded products, as shown in Table 1.

Table 1. Sample Selected—Future Commodities.

Agricultural Sector	Future Commodities	Ticker Symbol
Grains	Corn	ZC
	Oats	ZO
	Rough rice	ZR
	Soybean	ZS
	Soybean oil	ZL
	Wheat	ZW
Softs	Coffee	KC
	Cotton	CT
	Cocoa	CJ
	No. 11 Sugar	YO

The results of the descriptive statistics of all the variables are expressed in Table 2. Overall, this large sample took into account several major geopolitical events that occurred during the last twenty-two years, which included the large-scale terrorist attacks of 11 September 2001; the US–Iraq war; the Arab Spring; and the recent Russo–Ukrainian war. A total of 71,630 data samples were collected for this empirical study.

Table 2. Descriptive Statistics.

Variable	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Jarque–Bera	Observations
Cocoa	2219.426	2305.000	3774.00	674.00	661.3955	(0.323891)	2.292837	211.1480	5510
Coffee	125.1446	119.7500	304.90	41.50	49.21488	0.888628	3.942000	928.8945	5510
Corn	390.5204	365.7500	831.25	174.75	155.5385	0.810066	2.855730	607.3953	5510
Cotton	69.96968	65.32000	215.15	28.52	24.51531	2.220562	10.88385	187,98.00	5510
No. 11 sugar	34.64693	32.27000	35.31000	4.99000	13.192226	0.675241	2.840206	424.5771	5510
Oats	265.6213	254.5000	772.25	95.00	109.6390	1.439915	6.910046	5414.006	5510
Rough rice	11.11643	11.57000	24.46	3.43	3.4300	(0.143381)	2.668749	44.07062	5510
Soybean	14.22566	13.23500	1771.00	418.00	5.753274	0.785632	3.381945	600.3037	5510
Soybean oil	956.0087	945.3750	82.18	14.38	323.9262	0.210937	2.159180	203.1713	5510
Wheat	515.0902	497.2500	1425.25	233.5000	178.2246	0.690465	3.388311	472.4258	5510
Daily GPR	112.8891	99.51920	1045.604	9.491598	69.03425	4.641369	39.79286	330,573.3	5510
Daily GPR Act	113.9453	93.47909	1627.428	0.0000	108.1768	6.133046	60.94185	805,312.9	5510
Daily GPR Threat	112.5335	98.16797	811.5252	7.89	67.28846	3.064505	20.85715	81,833.31	5510

Descriptive statistics presented in Table 2 show that cocoa had the highest mean and median among the agricultural commodity prices. Moreover, cocoa had the highest standard deviation, which means that its values were more spread out when compared with those of the other agricultural commodities. On the other hand, rough rice registered the lowest mean and median among the agricultural commodity prices. In addition to this, rough rice had the lowest standard deviation. Cocoa also had the largest range of values, while rough rice had the smallest range when considering the maximum and minimum values obtained. All variables were positively skewed, with the exception of cocoa and rough rice, which were negatively skewed. The Jarque–Bera test results were positive and far from zero, indicating that the data were not normally distributed.

3.2. Study Design

The seminal work of Granger (1969) introduced the definition of a causality relationship, which examines the relationship between two variables x and y with respect to one period ahead. Fundamentally, the directional causality relationship occurs when one variable is able to predict the other variable, or simply denoted as "y is causing x" (Granger 1969). Conversely, a unidirectional causality is evident when one variable does not cause the other variable. Meanwhile, a bidirectional causality (also known as feedback) occurs whenever one variable affects the other variable (Granger 1969). Moreover, the innovative and seminal work of Sims (1980) pioneered a new approach to examining the Granger causality by introducing the concept of a vector autoregression (VAR) model. In essence, the VAR model illustrates the dynamic relationship between the variables, whereby each variable accounts for its lags and the lags of the other variables within the model (Jangir et al. 2022).

