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The Relationship between Agricultural Commodities and Stock Market in Case of Thailand: Safe-haven, Hedge, or Diversifier? – Cross Quantilogram Analysis

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Abstract: This paper proposes to identify Agricultural futures' roles (Safe-haven, Hedge, and Diversifier) in the Thai stock market during 2000-2020 by applying a bivariate Cross-Quantilogram (CQ) approach. The CQ approach can examine the cross-quantile correlation between assets, while the traditional approaches (such as GARCH, DCC, and MSV) examine only mean-to-mean dependency structures. The CQ methodology can estimate the tail dependencies and directional predictability between financial assets more accurately than traditional methods since financial assets typically have a skewed and asymmetric distribution. The correlation between assets during the extreme market condition (tail dependencies) is important to classify a financial asset as a Safe-haven role. The agricultural commodities considered in this study are the most active asset categories in the markets (cereals, oilseeds, other soft commodities, and miscellaneous commodities). The results show that the agricultural assets are more explicitly correlated with the Thai stock market in crisis periods, such as a negative result in canola during COVID-19. Agricultural commodities, including wheat, oats, and canola, can play a strong safe-haven role in the Thai stock market, according to the lowest cross-quantiles (bearish market) data. According to the results of overall quantiles (normal situations), wheat, corn, canola, soybean, and sugar can all be used as hedges. The rolling windows for directional predictability, which show the time-varying CQ, confirm that these agricultural commodities can be served as Safe-havens throughout the study periods. Therefore, including these specific agricultural commodities (Safe-haven or Hedge) in a portfolio of Thai stocks will help lower risk and boost performance under normal and extreme downturn situations.

Keywords: *Agricultural commodity, commodity market, CQ, quantile, safe-haven, stock market, Thailand*

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INTRODUCTION

The stock market has played an essential role in today's financial and economic environment. Its mechanisms and capital flow encourage the economy and financial performance. Most people focus on the success of a country's stock market as the best indicator of how well that economy is performing (Han, Linton, Oka, & Whang, 2016), The Importance of Stock Markets, Fx empire). Meanwhile, investors can make their money from speculative trading from dividends paid out rather than saving money in a static bank account with a low return. However, investing in the stock market is sometimes probably risky. Stock prices in the stock exchange market are varied daily. It can be affected by other externalities apart from the market mechanisms, such as government policy, legal and regulation, political conflict, natural disasters, or current pestilence situations, for instance, the COVID-19 pandemic since 2019. These factors play an important role in building investors' sentiments for both domestic and global investors. Thus, investors will always

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look for other investments to optimize portfolio combinations and diversify their risks and unexpected occurrence amid an uncertain economy.

When the assets or other investments are included in the investor's portfolio, the role (correlation) between assets is useful for investment strategy as managing their risk and return. Apart from the traditional correlation approach (normal market condition), a Safe-haven analysis was used to investigate the relationship between assets when the assets we that concerned (for this study, we adopt the Thai stock market) were going through extreme downturn condition. The definition of safe-haven assets appeared to be different across previous existing studies. Following Cho and Han (2021); Kaul and Sapp (2006); Ranaldo and Söderlind (2010), studies, investors are drawn to Safe-haven in uncertain times, which can provide hedging benefits for their reference assets during periods of financial distress, subject to the movements in global risk aversion. Furthermore, Baur and Lucey (2010); Baur and McDermott (2010) defined the asset role into three types (Hedge, Diversifier, and haven). The specific property of a haven asset is the non-positive correlation with other assets during extreme downturn market conditions. Therefore, the correlation may be either positive or negative during normal periods or bullish market conditions.

As we discussed the different roles of assets above, investors will therefore have a variety of strategies to manage their portfolios depending on their preference and risk acceptance. Likewise, the Commodity market, especially Agricultural commodities, is expanding traders in the recent exchange market, (Ahmad-Ur-Rehman, Haq, Jam, Ali, & Hijazi, 2010; Banton, 2020). Domanski and Heath (2007); Sieczka and Hołyst (2009) showed that commodity markets have become more like financial assets for investment. Figure 1 (sourced by Borg and Kits (2020)) shows the increase in the trade volume of commodities futures in the recent ten years. It also had traditionally been used as an attractive diversification opportunity and hedging risk in investor portfolio performance due to its sometimes low or negative correlation with stock market assets (Jensen, Johnson, & Mercer, 2000; Khan, Jam, Shahbaz, & Mamun, 2018). During the past twenty years (especially in 2008-2010 financial crisis), many institutional portfolio managers included commodity futures to their portfolios. This resulted from the use of commodity derivatives having substantial growth beyond historical levels associated with trade hedging.

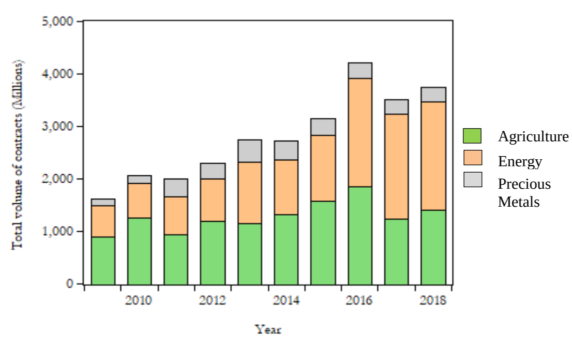


Figure 1 *Commodities Futures Trade Volume between 2009-2018 (Source: (Borg & Kits, 2020))*

Banton (2020) mentioned that some commodities showed more consistency than other assets, such as gold and oil, which also served as the reserve asset for central banks to buffer against financial market volatility. Nonetheless, the agricultural market was inevitably related to the overall stock market and individual stocks. Agricultural commodities have increased in trading in the last 10 years, especially in emerging markets (China, Brazil, India, Thailand, etc.). Likewise, the market trading system has become more advanced over time. Now, investors can trade the agricultural futures with uncalled-for real assets (CFDs). The agricultural futures have been added to institutional financial funds and have the larger portion in portfolios, as mentioned in The Economist, Bloomberg, and Financial Times. However, agricultural futures were not widely interested in or included in institutional funds and individual investors' portfolios in Thailand. Some of them may act as a Safe-haven, Hedge, or Diversifier against risk in the stock exchange of Thailand. Including certain agricultural commodities in the Thai stock market portfolio may improve the portfolio's performance significantly.

Many empirical studies investigated the correlation of commodities with the stock market on the assumption of haven analysis. Basu and Gavin (2010) found that using institutional investors' commodity futures to hedge against stock market risk is a relative event (Subprime crisis). Trading in commodity futures also increased along with the high growth expansion of trading in the markets. Baur and Lucey (2010); Baur and McDermott (2010) found the hedging role of gold to stocks on average and the haven in extreme stock market conditions in a developed country, especially during the recent financial crisis. For the relationship across Asia countries, Aftab, Shah, and Ismail (2019) found that gold could perform a hedge and haven role for Asian currencies. Kaur and Dhiman (2021) confirmed no causal link between agricultural commodities and main stock indices in India. These studies were examined by various econometric methodologies such as GARCH, Dynamic Conditional Correlation (DCC), and Multivariate Stochastic Volatility (MSV). However, they were not interested in detecting directional predictability and quantile dependence among pairwise two-asset time series that only examine the mean-to-mean dependency structures. They cannot assess the tail dependencies, which can ensure that the safe-haven asset will experience the same extreme condition of partly covering the negative stock returns. It's crucial to clarify that if one asset is in a bearish state (at the left quantile), the potential is anticipated to be in a bearish state on the same day or the following day. By reasoning, having two markets in completely different states (one bearish and the other bullish) is a rare scenario, as we know the co-boom and the co-crash in financial markets. The empirical works from Cenesizoglu and Timmermann (2008) showed that the financial time series has a heavy tail and asymmetric effect on the return distribution. They also found that the distribution center was less helpful in predicting different parts (quantiles) of stock return (including the tail and shoulders of the return distribution). Moreover, the study revealed by Cho and Han (2021) that the traditional approaches were not suitable for measuring cross-quantile correlation among financial assets. To extend the previous literature, we adopt the CQ approach developed by Han et al. (2016), which can investigate the correlation between assets in different quantities with more accuracy and flexibility.

The CQ approach is an extension of the Quantilogram method established by Linton and Whang (2007). This method examines the cross-quantile dependence and directionality analysis between variables in different quantiles, representing different market states (non-linear co-movement in the extreme of the tails). Another advantage of the CQ method is that it can measure cross-correlation for possible large lags. In addition, this methodology can provide different results presentations that are conceptually appealing and easy to understand, such as heatmap results and rolling windows.

Several papers studied the correlation between variables by using the CQ method (Ji, Zhang, & Zhao, 2020; Shahzad, Bouri, Roubaud, Kristoufek, & Lucey, 2019; Uddin, Rahman, Hedström, & Ahmed, 2019; Waheed, Klobas, & Ain, 2020; Waheed, Klobas, & Kaur, 2017). However, there were few studies on the relationship between agricultural commodities and the stock market, especially in Asia and ASEAN countries such as Thailand. Furthermore, understanding the dependence between individual agricultural products and the stock market other than the overall commodities index is also essential for investors in portfolio management decisions. So, by conducting the CQ approach, we can investigate the role of Agricultural commodities in the Thai stock market under extreme downturn situations (tail of price distribution).

Referring to previous arguments, this paper aims to identify the role of Agricultural commodities (safe-haven, hedge, or diversifier) in the Thai stock market by conducting a CQ approach as there was evidence of including agricultural commodities in many international financial institution funds in the past crises. This thesis also observes the behavior among different products (overall price index and individuals' futures prices) and other types of commodities (ex. oil, gold, precious metals) as their unique characteristics on the market. In addition, we also categorize the time series into sections for different samples (whole period and crisis) and lags to see the variety of results within the different periods. The results from this empirical study will provide a more in-depth correlation between assets by observing their tail dependencies and directional predictability at the different cross-quantiles.

RESEARCH METHODOLOGY

Theoretical Framework

Markowitz portfolio theory (Markowits, 1952): Markowitz's framework (Markowits, 1952). Markowitz Portfolio Theory was also known as a foundation of Modern Portfolio Theory (MPT) which was adopted in many financial studies and portfolio management (a summary of the MPT process is presented in Figure 2). MPT uses diversification as a central theme in finance. It expressed the idea of "diversification or non-diversification" by introducing the statistical concept of covariance and correlation. Certainly, many innovations in the finance field also applied the concept of diversification or the new method to improve estimates of variance and covariance to improve diversification and risk measurement.