A principal test related to the VAR model is the lag length test, which determines the optimal lag order for the VAR model underpinning the block exogeneity (VAR Granger causality) test. The scope of this test is to limit serial correlation whilst ensuring that the optimal degrees of freedom are also maintained. On the other hand, the main limitation of the optimal lag length test is the loss of observations when lagging the variables (i.e., the agricultural commodities). The VAR lag order selection criteria test and the VAR residual serial correlation Lagrange multiplier (LM) test were run prior to specifying the VAR model. The scope of the VAR lag order selection length criteria is to determine the optimal number of lags with respect to the independent variable. Clarke and Mirza (2006) acknowledge that such optimal lag length is required to avoid spurious causality. On the other hand, the VAR residual serial correlation LM test depends on the aforementioned test to ensure that the issue of serial correlation is eliminated at the chosen lag length from the respective variables.

Péguin-Feissolle et al. (2013) acknowledged that a causal relationship is evident when the second variable influences the variance of the prediction error's variance of the first variable. In fact, this has led to the introduction of the Granger non-causality concept whereby the null hypothesis is "x does not cause y" for the respective time horizon. Indeed, for the purpose of this empirical study, the VAR equation was determined as follows:

$$\mathrm{Y}(t) = \gamma + B(L)y\ (t-1) + u(t), \tag{1}$$

where Y refers to the set of variables included in the VAR, t denotes the period (such as $t = 1, \ldots, T$), γ is the constant term, $B(L)$ refers to the matrix polynomial, and $u(t)$ refers to the Gaussian vector having a zero and a variance-covariance matrix.

$$\begin{pmatrix} Y_t \\ X_t \\ Z_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} + \begin{pmatrix} \varphi^1 yy & \varphi^1 yx & \varphi^1 yz \\ \varphi^1 xy & \varphi^1 xx & \varphi^1 xz \\ \varphi^1 zy & \varphi^1 zx & \varphi^1 zz \end{pmatrix} \begin{pmatrix} Y_{t-1} \\ X_{t-1} \\ Z_{t-1} \end{pmatrix} + \cdots\cdots\cdots\cdots\cdots + \begin{pmatrix} \varphi^P yy & \varphi^P yx & \varphi^P yz \\ \varphi^P xy & \varphi^P xx & \varphi^P xz \\ \varphi^P zy & \varphi^P zx & \varphi^P zz \end{pmatrix} \begin{pmatrix} Y_{t-p} \\ X_{t-p} \\ Z_{t-p} \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \\ u_3 \end{pmatrix} \tag{2}$$

where Y denotes the price of the future agricultural commodity. X and Z denote the GPR sub-indices GPR Threat and GPR Act, respectively. φ refers to the matrix polynomial, whereby the subscripts of the coefficients (x, y, and z) are notation used to illustrate which variables these belong to, and p denotes the lag length.

Moreover, the VAR matrix model can also be illustrated in terms of the lag operator denoted as (L):

$$\begin{pmatrix} Y_t \\ X_t \\ Z_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} + \begin{pmatrix} \varphi_{yy(L)} & \varphi_{yx(L)} & \varphi_{yz(L)} \\ \varphi_{xy(L)} & \varphi_{xx(L)} & \varphi_{xz(L)} \\ \varphi_{zy(L)} & \varphi_{zx(L)} & \varphi_{zz(L)} \end{pmatrix} \begin{pmatrix} Y_{t-1} \\ X_{t-1} \\ Z_{t-1} \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \\ u_3 \end{pmatrix} \tag{3}$$

where Y denotes the price of the agricultural future commodity price. X represents the GPR Act and Z represents the GPR Threat.

$$\varphi_{m,n} = \sum_{i=0}^{P} \varphi^i \, L^i \tag{4}$$

where $m = \{y, x, z\}$, $n = \{y, x, z\}$, and P denotes the lag length.