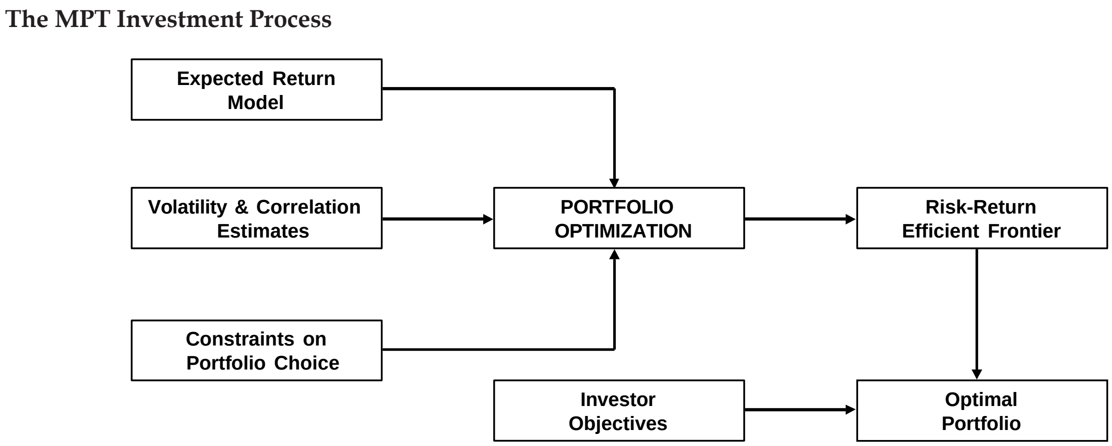


Figure 2 *MPT framework (Source: (Fabozzi, Gupta, & Markowitz, 2002))*

As necessary for our findings, we only bring up the diversification concept (especially the point on correlation), which does not mention utility function and Risk Acceptant preference. The link between correlations and portfolio risk is referred to as "diversification" in Markowitz's Portfolio Selection Theory and MPT. The goal of diversification is to invest in a variety of investment categories to optimize returns and minimize risk. So, it cannot be denied that the diversification concept relates to the correlation between assets in investors' portfolios. Correlation is an important indicator of diversification's impact. It serves as a useful indicator of the covariance of portfolio performance. A portfolio with a smaller correlation is suggested to be less risky (variance) than a larger correlation portfolio (Mangram, 2013).

Feasible and efficient portfolio:

Efficient portfolios are the portfolio that provides a maximum possible expected return subjected to the given levels of risk. Constructing an efficient portfolio is important to assume investors' making decisions such as risk averse. Figure 3 shows the Feasible set and Markowitz's efficient set of investors' portfolios with more than one asset class. The efficient set of portfolios is probably called the "efficient frontier." Then, an investor will aim to hold one portfolio on the efficient frontier at their level of risk by trade-off the expected return. The best portfolio held by an investor from all those efficient frontiers is called "the optimal portfolio."

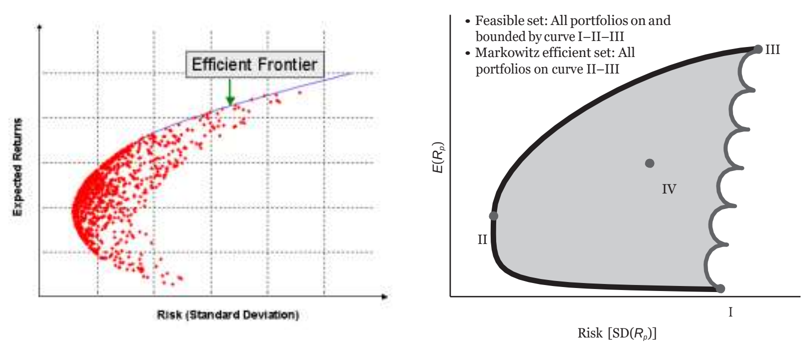


Figure 3 *Feasible and efficient Portfolios with more than one asset (Source: (Fabozzi, Markowitz, Kolm, & Gupta, 2012)*

Definition of Weak/Strong Safe-haven, Hedge, and Diversifier

Based on the argument of safe-haven analysis from Baur and Lucey (2010); Baur and McDermott (2010) the relationship between assets can be separated into three main types (safe-haven, hedge, and diversifier). The assets are labeled as a Strong haven when there is negative predictability from stock asset return to the potential asset in the low quantiles of both assets. This guarantee that the extreme stock downturn is followed by the future positive return of the safe-haven asset. Meanwhile, the weak haven is not performing the evidence of predictability from the stock index to the potential safe-haven asset at the low quantile. A Hedge is an asset generally uncorrelated or negative with based assets (stock market) for over the entirety of the assets' correlation. On the contrary, a Diversifier is a potential asset that positively correlates with a based asset on average.

CQ Approach (Han et al., 2016)

The CQ approach to investigate the safe-haven role is implemented for a robustness check, followed by Ji et al. (2020); Shahzad et al. (2019). The pair-wise CQ between equity indices and potential safe-haven assets was calculated and compared their cross-quantile dependence over the samples. The theoretical approach can be explained as follows.

Given two time series data as a stationary pairwise variables $\{x = xi, t\} t\varepsilon[1, T], i = 1, 2, ..., T$ where $x_{1,t}$ and $x_{2,t}$ represent the potential asset return and stock market index respectively. The unconditional quantile of the return of $\{x = xi, t\}, i = 1, 2$ is defined as $q_i(\alpha) = inf\{u; F_i(u) \geq \alpha\}$ where the conditional distribution function of series xi, t is equipped with the density function $(f.)$. The two-dimensional series of quantiles is expressed by $\{q_1(\alpha_1), q_2(pha_2)\}$ where q is specified as the quantile rank we are interested in evaluating the directional predictability (ex. $\alpha_1 = 0.95, \alpha_2 = 0.05$.

Then, the measurement and testing for the directional predictability between $x1, t$, and x_2, t for difference quantiles of the CQ for α-quantile with h lags can be written as (Han et al., 2016)):

$$\rho_\alpha(h) \equiv \rho_{\alpha_1,\alpha_2}(h) = \frac{\mathbb{E}\left[\psi_{\alpha_1}\left(x_{1,t} - q_1\left(\alpha_1\right)\right)\psi_{\alpha_2}\left(x_{2,t-h} - q_2\left(\alpha_2\right)\right)\right]}{\sqrt{\mathbb{E}\left[\psi^2_{\alpha_1}\left(x_{1,t} - q_1\left(\alpha_1\right)\right)\right]}\sqrt{\mathbb{E}[\psi^2_{\alpha_2}(x_{2,t-h} - q_2(\alpha_2))]}} \tag{1}$$

For h = 0, +1, +2, ..., where $\psi_\tau(u) \equiv \Pi(u \geq 0)$, for an indicator function Π and $[x_(i,t) - q_i(\alpha_t)]$ is the quantile exceedance process. So that $\psi_{\tau_i}(x_{i,t} - q_i(\alpha_i))$ describes the violation or "hit" process. According to the formula, the CQ measures the serial correlation between a pair of variables at different quantiles. When h = 1, $\rho_\alpha(1)$ it represents the cross-dependence between the quantile of a potential safe-haven stock index $y_{1,t}$ at time t and the quantile of a stock index $x_{2,t}$ at time t-1. There is no predictability from the stock index to the quantile α_1 of safe-haven assets if $\rho_\alpha(1) = 0$, i.e., $x_{1,t}$ is not provided useful information from stock market return $(x_{2,t})$ for predicting the safe-haven assets' returns on the next trading day. In contrast, if $\rho_\alpha(1) \neq 0$ $x_{1,t}$ is provided one-day directional predictability from stock returns to safe-haven assets' returns at $\alpha = \alpha_{\text{stock return}}(\alpha_{\text{potential asset}})$ and will be a strong safe-haven asset when the sign is negative.

Furthermore, to examine the null hypothesis of no cross-dependence, $H_0 : \hat{\rho}_\alpha(h) = 0, \forall h \equiv [1, H]$ $H_0 : \hat{\rho}_\alpha(h) = 0, \exists h \equiv [1, H]$ portmanteau-typed statistics is proposed to detect the null hypothesis (Han et al., 2016),

$$\widehat{Q}^H_\alpha = \frac{T(T+2)\sum_{h=1}^{H}\widehat{\rho}^2_\alpha(h)}{T-H} \tag{2}$$

Given that there is noise in the asymptotic CQ under the null hypothesis of no directional predictability, Han et al. (2016) proposed the Stationary Bootstrap (SB) method from Politis and Romano (1994) to approximate the distribution of the testing statistic under the null hypothesis, which can then be utilized for statistical inference and used to calculate critical values and confidence intervals. This method can be combined with a rolling window approach to monitoring the time-varying CQ throughout the period. Our study considers the dependence between all pairs of quantiles given by 0.05, 0.10,0.15, ..., 0.95. And evaluate across four lag values as k = 1, 5, and 22 which involve the relationship among assets on daily, weekly, and monthly trading days.

DATA DESCRIPTION AND ANALYSIS METHODOLOGY

Data Description

In this study, we employ the daily data from January 2000 to December 2020. For Agricultural commodities prices, we use daily data of futures derivatives from DataStream and CEIC, which can provide a full length of data and provide us with many Agricultural products separately. We decided to choose the Agricultural commodities which are more suitable for Thai stock markets and widely traded on futures markets, such as rice, soybean, coffee, etc. The variables mostly refer to the 24-hour CFDs real-time market that Thai investors or financial advisors easily follow and trade in the market. For Thai Stock price index, or SET Index, is derived from the Stock Exchange of Thailand. For the stationary process, we apply log return transformation and calculated logarithmic difference at time t and t-1 for each asset time series.

Moreover, our analysis will be performed in subperiods to compare the results with full period samples. The subsample is the period during the crisis (for example, the Global Financial Crisis (GFC)). The dating of GFC almost corresponded to the study of Baumöhl and Lyócsa (2017), which dated from June 2007 to February 2009. The COVID-19 crisis will be largely referenced by the dating employed by Ji et al. (2020); Kinateder, Campbell, and Choudhury (2021), January 2020 to December 2020. These dating we analyzed will also be suitable for the stock market downturn in Thailand, such as the timeline during the 2008 GFC and 1st and 2nd wave outbreaks of COVID-19.

Analysis Methodology

Our empirical analysis is conducted with continuous log return. We present the summary statistics of the daily return series with the static test. It will provide the standard indicators such as mean return, standard deviation, quick ratio, skewness, and kurtosis. A time series plot of each asset is given to see its' trend and exhibit among the period; all the variables are transformed into natural logarithms to reduce heteroskedasticity in the data series. We can see a comparison across the series, how its' series resemble, and the possible linkage logical to the economic events. Then, we pretend to apply the CQ approach to examine the cross-quantile dependence between the variables and confirm the validity of potential assets' performance at any quantile of assets' return. Apart from detecting Safe-haven properties of assets, investment implications (the benefits from adding potential assets to the portfolio) are also important to an investor's decision-making or strategy. We, therefore, simulate the simple pairwise optimized portfolio to observe return/loss and volatility in each asset's performance.

CQ analysis: The CQ approach can present the estimation in many forms of results. It can be illustrated in heatmaps figures at different lags under Stationary Bootstrap Procedure which is uncomplicated to define (see Figure 4). The statistical significance of predicted directionality is determined using the Box-Ljung test. (Eq. 2), and all little dependence is set to zero. The color bar shows the magnitude of cross-correlation when significant and denotes causal flows from the stock market return to safe-haven assets. The blue on the heatmap denotes a negative effect, meaning that the potential asset can be identified as a strong safe-haven asset. The red color denotes positive predictability between the stock market and potential assets, while the green color stands for no predictability on their low quantiles (the null hypothesis of no predictability cannot be rejected.), i.e., a weak version of the safe-haven asset. The results are divided into three values of lags parameter k (1, 5, and 22 days) and 2 subsamples: full sample and crisis.