The VAR Granger causality/block exogeneity Wald tests were run to determine the causality relationship between the independent and dependent variables. The VAR matrix model specification was set up to assess the relationship between the independent variable and the dependent variable. The following null and alternative hypotheses were used for this test:

H_0. *There is no causal relationship between the GPR sub-indices (GPR Act and GPR Threat) and the respective future commodity price.*

H_A. *There is a causal relationship between the GPR sub-indices (GPR Act and GPR Threat) and the respective future commodity price.*

4. Results

The augmented Dickey–Fuller (ADF) test was carried out for both the agricultural commodities and the GPR sub-indices to test the stationarity of data. Table 3 presents the ADF unit root test results.

Table 3. ADF Unit Root Test with the Trend.

Agricultural Future Commodity	Difference Level (*p*-Value)	1st Difference (*p*-Value)
Cocoa	0.0535	0.0001
Coffee	0.4522	0.0001
Corn	0.5459	0.0001
Cotton	0.3285	0.0001
No. 11 sugar	0.1586	0.0001
Oats	0.8837	0.0000
Rough rice	0.1498	0.0001
Soybean	0.5211	0.0001
Soybean oil	0.7623	0.0001
Wheat	0.2229	0.0000
GPR Act	0.0000	
GPR Threat	0.0000	

Source: Authors' computation.

For the purpose of the ADF test, we took into consideration a 5% significance level (0.05). As can be seen from the resulting probability values (*p*-values), all agricultural commodity prices were non-stationary and integrated with order one (i.e., became stationary when differenced). Hence, all subsequent analysis was performed using the first-differenced values of the commodity prices. As can be noted, contrary to the majority of the ADF unit root tests carried out for the agricultural future commodities, the null hypothesis concerning the presence of a unit root was rejected for both indices at the chosen level of significance.

Preliminary statistical tests were performed to examine the results of both the VAR model and the Granger causality test. Therefore, the VAR lag order selection criteria test was performed to determine the optimal number of lags for the respective agricultural commodities. Over the years, different types of information criteria were introduced, such as the Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan–Quinn information criterion (HQ), which can be applied to a time-series study. The likelihood ratio (LR) test was also found to be beneficial when choosing the optimal number of lags in a VAR model. The optimal lag length was selected on the basis of the LR test.

Furthermore, we carried out additional tests to assess the robustness of the obtained empirical findings. The VAR residual serial correlation Lagrange multiplier (LM) test was carried out for every agricultural commodity price model specification of the Granger test to assess the quality of the residuals. Due to the dynamics between the respective variables, which accounted for the geopolitical implications on the respective commodity market, it was noted that a lag of 29 was optimal for cocoa, wheat, and rough rice, while a lag of 22 was optimal for corn, soybean, and soybean oil. On the other hand, a lag of 24 was optimal for coffee, oats, and no. 11 sugar.

The main scope of the LM statistical test is to detect the presence of a serial correlation at the chosen lag length. If the serial correlation is still present, the residuals are rendered less efficient. The null hypothesis for this test is that of no serial correlation at lag h. In fact, the results obtained revealed that the null hypothesis of no serial correlation was not rejected at the critical value of 0.05 for the residuals of the underlying VAR with respect to all soft commodity prices. Similarly, the null hypothesis of no serial correlation was not rejected for all the grain commodities. Therefore, these results imply that the issue of serial correlation was omitted.

The VAR Granger causality test revealed the causality direction between the variables and whether the causality relationship was unidirectional, bidirectional, or neutral. The employed H_0 states that the independent variable (i.e., agricultural commodity price) does not cause the dependent variable (i.e., GPR Daily Act and GPR Daily Threat). Table 4 presents the obtained empirical results, which indicate that the studied GPR sub-indices Granger-caused changes in the agricultural commodity prices. Furthermore, the results also indicate whether both sub-indices jointly contained sufficient information to "predict" the future commodity price of the commodity in question.

Table 4. Agricultural Commodities—VAR Granger Causality.

Excluded	Chi-Square	Degrees of Freedom	Probability
Dependent variable: cocoa future price (included observations 5487)			
GPRD_Act	20.07076	22	0.5786
GPRD_Threat	19.24960	22	0.6299
All	39.61217	44	0.6600
Dependent variable: coffee future price (included observations 5487)			
GPRD_Act	16.83384	22	0.7725
GPRD_Threat	43.46527	22	0.0041
All	58.13955	44	0.0749
Dependent variable: cotton future price (included observations 5480)			
GPRD_Act	29.91529	29	0.4182
GPRD_Threat	19.89438	29	0.8962
All	49.34170	58	0.7838
Dependent variable: no. 11 sugar future price (included observations 5481)			
GPRD_Act	21.77311	28	0.7917
GPRD_Threat	26.18746	28	0.5627
All	27.04766	56	0.7972
Dependent variable: corn future price (included observations 5487)			
GPRD_Act	15.72131	22	0.8295
GPRD_Threat	29.45956	22	0.1322
All	43.99508	44	0.4719
Dependent variable: oats future price (included observations 5485)			
GPRD_Act	39.90133	24	0.0448
GPRD_Threat	38.38025	24	0.0317
All	76.51345	48	0.0055

Table 4. *Cont.*

Excluded	Chi-Square	Degrees of Freedom	Probability
Dependent variable: rough rice future price (included observations 5480)			
GPRD_Act	17.43909	29	0.9549
GPRD_Threat	31.71250	29	0.3326
All	50.10420	58	0.7601
Dependent variable: wheat future price (included observations 5480)			
GPRD_Act	26.25644	29	0.6118
GPRD_Threat	78.53201	29	0.0000
All	100.0333	58	0.0005
Dependent variable: soybean future price (included observations 5487)			
GPRD_Act	18.45569	22	0.6787
GPRD_Threat	28.10236	22	0.1723
All	46.82797	44	0.3572
Dependent variable: soybean oil future price (included observations 5487)			
GPRD_Act	12.85083	22	0.9372
GPRD_Threat	36.49668	22	0.0268
All	46.49765	44	0.3699

Since the critical *p*-value was set at 0.05, it can be concluded that the null hypothesis was not rejected for cocoa, cotton, and no. 11 sugar at all levels of significance. Although the null hypothesis concerning coffee was not rejected at all levels, it can be noted that the GPR Threat sub-index on its own Granger-caused the price of coffee. A possible explanation for this might be that geopolitical events, such as war and nuclear threats, affect the price of coffee futures. In contrast, the grains commodities registered a different Granger causality result. The null hypothesis concerning corn, rough rice, and soybean was not rejected. This implies that the GPR sub-indices did not Granger-cause the change in price for these aforementioned commodities. However, on taking a closer look at the empirical results obtained for both oats and wheat at all significant levels, it can be noted that the null hypothesis was rejected at the critical value of 0.05. This implies that both GPR sub-indices Granger-caused the change in prices for both oats and wheat in tandem. Nonetheless, it is important to highlight that the null hypothesis with respect to the GPR Act for wheat futures was not rejected. On the other hand, the GPR Threat sub-index tended to Granger-cause the soybean oil future commodity price. Overall, based on the empirical results obtained from the estimation model, a Granger causality relationship existed for certain agricultural commodities throughout the period 2000–2022.

5. Discussion

As outlined in the literature review, empirical studies concerning the implications of geopolitical risk on the commodity market only intensified following Caldara and Iacoviello's (2022) seminal work in 2018. Up to now, however, research on geopolitical risk has focused predominantly on the energy markets (Bouoiyour et al. 2019; Cunado et al. 2020; Su et al. 2021; Qin et al. 2020) and precious metals (Baur and Smales 2020; Das et al. 2019; Yilanci and Kilci 2021) rather than on the agricultural market.