For traditional setting, we acknowledge the potential asset as a clear characteristic (safe-haven, hedge, and diversifier) in the cases below

(1) STRONG SAFE-HAVEN: If there are significant negative cross-quantiles only in the left corner of the heatmap, especially during the crisis sample i.e., extreme negative stock returns (market distress) are followed by positive assets returns in the future.

(2) WEAK SAFE-HAVEN: If no directional predictability between assets occurred on the left corner of a heatmap, the other cross-quantile results could be a positive or negative sign.

(3) HEDGE: If there are negative significant or non-significant in the overall cross-quantiles of heatmap illustration.

(4) DIVERSIFIER: If there are mainly positive significant coefficients in the left-corner and overall quantiles of heatmap illustration.

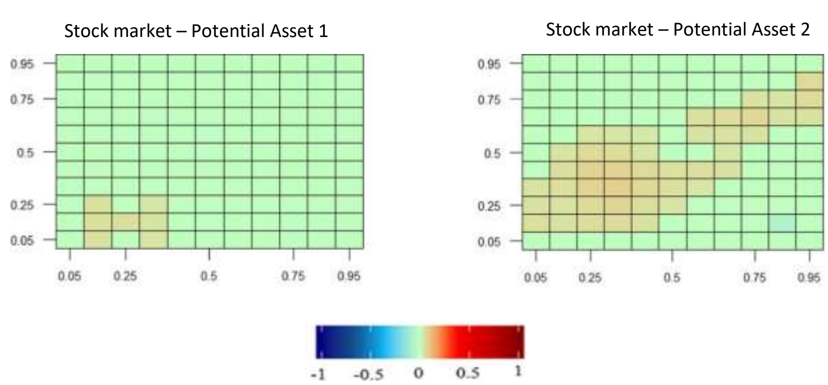


Figure 4 *Heatmap illustration from stationary bootstrap procedure (Source: (Uddin et al., 2019)*

Moreover, the CQ is illustrated as example plots of time-varying results (or Rolling window directional predictability) from equity indices to potential Agricultural commodities (Figures 5a and 5b). The Rolling window displays provide the whole-time trend empirical results as it would be practically interesting to consider a sample period that includes the recent crisis and post-crisis. For our study, we attempt to use line Rolling window directional predictability (Figure 5b) as a more comfortable way to observe and interpret the results. Finally, the summary of this rolling window was estimated in percentage terms of the overall crisis period.

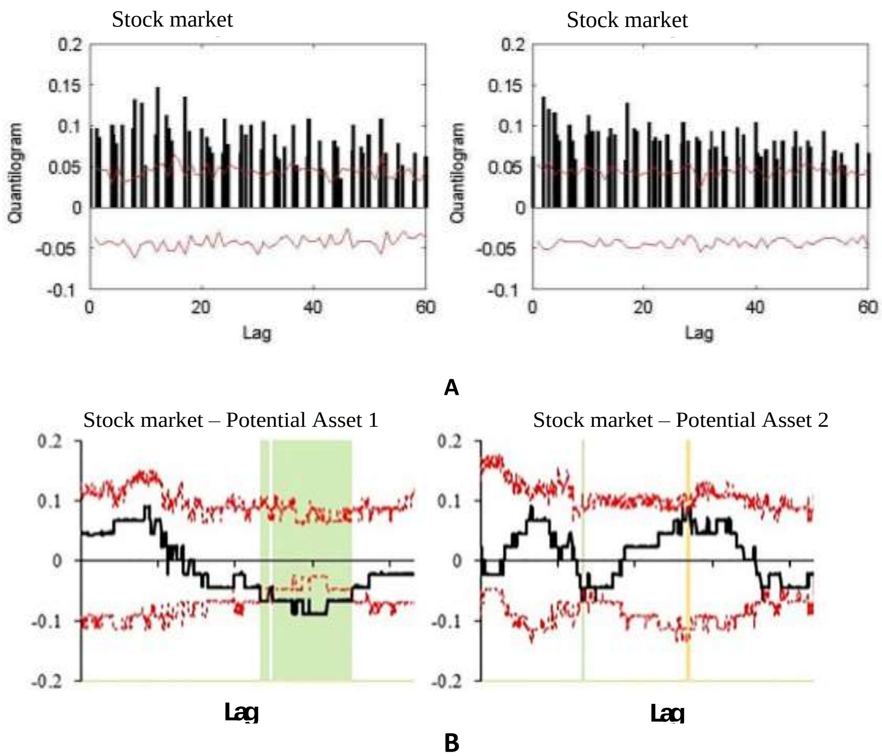


Figure 5 *CQ rolling window directional predictability (Source: (Han et al., 2016; Shahzad et al., 2019))*

Pairwise portfolio simulation: In practice, these potential assets can be added to portfolios as investors' strategies for their benefits of diversification (diversifying opportunities or hedging risk). It is necessary to make some assumptions about how investors behave when making investment decisions. From Asset allocation theory, an investor will seek to maximize the expected possible return given the risk level by investing in various assets. But in case we are interested, we will be looking for individuals' performance when they are gathered with the stock market in the pairwise portfolio. The asset will be beneficial if its pairwise cumulative portfolio return can perform more efficiently as either higher expected returns or less negative loss than a single investment from the stock market. We designate the sample as crisis period (stock market were at extreme downturn condition of 10 percentile rank) and normal period (stock market were at 50 percentile rank). The pair of portfolio performances are compared to an individual stock market return as the value of Expected return, Sharp Ratio, correlation, and volatilities. Therefore, the time-varying pairwise optimized portfolio with the Thai equity index (SET Index) is constructed to observe their performance (return and loss) through the different periods (For adequate of author's study, the weight set in the example is defined in moderated value as 25%). Moreover, the recent traded volume of these potential assets could be analyzed as the investors' interest in commodity and agricultural commodity markets.

RESULTS AND DISCUSSION

Data Analysis

For each market, we collect the daily closing price of the SET Index followed by S&P GSCI indices (commodity, gold, oil, agricultural commodity, and precious metal). Following the objective of this study, the daily price of agricultural products in each category (including cereals, oilseeds, other soft commodities, and miscellaneous commodities) are collected. The variables are adjusted to balance panel data with the same trading days (a reference to the opening market of the SET Index). The agricultural futures prices are mainly modulated in the same unit as dollars/ ton to eliminate risk from exchange rates. The time series plot of each asset price is given in Figure 6. We can see the evolution of assets price through different periods. The price of many assets such as gold index, metal index, oilseeds category, rice, wheat, corn, and cocoa has more substantial growth than other assets and can perform a good trend against SET Index downturn during crisis period from the vertical highlight in GFC or COVID-19 cases.

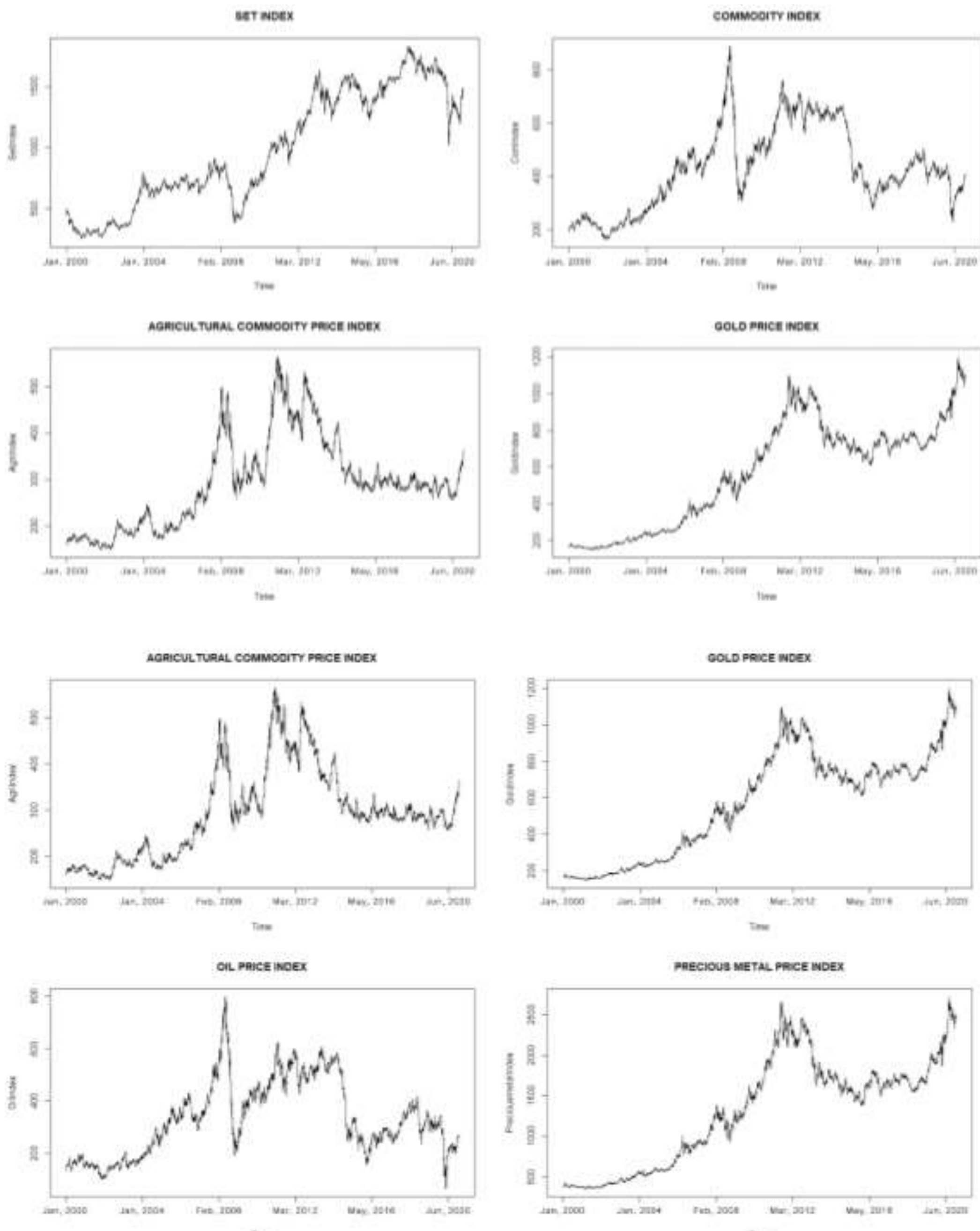
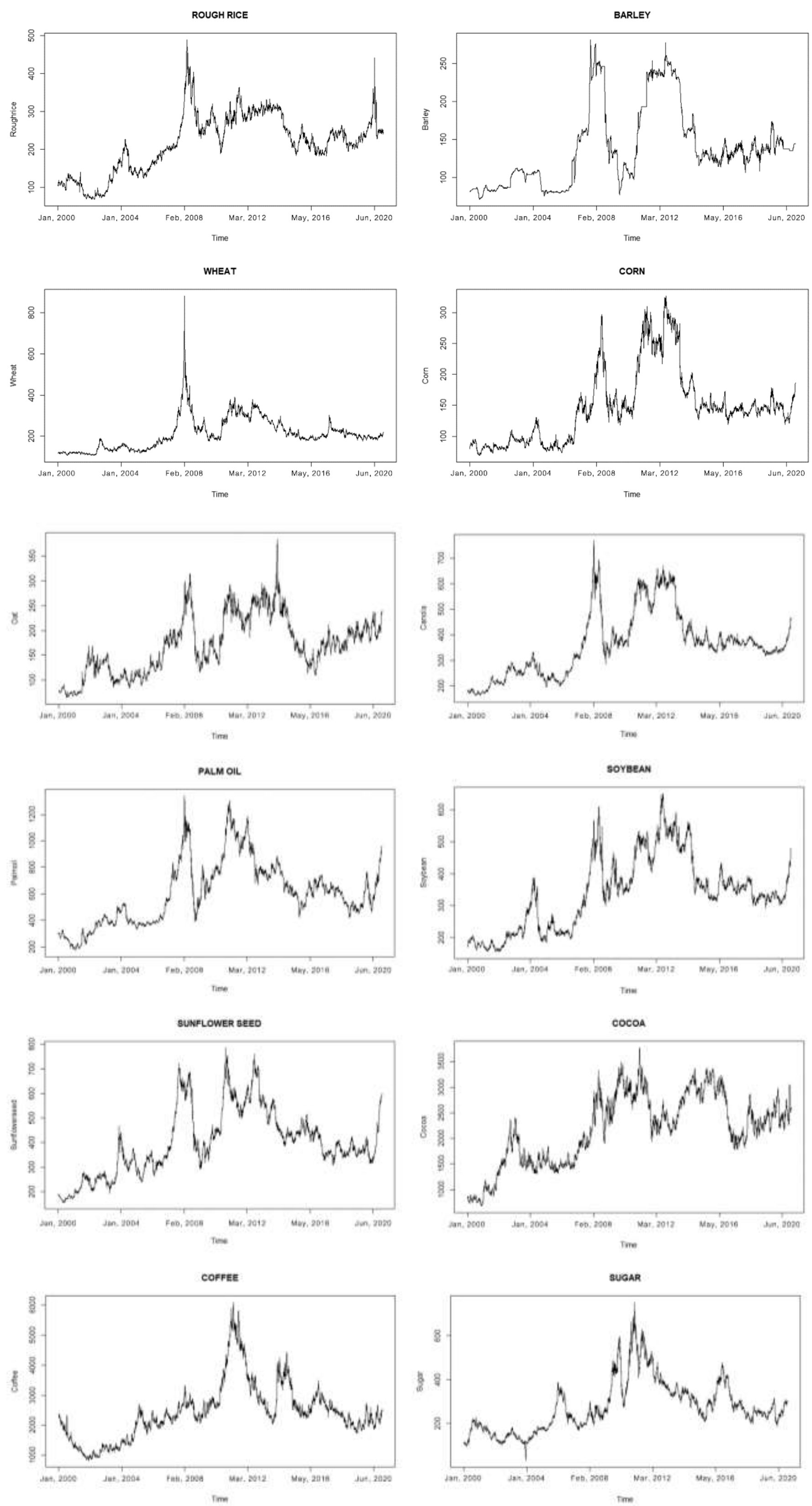