Bouoiyour et al. (2019) examined the dynamic relationship between oil prices and geopolitical risks, finding that the reaction of oil to geopolitical risks is conditional on the type of geopolitical risk. For the period of February 1974 to August 2017, Cunado et al. (2020) looked at the dynamic effects of geopolitical risks on real oil returns using a time-varying parameter structural vector autoregressive (TVP-SVAR) model. Their findings emphasized the danger of assuming that greater GPRs produce higher oil prices by linking all GPRs to oil supply shocks brought on by Middle Eastern geopolitical tensions. Using the rolling window approach, Su et al. (2021) investigated the link between global geopolitical risks and renewable energy. The findings indicate a two-way causality between geopolitical risks and renewable energy that is dispersed over several sub-samples. By dividing geopolitical risks into geopolitical threats and geopolitical acts, Qin et al. (2020) investigated the asymmetric effects of geopolitical risks on energy returns and volatility under various market conditions. They found that both threats and acts have different effects on energy returns and volatility.

Yilanci and Kilci (2021) investigated the relationship between geopolitical risk and the price of precious metals. They used the time-varying causality test, as well as the Hacker and Hatemi-J bootstrap causality, to examine the causality link on a monthly basis for both the global EPU index and the GPR index for the period from January 1995 to August 2020. In their investigation into the link between geopolitical risk and asset prices, Baur and Smales (2020) found that precious metals respond to geopolitical risk very differently from other assets, and that geopolitical risk is distinct from existing measures of economic, financial, and political risks.

Our empirical findings broadly support the work of previous studies, which demonstrated the importance of taking geopolitical risk into account when considering the commodity markets. However, various distinctions should be noted between the previously mentioned studies and this research, such as the type of commodities investigated and the type of causality test employed. Moreover, we took a different approach by employing VAR Granger/block exogeneity Wald tests to assess the causality relationship between the GPR sub-indices and the daily agricultural future commodity prices for the period March 2000 to March 2022.

When comparing both geopolitical threats and geopolitical acts, we noted that the GPR Threat sub-index played a more significant role as it impacted oats, wheat, soybean oil, and coffee. A plausible explanation for this Granger causality result might have been due to the different categories of geopolitical threats. Indeed, in their seminal work, Caldara and Iacoviello (2022) identified five main categories of geopolitical threats for the establishment of the GPR Threat as a sub-index, which include war, military buildup, nuclear threats, terrorist threats, and peace threats. Another important finding was a Granger causality relationship between GPR Threat and the following commodities: coffee, soybean oil, wheat, and oats. Perhaps the most compelling finding of this study was the Granger causal relationship between the GPR Act and oats. In essence, this means that the beginning and escalation of war affects the price of oats.

Another significant implication emanating from this study's findings is how the studied GPR sub-indices could provide information concerning agricultural commodity prices. These findings, in fact, highlight the predictive power of the GPR sub-indices in relation to changes in future commodity prices, as these contain information that can shed light on the course prices are likely to take following a particular geopolitical event. The VAR Granger causality test employed for this study suggests that changes in the agricultural future commodity prices are reflected within less than a month after a particular geopolitical event. For instance, changes in the commodity prices for both oats and wheat occurred within 24 days and 29 days, respectively. On the other hand, when each GPR sub-index was considered separately, it can be noted that the GPR Threat sub-index led to a price change for both coffee and soybean oil within 22 days. Additionally, the same sub-index led to a price change for wheat within 29 days. In contrast, the GPR Act only led to a price change for oats within 24 days. Based on these findings, it can be concluded that the aforementioned commodities are vulnerable to an increase in geopolitical threats and the possibility of geopolitical conflicts affecting the food system on a global scale.

The causal relationship identified for both oats and wheat is pivotal to better understanding the "bigger picture" of how geopolitics influences both the production and the distribution of agricultural commodities. Over the years, agricultural commodities have become more vulnerable due to the intensification of geopolitical events. Indeed, the "food regime" concept coined by Friedma and McMichael (1989) interprets how both economic and political issues have influenced the food system over the years, and is a theory whose relevance will likely remain in the foreseeable future. A possible explanation for the causality revealed by this study was that both oats and wheat are considered to be staple foods across the globe. Wheat, however, is a principal agricultural commodity, as both emerging and underdeveloped nations are highly dependent on such imports (Magnan 2017).

Undoubtedly, geopolitical implications impacted each food regime period differently. Nevertheless, it is evident that both emerging and developing nations are becoming highly vulnerable to food insecurity, which poses a significant threat to the supply of various agricultural commodities across the globe (Bhatnagar et al. 2022). Eventually, the respective governments have to intervene in order to secure food supply to the whole nation. Furthermore, any geopolitical event might lead to an abrupt change in the price of affected agricultural commodities, leading to an increase in geopolitical risk, which would also impact the volatility of the commodity prices. As a result, significant price increases may take place, which would result in commodity price inflation, also known as "agflation" (McMichael 2009). For instance, this situation was evident in the case of the Arab Spring uprising, which was initiated due to an increase in various commodity prices in Tunisia in 2010–2011 and such a geopolitical event spread particularly quickly across other Northern African and Middle Eastern neighboring countries with serious economic repercussions.

These empirical findings have significant implications for the understanding of how the studied GPR sub-indices could provide information on agricultural commodity prices. Moreover, these empirical findings also highlight the predictive power of the indices when it comes to changes in future commodity prices; indeed, they may contain information that can shed light on the course prices are likely to take following a particular geopolitical event. It is important to note that such empirical findings highlight the commodities' vulnerability to both geopolitical acts and geopolitical threats. Eventually, such situations would intensify the uncertainty in the agricultural commodity and would impact the interrelationship between the agricultural and the energy commodity markets (Tiwari et al. 2021; Garg et al. 2023).

Along the same line of thought of this study, Bouoiyour et al. (2019) also questioned whether geopolitical threats or geopolitical acts impact oil future commodity prices. However, contrary to the empirical findings outlined above, recent research by Bouoiyour et al. (2019) outlined that geopolitical acts have a significant impact on the oil market. On the other hand, this research outlined that various agricultural commodities prices were influenced mostly by geopolitical threats rather than geopolitical acts, with the exception of wheat and oats, which were impacted by both GPR Threat and GPR Act. Nevertheless, this difference between the two commodity markets is that the oil market tends to be more complex in nature when compared with the agricultural market. Moreover, Bouoiyour et al. (2019) highlighted several factors that affect the oil price, which were categorized as geopolitical threats, such as the characteristics of the oil market whereby both the buyers and sellers have imperfect information, the impact of previous geopolitical events on supply disruption, and the rise of populism across the globe. It seems possible that these factors are also applicable to the agricultural commodities markets and, as such, geopolitical threats are being witnessed lately.

Let us now consider the previous empirical research on the geopolitical effects on precious metals. A key distinction between agricultural and precious metal commodities is that the latter act as a haven, as well as a hedging instrument, especially during periods when geopolitical risk intensifies (Qin et al. 2020). Similar to the empirical findings outlined above, the comprehensive study of Baur and Smales (2020) confirmed that precious metals in particular are impacted by GPR Threat rather than GPR Act. A possible explanation for this might be that geopolitical events, such as war and nuclear threats, affect both agricultural and precious metal commodities. Conversely, this empirical research differed from the recent study of Yilanci and Kilci (2021) since the causality relationship was evident in certain periods concerning the precious metals market for the period January 1995 to August 2020. A plausible explanation of the causality instabilities identified by Yilanci and Kilci (2021) was due to the inclusion of monthly GPR data rather than the daily GPR index. Moreover, Yilanci and Kilci (2021) failed to account for the GPR sub-indices in order to better understand the causality relationship in the precious market.