Figure 6 *Time series plot of SET index, main indices, and agricultural futures prices (Note: these time series plots are collected in daily data from 1 January 2000 to 31 December 2020.)*



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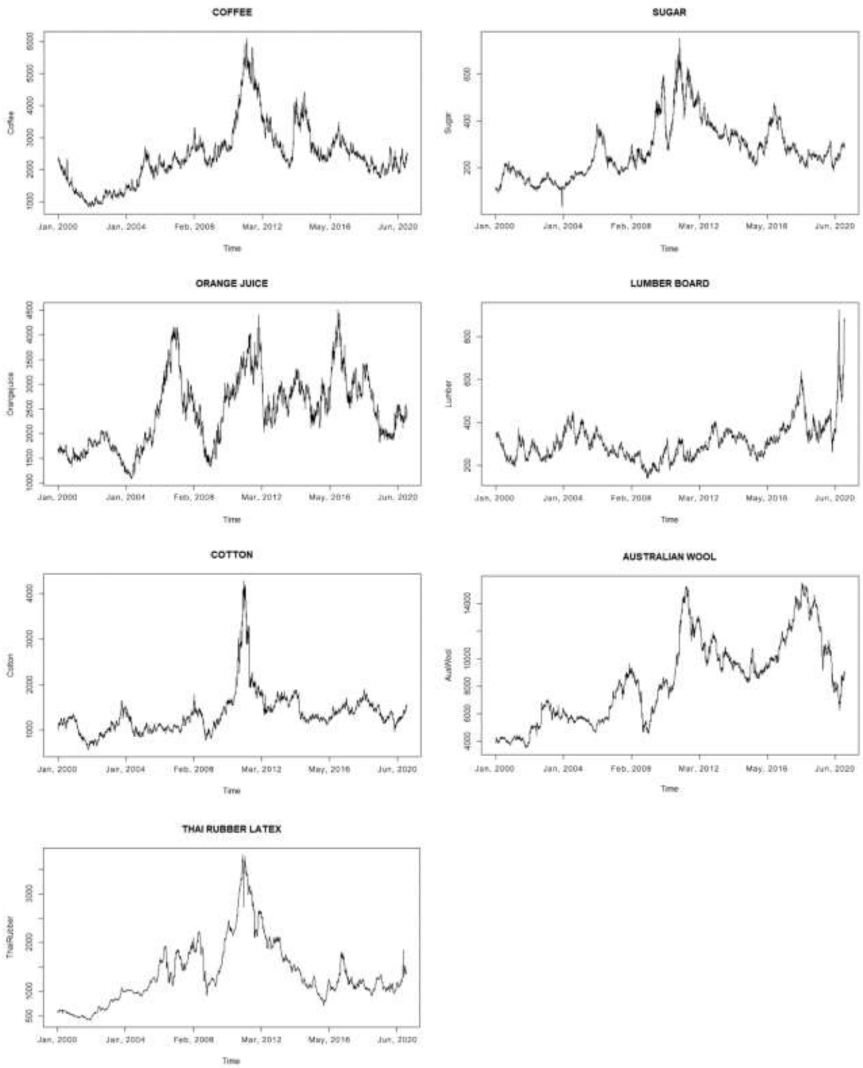

Figure 6 Continue....

As argued by many empirical papers, the financial asset price is non-stationary. Our analysis is conducted with a logarithmic difference at first for stationary significance. Table 1 – 3 presents the summary of key descriptive statistics for the time series considered in this study, along with some additional statistics. Surprisingly, apart from gold and precious metal price index, some agricultural commodities such as oilseeds products, cocoa, etc. have an unexpected high sharp ratio with a lower standard deviation than other categories. However, in the crisis period (GFC and COVID-19 sample), many commodities have a sharp negative ratio. Next, overall skewness and kurtosis values, most agricultural futures show the value of higher kurtosis and less skewness than gold and oil index, which can provide that agricultural is going to be frequent small gain and less extreme losses. We also observe the stationary of the series with augmented Dickey-Fuller (ADF) and Kwiatkowski Phillips Schmidt Shin (KPSS) tests and verify the stationary evidence in all variables.

CQ analysis: To achieve our findings and objectives, we implement the CQ approach as applied in Ji et al. (2020); Shahzad et al. (2019), to evaluate the validity of potential safe-haven assets among normal market (gross sample) and crisis period (GFC and COVID-19), respectively. At first, we apply "Heatmap illustration." We examine their relationship in normal market conditions with a full gross sample (Figure 7 – 9). For the author's estimation, the quantiles interested are examined in the "Decile unit" for every 10% return distribution. Each result illustration displays a Decile of SET Index and potential safe-haven assets on the X and Y axes, respectively. The magnitude of positive/negative spillover is illustrated through the color scale from blue (negative correlated) through soft grey (uncorrelated) to red (positive correlated). Moreover, we also observe the sample from the Global Financial Crisis period (Figure 10 - 11) and the Covid-19 pandemic period (Figure 12 - 13). The summary of heatmap results (referenced from these figure illustrations) is represented in table 4 as it is aimed to make the result's interpretation (author's perspective) can be easier to follow.

As indicated in the Methodology section, potential assets will be a strong safe-haven asset if the heatmap's lowest left corner (10% cross-decile) is blue or light blue, which introduces extreme negative stock returns followed by future positive potential assets price return in the next trading periods. Meanwhile, if the left corner and most of the heatmap are red or light orange, the counterpart asset is suggested to be a diversifier. Furthermore, the asset will be a weak haven for the stock market if the lowest left corner of the heatmap is light grey color, meaning that no dependence exists among the lower deciles. An independence test is performed to test the significance of the CQ under the stationary bootstrapping procedure (eq. 2). We, therefore, fill a zero value to the CQ if the null hypothesis of no predictability cannot be rejected.

Overall heatmap results, we can summarize the into 3 main issues. At first, comparing the overall outlook from the full sample and crisis sample, there is less correlation among variables in the full gross sample than in the crisis period sample. The results from crisis samples tend to have a more clear correlation among assets than the overall gross sample (such as negative results to gold and precious metal during COVID-19). For example, cereal products (rough rice, barley, wheat, corn, oat), selected indices, and cocoa tend to have a more positive relationship in low deciles at a 5-day lag than a 1-day lag. Meanwhile, the major oilseed products, sugar, and cotton perform a consistent result from major cases and lags with no predictability in general. Furthermore, some agricultural futures show an independent outcome among different period samples, such as Australian wool, which performs almost negative in overall and GFC samples but positive for the COVID-19 case.

Secondly, we analyze the results from the full gross sample (see Figures 7 - 9). It is unsurprisingly that there is an absence of negative predictability from the SET Index (blue color on the lowest left corner of the heatmap) in major cases and correlations, although some assets such as wheat, oat, and canola can perform the negative correlate in lowest left-corner at least 1 case in any lags. Consequently, these results suggest that most tested variables could be weak safe-haven assets to the SET Index. Meanwhile, many indices (commodity, gold, agricultural), wheat, corn, canola, soybean, cocoa, coffee, sugar, cotton, and Australian wool have negative relationships and no predictability at most cross deciles on average (during both normal and crisis condition). However, some positive predictabilities occurred on the lowest left-corner results, such as gold and precious metal (lag 5 and 22), barley, lumber, and palm oil.

And the third issue is that we monitor their relationship during crisis periods (see Figures 10 - 13). The selected case studies are the Global financial crisis (GFC) and the COVID-19 pandemic. The results from the crisis period sample are slightly different from the overall gross sample. For the GFC case, the potential assets tend to be a more positive relationship with SET Index. Only wheat and orange juice can perform as strong haven assets. From the COVID-19 pandemic, the relationships between assets are more correlated than in the GFC case. Some assets can perform such an excellent hedging asset like gold, precious metal, corn, oat, canola, soybean, and sugar as either virtually negative or not correlated with SET Index overall. Wheat and sunflower seed can perform the negative correlate in the lower left corner (strong haven). Afterward, the assets, for instance, agriculture index, oil, rough rice, canola, soybean, and Thai rubber, are uncorrelated with SET Index at the lowest decile.

Table 1 *DESCRIPTIVE STATISTICS AND UNIT ROOT TESTS OF FULL PERIOD SAMPLE*

	Mean%	Std. dev %	Min	Max	Sharp Ratio	Skewness	Kurtosis	ADF	KPSS
Index									
SET Index	0.021	1.319	-0.160	0.110	0.016	-0.880	11.530	-16.182***	0.086
Gold Price Index	0.037	1.119	-0.080	0.090	0.033	-0.140	5.700	-15.985***	0.204
Commodity Price Index	0.015	1.523	-0.130	0.130	0.010	-0.310	5.760	-17.600***	0.145
Oil Price Index	0.012	2.732	-0.570	0.440	0.005	-1.320	60.670	-16.96***	0.111
Agricultural Price Index	0.016	1.244	-0.080	0.080	0.013	-0.050	3.050	-16.587***	0.107
Precious Metal Price Index	0.037	1.176	-0.090	0.090	0.031	-0.290	5.670	-17.598***	0.144
CEREAL									
Rough Rice	0.016	1.899	-0.300	0.280	0.009	-0.26	39.880	-19.091***	0.078
Barley	0.011	1.415	-0.320	0.310	0.008	-1.560	161.960	-15.450***	0.091
Wheat	0.012	1.700	-0.230	0.220	0.007	-0.400	18.890	-17.136***	0.082
Corn	0.017	1.868	-0.270	0.170	0.009	-0.490	14.460	-16.408***	0.066
Oat	0.023	2.375	-0.250	0.150	0.010	-1.260	13.630	-17.950***	0.041
OIL SEEDS									
Canola	0.017	1.260	-0.130	0.080	0.014	-0.560	7.880	-15.760***	0.047
Palm Oil	0.024	1.654	-0.110	0.100	0.014	-0.090	5.130	-14.700***	0.049
Soybean	0.020	1.644	-0.230	0.200	0.012	-1.070	18.870	-16.830***	0.068
Sunflower Seed	0.039	1.264	-0.150	0.100	0.031	-0.730	12.780	-15.900***	0.068
OTHER SOFT COMMODITY									
Cocoa	0.022	1.987	-0.120	0.140	0.011	-0.120	2.790	-18.900***	0.085
Coffee	0.001	2.199	-0.130	0.270	0.001	0.470	7.180	-18.000***	0.070
Sugar	0.019	2.976	-0.490	1.320	0.006	16.110	771.480	-18.340***	0.066
Orange Juice	0.008	2.005	-0.140	0.150	0.004	0.110	3.950	-18.640***	0.041
MISCELLANEOUS COMMODITY									
Lumber	0.018	2.100	-0.240	0.150	0.008	0.270	6.180	-16.420***	0.168
Cotton	0.008	1.897	-0.270	0.170	0.004	-0.420	11.930	-17.900***	0.034
Australian Wool	0.013	1.014	-0.130	0.130	0.013	0.180	43.310	-15.830***	0.115
Thai Rubber	0.012	0.981	-0.170	0.110	0.012	-1.400	29.430	-15.950***	0.192

Notes: The table presents the descriptive statistics and unit root tests for the time series of variables price. The sample period is from 1 January 2000 to 31 December 2020. ADF and KPSS tests present empirical statistics of the Augmented Dickey-Fuller unit root test (Dickey & Fuller, 1979) and KPSS (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) stationarity test, respectively.

Table 2 *DESCRIPTIVE STATISTICS AND UNIT ROOT TESTS OF THE GLOBAL FINANCIAL CRISIS PERIOD SAMPLE*

	Mean%	Std. dev %	Min	Max	Sharp Ratio	Skewness	Kurtosis	ADF	KPSS
INDEX									
SET Index	-0.130	1.886	-0.110	0.080	-0.069	-0.660	5.600	-8.405***	0.328
Gold Price Index	0.077	1.687	-0.060	0.090	0.046	0.250	2.630	-7.879***	0.083
Commodity Price Index	-0.081	2.281	-0.080	0.130	-0.035	0.220	4.250	-8.198***	0.885***
Oil Price Index	-0.087	3.279	-0.130	0.220	-0.027	0.550	6.820	-8.068***	0.780***
Agricultural Price Index	0.008	2.022	-0.080	0.070	0.004	-0.410	1.350	-7.579***	0.511***
Precious Metal Price Index	0.067	1.750	-0.060	0.090	0.039	0.100	2.560	-7.918***	0.089
CEREAL									
Rough Rice	0.045	1.940	-0.110	0.080	0.023	-0.430	3.480	-6.479***	0.546***
Barley	-0.054	2.077	-0.320	0.060	-0.026	-8.390	125.830	-6.009***	0.509***
Wheat	0.036	3.202	-0.230	0.220	0.011	-1.050	14.690	-6.764***	0.473***
Corn	-0.018	2.752	-0.150	0.170	-0.007	0.070	5.560	-7.255***	0.273
Oat	-0.102	2.472	-0.090	0.100	-0.041	0.070	1.820	-7.436***	0.411
OIL SEEDS									
Canola	0.009	2.104	0.080	0.070	0.004	-0.420	2.790	-7.676***	0.457
Palm Oil	-0.079	2.734	-0.110	0.100	-0.029	-0.190	2.480	-7.899***	0.234
Soybean	0.016	2.723	-0.230	0.200	0.006	-0.830	18.870	-7.365***	0.437
Sunflower Seed	0.011	1.376	-0.080	0.090	0.008	0.130	6.010	-7.225***	0.671
OTHER SOFT COMMODITY									
Cocoa	0.067	2.337	-0.110	0.080	0.029	-0.520	2.370	-6.878***	0.072
Coffee	-0.016	1.952	-0.110	0.080	-0.008	-0.650	3.380	-6.808***	0.151
Sugar	0.088	2.612	-0.110	0.150	0.034	0.330	4.440	-8.077***	0.034
Orange Juice	-0.186	2.533	-0.100	0.090	-0.073	-0.340	1.570	-8.189***	0.063
MISCELLANEOUS COMMODITY									
Lumber	-0.148	2.373	-0.070	0.150	-0.062	1.430	7.600	-8.575***	0.127
Cotton	-0.042	2.271	-0.090	0.090	-0.019	0.090	1.850	-6.662***	0.452
Australian Wool	-0.079	1.203	-0.090	0.090	-0.066	-0.200	23.370	-6.829***	0.118
Thai Rubber	-0.059	1.254	-0.060	0.110	-0.047	0.540	15.480	-5.159***	0.216

Notes: The table presents the descriptive statistics and unit root tests for the time series of variables price. The sample period is from 1 June 2007 to 28 February 2009. ADF and KPSS tests present empirical statistics of the Augmented Dickey-Fuller unit root test (Dickey & Fuller, 1979) and KPSS (Kwiatkowski et al., 1992) stationarity test, respectively.

Table 3 *DESCRIPTIVE STATISTICS AND UNIT ROOT TESTS OF COVID-19 PERIOD SAMPLE*

	Mean%	Std. dev %	Min	Max	Sharp Ratio	Skewness	Kurtosis	ADF	KPSS
INDEX									
SET Index	-0.040	1.916	-0.110	0.080	-0.021	-1.590	10.040	-5.238***	0.276
Gold Price Index	0.089	1.365	-0.050	0.060	0.065	-0.20	3.610	-7.767***	0.077
Commodity Price Index	-0.028	2.217	-0.130	0.070	-0.013	-1.510	8.520	-4.978***	0.477***
Oil Price Index	-0.097	7.259	-0.570	0.440	-0.013	-1.440	22.380	-5.386***	0.185
Agricultural Price Index	0.077	0.980	-0.030	0.030	0.079	0.080	0.930	-7.302***	0.829***
Precious Metal Price Index	0.096	1.469	-0.050	0.060	0.065	-0.330	3.270	-7.576***	0.058
Rough Rice	-0.024	3.169	-0.300	0.150	-0.008	-3.290	34.410	-5.610***	0.064
Barley	-0.018	0.581	-0.030	0.020	-0.031	-0.060	6.190	-6.965***	0.414
Wheat	0.027	1.182	-0.030	0.050	0.023	0.430	1.140	-7.619***	0.293
Corn	0.079	1.393	-0.040	0.040	0.057	-0.090	0.700	-6.348***	0.800***
Oat	0.065	2.172	-0.210	0.050	0.030	-3.810	35.430	-5.733***	0.128
Canola	0.112	0.819	-0.020	0.030	0.137	-0.020	0.380	-6.900***	0.752***
Palm Oil	0.089	2.181	-0.100	0.050	0.041	-0.720	2.030	-6.855***	0.686***
Soybean	0.133	1.038	-0.030	0.030	0.128	0.030	1.110	-6.532***	0.974***
Sunflower Seed	0.161	1.102	-0.050	0.050	0.146	0.180	2.970	-4.728***	0.336
Cocoa	0.010	2.157	-0.070	0.110	0.005	0.310	3.700	-5.605***	0.051
Coffee	-0.006	2.410	-0.080	0.080	-0.002	0.200	0.930	5.957***	0.162
Sugar	0.063	1.981	-0.060	0.060	0.032	-0.070	0.430	-5.932***	0.246
Orange Juice	0.082	2.135	-0.100	0.080	0.039	-0.180	2.360	-5.652***	0.049
Lumber	0.291	3.538	-0.240	0.150	0.082	-1.160	9.270	-5.248***	0.239
Cotton	0.049	1.647	-0.080	0.050	0.030	-0.510	2.620	-6.591***	0.458
Australian Wool	-0.118	1.880	-0.120	0.100	-0.063	-0.040	14.700	-5.685***	0.294
Thai Rubber	0.128	1.725	-0.100	0.070	0.074	-1.390	10.200	-6.827***	0.044

Notes: The table presents the descriptive statistics and unit root tests for the time series of variables price. The sample period is from 1 January 2020 to 31 December 2020. ADF and KPSS tests present empirical statistics of the Augmented Dickey-Fuller unit root test (Dickey & Fuller, 1979) and KPSS (Kwiatkowski et al., 1992) stationarity test, respectively.