From a practical perspective, these empirical findings are particularly relevant with respect to the ongoing Russo–Ukrainian war since much of the increase in agricultural commodity prices stems from the economic effects of war. Both Russia and Ukraine are major producers and exporters of various agricultural commodities, such as oats, corn, and wheat (World Bank 2022). In fact, wheat is the most important commodity produced by both nations, with both of them jointly producing 30% of the wheat traded (Behnassi and El Haiba 2022). With immediate effect, the Russian war in Ukraine accelerated the prices of various commodities, especially those concerning both energy and agriculture. The subsequent advancement of the Russian military force across Ukraine halted both the production and the exportation of grains since numerous Ukrainian ports had been closed for a period until the beginning of August 2022. Behnassi and El Haiba (2022) acknowledged that developing nations, such as Egypt, Lebanon, and Tunisia, are highly dependent on wheat imports that originate from Ukraine. Thus, if the Russo–Ukrainian war persists, the world will face a food shortage crisis. Consequently, food security would not be guaranteed to all nations. This situation would bring about serious consequences in terms of the quantity and quality of food, with emerging and underdeveloped nations suffering the most (Behnassi and El Haiba 2022; Jagtap et al. 2022).

6. Conclusions

The following research question was addressed in this study: Is there a causal relationship between the GPR sub-indices (GPR Threat and GPR Act) and agricultural future commodity prices (grains and softs)? The Granger causality analysis revealed that, in tandem, the GPR sub-indices impacted the prices of certain grain commodities, including wheat and oats. On the other hand, when each respective GPR sub-index was considered separately, it was noted that GPR Threat had further implications when compared with GPR Act.

Overall, this empirical study strengthened the idea that certain agricultural commodities, specifically grains more than softs, were susceptible to geopolitical events during the period 2000–2022. Indeed, this sample period included several geopolitical events. In fact, both the Arab Spring and the ongoing Russo–Ukrainian war are two geopolitical events that have impacted the agricultural commodities market. These empirical findings highlight the predictive power of the GPR sub-indices in relation to changes in future commodity prices, as these contain information that can shed light on the course prices are likely to take following a particular geopolitical event.

In fact, such research findings are envisaged to be beneficial to various economic stakeholders, such as policymakers, businesses, and institutional investors. Undoubtedly, in today's uncertain world, geopolitical risks are significantly increasing, generally materializing as either a threat or an act. First and foremost, this study on the effects of geopolitical risk on the commodity markets is of utmost importance to policymakers as they need to make effective decisions when faced with such an increase in geopolitical risk. Indeed, the primary function of policymakers is to undertake actions in the best possible way, especially during an unforeseeable crisis that could severely affect the overall economy. Corporate entities are also significantly dependent on the agricultural commodity market; therefore, this empirical study can assist these economic actors by providing them with adequate knowledge on how to deal with geopolitical risk. Ever since the financialization of the commodity market took precedence, institutional investors only accounted for financial risks that involve market, credit, and liquidity risks. This empirical study, however, clearly illustrated the importance of accounting for non-financial risks, namely, geopolitical risks, when trading such commodities.

Overall, this study should assist various actors in developing suitable strategies to better manage geopolitical risks while encouraging them not to underreact to geopolitical events but to counteract the situation of an increase in geopolitical risk. Yet, to a certain extent, geopolitical risk could prove uncontrollable, leading to serious economic repercussions. This issue is clearly illustrated in the current ongoing Russo–Ukrainian war and such an impact could potentially spill over onto other commodities, with ordinary citizens bearing this additional cost.

It is important to highlight that commodity prices are affected by other macroeconomic variables, such as inflation, supply, and demand, which were not controlled in this model. Data related to these macroeconomic variables were not available; hence, these variables could not be included in the model. For instance, since the empirical study was based on the daily prices, the data in relation to inflation could not be included in this model, as the latter is issued on a monthly and annual basis.

Another limitation of the study is that the Johansen cointegration test could not be performed since both GPR sub-indices (GPR Threat and Act) were identified as stationary when conducting the difference-level test. Overall, the scope of this test was to assess the long-term relationship between the GPR Act and Threat sub-indices and the respective agricultural commodity prices. However, while the GPR sub-indices were stationary, the agricultural commodity prices were non-stationary. Hence, the Johansen cointegration test was not possible, and thus, a distributed lag was adopted.

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