Figure 7 *Directional Predictability from SET Index to Potential Safe-haven assets - Full sample – 1-day lag*

Figure 8 *Directional Predictability from SET Index to Potential Safe-haven assets - Full sample – 5-day lag*

Figure 9 *Directional Predictability from SET Index to Potential Safe-haven assets - Full sample – 22-day lag*

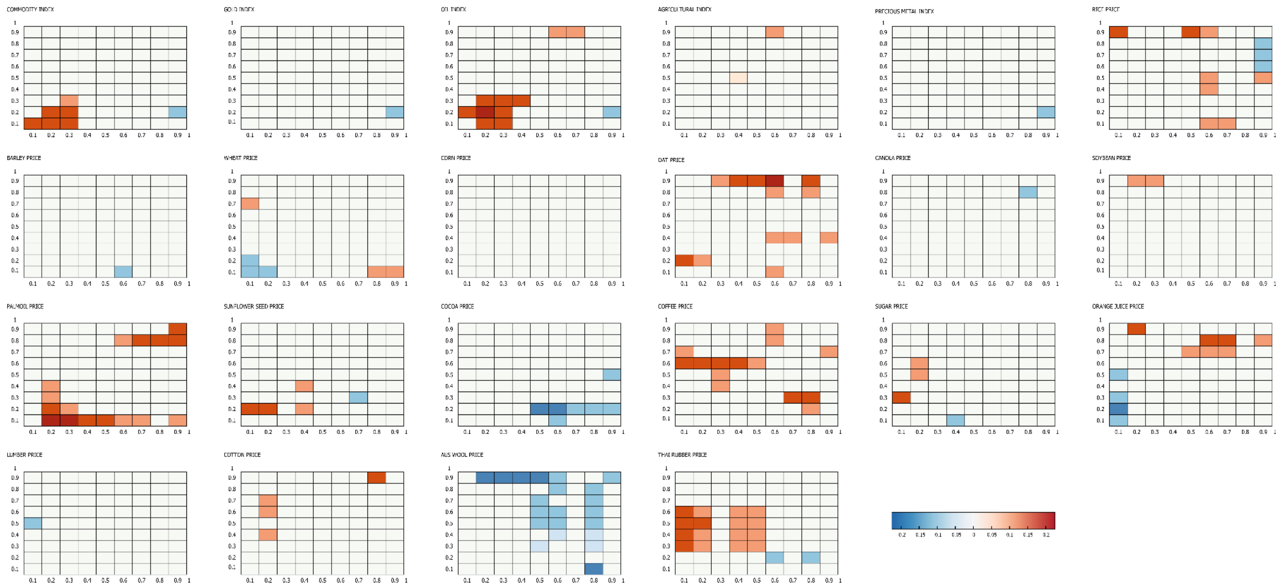

Figure 10 *Directional predictability from SET index to potential safe-haven assets - GFC sample – 1-day lag*

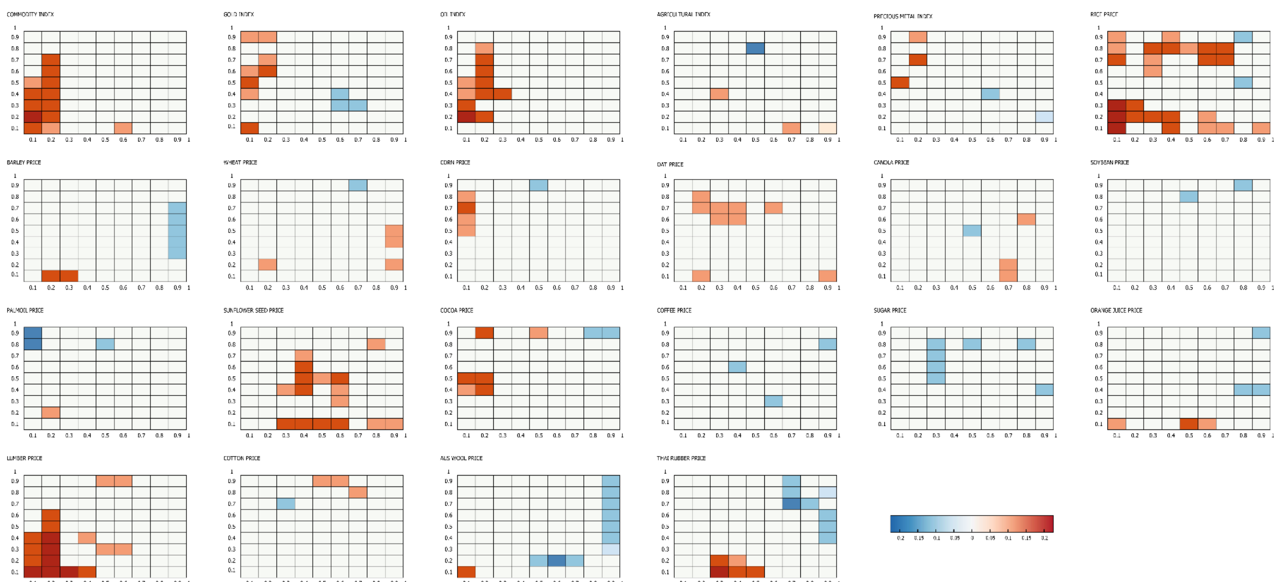

Figure 11 *Directional predictability from SET index to potential safe-haven assets - GFC sample – 5-day lag*

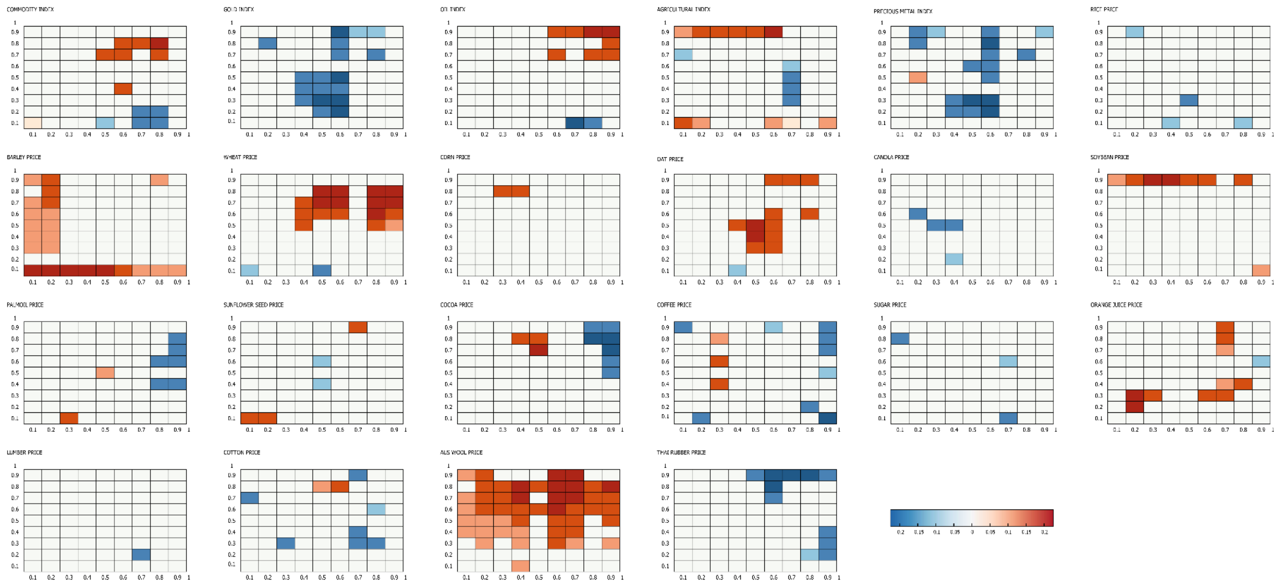

Figure 12 *Directional Predictability from SET Index to Potential Safe-haven assets - COVID-19 PANDEMIC – 1-day lag*

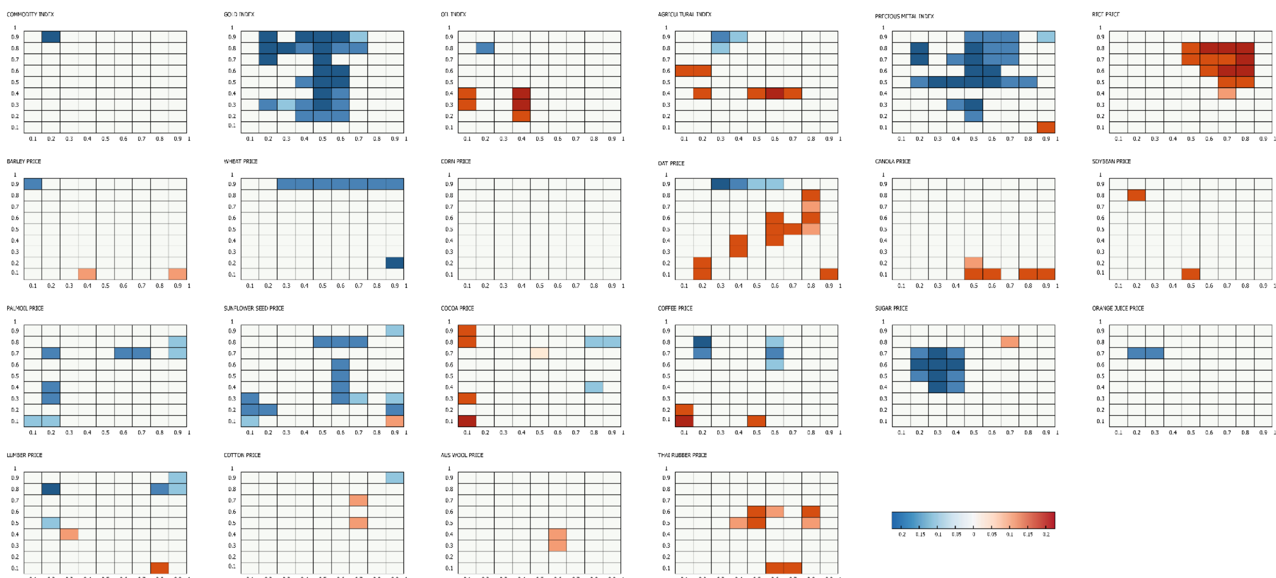

Figure 13 *Directional predictability from SET Index to Potential Safe-haven assets - COVID-19 PANDEMIC – 5-day lag*

	Full gross sample						GFC				COVID-19				Interesting role (Author's perpective)
	lag =1		lag =5		lag =22		lag =1		lag =5		lag =1		lag =5		
	lower-left corner	overall display	lower-left corner	overall display	lower-left corner	overall display	lower-left corner	overall display	lower-left corner	overall display	lower-left corner	overall display	lower-left corner	overall display	
INDEX															
Gold Price Index	non	non	non	(-)	(+)	non	non	|non|	(+)	non	non	(-)	non	(-)	hedge
Commodity Price Index	non	(-)	(+)	non	non	non	(+)	non	(+)	non	non	non	non	|non|	weak safe-haven, diversifier
Oil Price Index	non	(-)	(+)	non	non	non	non	(+)	non	non	non	non	non	non	weak safe-haven, diversifier
Agricultural Price Index	non	(-)	(+)	non	non	non	non	non	non	non	(+)	(+)	non	non	weak safe-haven, diversifier
Precious Metal Price Index	non	non	non	(-)	non	non	non	|non|	non	non	non	(-)	non	(-)	hedge
CEREAL															
Rough Rice	non	|non|	non	non	(+)	non	non	non	(+)	(+)	non	non	non	non	weak safe-haven
Barley	non	(+)	non	non	non	(+)	non	|non|	non	non	(+)	(+)	non	|non|	diversifier
Wheat	(-)	non	non	(-)	non	(-)	(-)	non	non	non	(-)	(+)	non	non	safe-haven, hedge
Corn	non	(-)	non	(-)	non	|non|	non	|non|	non	non	non	|non|	non	|non|	hedge
Oat	(-)	non	non	|non|	(-)	|non|	non	(+)	non	non	non	non	non	non	safe-haven, hedge
OIL SEEDS															
Canola	non	non	non	non	(-)	|non|	non	|non|	non	non	non	non	non	non	safe-haven, hedge
Palm Oil	(+)	non	non	non	(+)	non	non	(+)	non	non	non	non	(-)	non	diversifier
Soybean	non	non	non	|non|	non	non	non	|non|	non	|non|	non	non	non	non	hedge
Sunflower Seed	non	non	non	non	non	|non|	non	non	non	(+)	(+)	non	(-)	(-)	weak safe-haven, diversifier
OTHER SOFT COMMODITY															
Cocoa	non	(-)	non	non	non	non	non	non	non	non	non	non	(+)	non	hedge
Coffee	non	non	non	non	non	|non|	non	(+)	non	non	non	non	(+)	non	hedge
Sugar	non	(-)	non	non	non	|non|	non	non	non	non	non	non	non	non	hedge
Orange Juice	non	non	non	|non|	non	(+)	(-)	non	(+)	non	non	non	non	|non|	weak safe-haven, diversifier
MISCELLANEOUS COMMODITY															
Lumber	non	non	(+)	non	non	non	non	non	(+)	(+)	non	|non|	non	non	diversifier
Cotton	non	non	non	non	non	non	non	non	non	non	non	non	non	non	hedge
Australian Wool	non	(-)	non	non	non	non	non	(-)	(+)	non	non	(+)	non	|non|	weak safe-haven, diversifier
Thai Rubber	non	(+)	non	non	non	non	non	(+)	non	non	non	non	non	non	weak safe-haven, diversifier

Figure 14 *Summary table for heatmap illustration results of CQ*

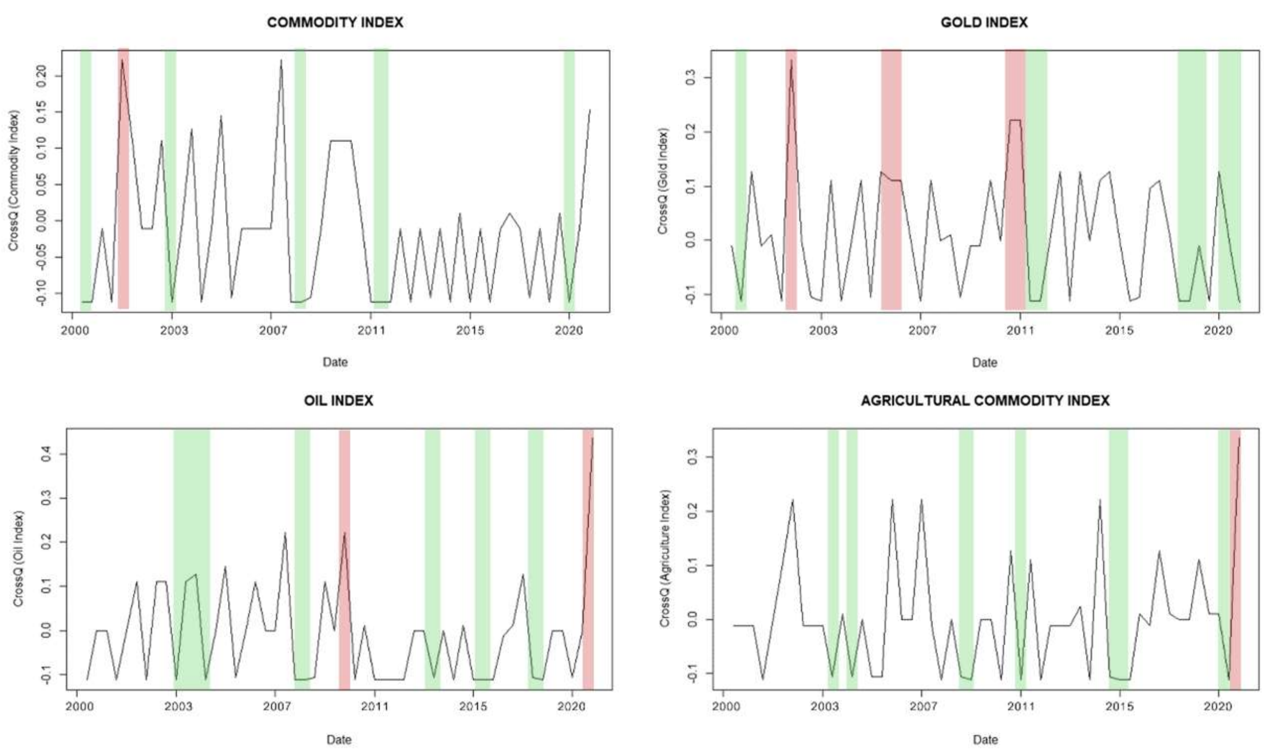

Figure 15 *Rolling window directional predictability from SET Index to safe-haven assets*

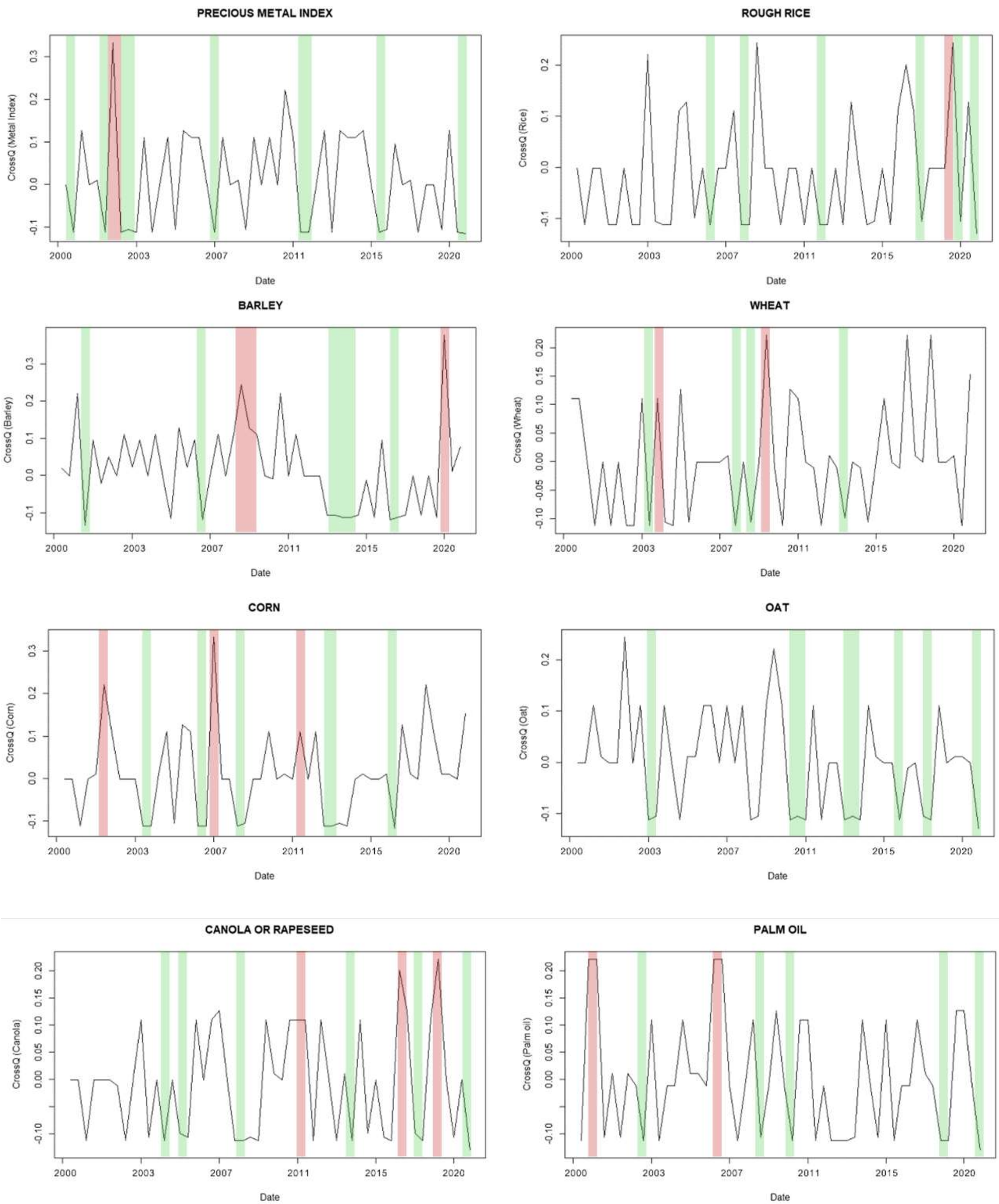

Figure 15 Continue....

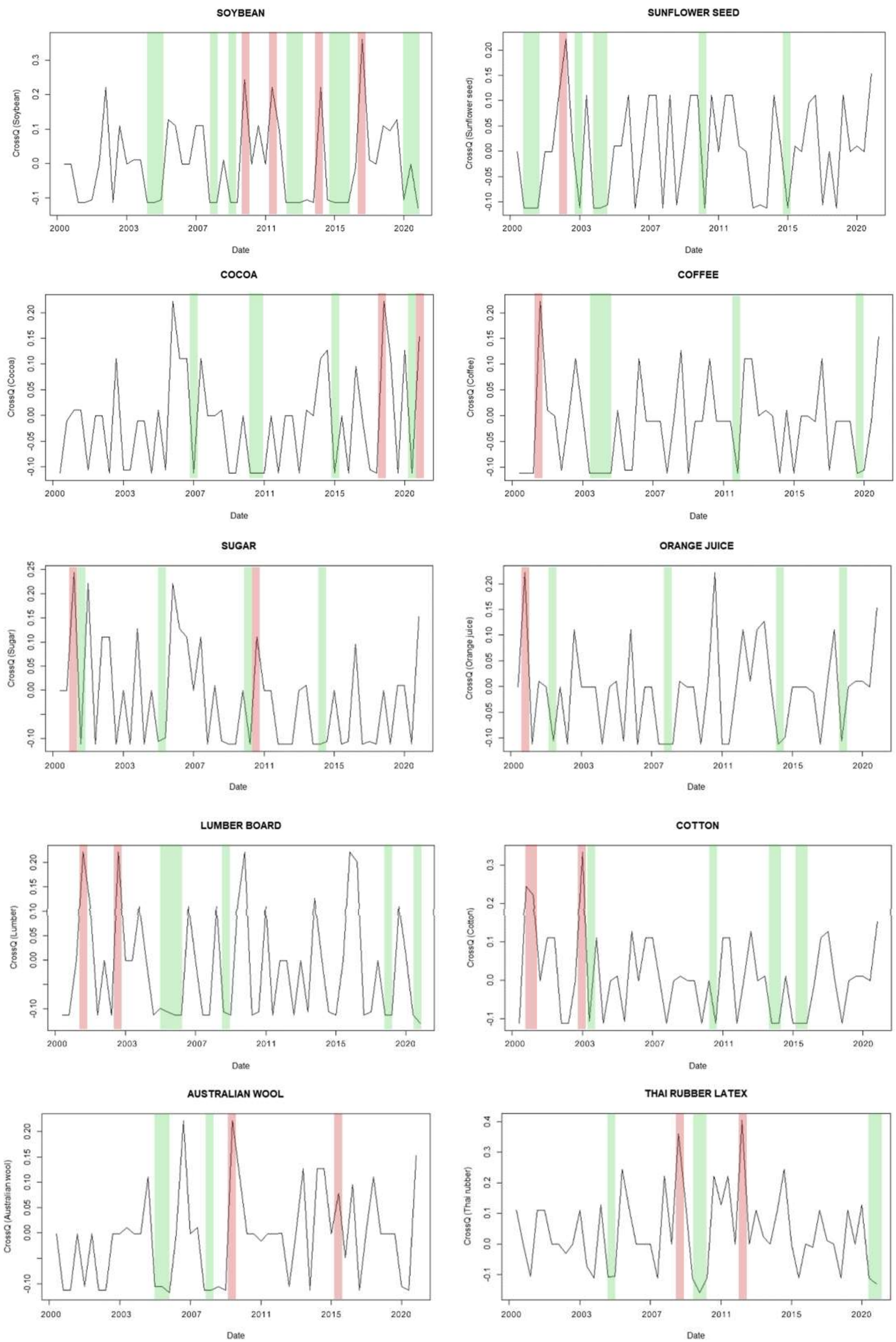

Figure 15 Continue....

Note: The Figure 15 shows the time-varying CQ spillover from SET Index to potential safe-haven assets at the lowest 10% decile (α = 0.1) as one-day cross-correlation (lag h = 1). The sequence of cross-correlations starts in January 2000 as the 100-day rolling window is used to obtain its evolution over time. Black lines are CQ while the vertical shaded area indicates the significance of negative (green) or positive (red) Directional Predictability on 95% bootstrapped confidence intervals under the rejected hypothesis of no predictability based on 1000 bootstrapped replicates.

		Full Training sample			***GFC crisis sample***			***COVID-19 pandemic sample***		
Predictability from	**Predictability of**	No predictability (Weak safe-haven)	Negative predictability (Strong safe-haven)	Positive predictability (Diversifier)	No predictability (Weak safe-haven)	Negative predictability (Strong safe-haven)	Positive predictability (Diversifier)	No predictability (Weak safe-haven)	Negative predictability (Strong safe-haven)	Positive predictability (Diversifier)
SET Index	**INDEX**									
	Gold Price Index	84.6%	9.6%	5.8%	42.8%	52.4%	4.8%	50.0%	50.0%	0%
	Commodity Price Index	86.5%	11.5%	1.9%	47.6%	52.4%	0.0%	50.0%	50.0%	0%
	Oil Price Index	82.7%	13.5%	3.8%	42.9%	57.1%	0.0%	41.7%	50.1%	8.2%
	Agricultural Price Index	82.7%	15.4%	1.9%	42.8%	52.4%	4.8%	20.3%	65.0%	14.7%
	Precious Metal Price Index	82.7%	15.4%	1.9%	47.6%	52.4%	0%	50.0%	50.0%	0.0%
	CEREAL									
	Rough Rice	84.6%	13.5%	1.9%	47.6%	42.9%	9.5%	27.0%	48.5%	24.5%
	Barley	78.8%	13.5%	7.7%	66.7%	14.3%	19.0%	75.0%	8.3%	16.7%
	Wheat	88.5%	7.7%	3.8%	42.0%	58.0%	0.0%	55.0%	45.0%	0%
	Corn	82.7%	11.5%	5.8%	57.2%	33.3%	9.5%	33.3%	52.5%	14.2%
	Oat	86.5%	13.5%	0%	47.0%	53.0%	0%	66.7%	33.3%	0%
	OIL SEEDS									
	Canola	78.8%	15.4%	5.8%	48.0%	52.0%	0%	58.3%	41.7%	0.0%
	Palm Oil	82.7%	11.5%	5.8%	42.9%	52.0%	5.1%	50.0%	33.3%	16.7%
	Soybean	78.8%	13.5%	7.7%	39.0%	57.1%	4.9%	41.7%	58.3%	0.0%
	Sunflower Seed	86.5%	11.5%	1.9%	57.1%	28.6%	14.3%	66.7%	25.0%	8.3%
	OTHER SOFT COMMODITY									
	Cocoa	80.8%	17.3%	1.9%	33.5%	61.0%	5.5%	33.3%	66.7%	0.0%
	Coffee	82.7%	15.4%	1.9%	52.4%	42.9%	2.8%	58.3%	41.7%	0.0%
	Sugar	82.7%	11.5%	5.8%	39.0%	56.1%	4.9%	50.0%	41.0%	9.0%
	Orange Juice	86.5%	11.5%	1.9%	33.5%	60.9%	5.6%	58.3%	33.0%	8.6%
	MISCELLANEOUS COMMODITY									
	Lumber	75.0%	21.2%	3.8%	25.0%	60.7%	14.3%	58.0%	42.0%	0.0%
	Cotton	82.7%	11.5%	5.8%	39.7%	60.3%	0%	25.0%	58.3%	16.7%
	Australian Wool	92.3%	5.8%	1.9%	61.9%	28.6%	9.5%	67.0%	33.0%	0.0%
	Thai Rubber	90.4%	5.8%	3.8%	52.4%	33.3%	14.3%	58.3%	33.1%	8.6%

Figure 16 *Summary of Rolling window directional predictability from SET Index to Safe-haven assets at the lowest 10% decile (α = 0.1)*

Note: This Figure summarizes directional predictability over the entire sample by conducting a rolling window approach (Figure 16). The values are shown in the percentage of no directional predictability significant or directional predictability significant (positive/negative) from SET Index to other assets. We use 100 window lengths of trading days for the full gross sample. Meanwhile, we conduct 20 window length for the crisis period (GFC and COVID-19 pandemic).

Then, it is generally found in previous studies that the relationship between assets is dynamic and can be changed over time. So, we simulate the frame using a 100-day fixed window for every 100 days of trading on the markets. But for the crisis period, we use only 20 days window length as it is more adequate for short-term period investigation. We concentrate on our interested quantile level at the lowest (10%) decile of both asset distributions. Figure 15 shows the example plots of time-varying CQ from potential assets in a full sample period with lag h =1 and quantile α = 0.1 (10%). The black line represents the time-varying CQ through different periods of the estimated rolling window. The vertical shaded areas indicate the significance of Directional Predictability on 95% bootstrapped confidence intervals under the rejected hypothesis of no predictability based on 1000 bootstrapped replicates; the green color stands for negative predictability while the red color is positive predictability.

The plots show that potential assets (commodity indices and agricultural futures) can perform more with negative predictability than with positive predictability. Some assets have quite better properties than others, such as commodity index, agricultural commodity, rough rice, wheat, corn, oat, canola, soybean, cocoa, lumber board, and Thai rubber, which can show a negative correlation with SET Index during crisis period either GFC or COVID-19 pandemic. Finally, the summary of these rolling window estimates in percentage terms is in Figure 16. It also represents the results from the rolling window at the crisis period sample (GFC and COVID-19) using a 20-day fixed window with the same lag h = 1 and quantile α = 0.1. This table confirms the safe-haven role of selected agricultural futures and commodities indices. Unsurprisingly, the potential assets like gold index, agricultural commodity index, wheat, corn, soybean, cocoa, and cotton could perform well as either a safe-haven asset or hedge as it is predominant negative predictability occurring from overall and crisis period.

Investment Implications

Among all candidates tested to be a safe-haven asset from the previous section, some assets, including Gold, Wheat, Corn, Oat, Canola, Soybean, and Sugar, are found to be more potential for making investors' portfolios more efficient during our observation periods. Thus, these assets can be included in portfolios to avoid negative loss from the Thai stock market (SET Index). The benefits of adding potential assets to the portfolio are also important to an investor's decision-making or strategy. First, we calculate the price return (%) of interested assets among these potential variables in an active market such as investing.com. The sample of Expected return, Sharp ratio, and Volatilities are generated in table 6 by analyzing different conditions in the Thai stock market (crisis and normal period). For crisis conditions, we set the sample during SET Index with experience at 10 percentile rank of 2020 (Mar 2020) while the normal market was set at 50 percentile rank of 2020 (May - Jul 2020). The Standard Deviation (SD), Expected return, and Sharp ratio of each asset and portfolio (by adopting the asset's weight at 25%) are observed to analyze their Beneficial return and volatility (risk) from adding these assets into the portfolio at different situations. The Cross-quantile values (Cross-q) are also applied to represent the correlation between variables in different quantiles at the time estimates. We, therefore, simulate the example of the weekly time-varying pairwise optimized portfolio with the Thai equity index (SET Index) over the last 5 years (2016 - 2020) as shown in Figure 16, which includes the assets' performance at the 25% weight. We also examine the trade volume of agricultural futures in recent active market.

Table 4 *RESEARCH INTO*

Securities	Average Return	*SD*	Asset's Sharp Ratio	Percentile Rank	Cross -q (CORR)	Portfolio Return	Portfolio SD	Portfolio Sharp Ratio
Crisis period sample (March- 2020)								
SET	-0.054%	4.798%	-1.120%	10%				
GOLD	0.333%	2.779%	11.968%	10%	0.024	0.043%	3.681%	1.164%
WHEAT	0.390%	2.274%	17.141%	50%	-0.020	0.057%	3.632%	1.574%
CORN	-0.654%	1.642%	-39.852%	40%	-0.013	-0.204%	3.617%	- 5.636%
OAT	0.152%	1.749%	8.686%	10%	0.063	-0.002%	3.652%	-0.063%
CANOLA	0.027%	0.869%	3.140%	20%	-0.043	-0.033%	3.596%	-0.931%
SOYBEAN	-0.015%	1.413%	- 1.079%	20%	-0.006	-0.044%	3.614%	- 1.220%
SUGAR	-0.805%	2.491%	-32.331%	20%	0.024	-0.242%	3.666%	-6.589%
Normal period sample (May - Jul 2020)								
SET	0.098%	1.202%	8.149%	50%				
GOLD	0.167%	1.157%	14.409%	44%	-0.120	0.115%	0.913%	12.607%
WHEAT	0.033%	1.577%	2.067%	20%	-0.100	0.082%	0.947%	8.617%
CORN	0.202%	1.310%	15.407%	20%	0.002	0.124%	0.960%	12.911%
OAT	0.238%	2.000%	11.876%	80%	0.060	0.133%	1.057%	12.570%
CANOLA	0.075%	0.844%	8.835%	30%	0.003	0.092%	0.927%	9.941%
SOYBEAN	0.124%	0.837%	14.785%	20%	-0.039	0.104%	0.918	11.379%
SUGAR	0.325%	2.105%	15.417%	20%	-0.070	0.155%	1.012%	15.283%

Adding potential agricultural assets to traditional stock market portfolios can verify beneficial performance in many aspects. Firstly, the Safe-haven asset (wheat, oat, and canola) can reduce the major portfolio volatility and negative loss during the crisis period by less negative correlation to the SET Index. The Portfolio return (Expected return) and Sharp ratio value after including these assets in the portfolio are substantially higher than the pure SET Index. Consequently, after including Safe-haven and Hedging assets in SET Index in the normal market situation, the results can show the performance improvement as a higher quick ratio and lower volatility. Then, the weekly time varying Cumulative Pairwise Portfolio return shows great hedging benefit by less negative loss during the stock market slump. There was the exceedance of the red line (pure SET Index) over the black line (pairwise return) at extreme loss periods (Mar 2020). Wheat, corn, oat, and canola can perform an outstanding ability to decrease negative loss compared to others. They also tend to make the positive return the same as pure SET Index on average. Due to return/loss and volatility, trade liquidity is also important to investment implications. It can show how interested and active they are in the markets (investors, financial institutions, and exchange markets). In this study, we gather trade volume in 2 markets (1) Investing.com (active market in Thailand) and (2) 24-hour worldwide markets such as CME and ICE markets. The result shows that the trade volume of these selected assets in each market tends to be seasonal movement. The highest liquidity of selected assets in both markets is corn and sugar, while oat futures have the lowest trade volume. These can tell how agricultural futures are continuously traded in the markets by investors or financial institutions.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The magnitude of the correlation between assets and the stock market has been debated and studied until the present. The characteristics of the relationship between assets are substantially related to financial strategies and decisions of investors and financial institutions, including the Thai market. To extend our interest, we examine directional predictability from the Thai stock market (SET Index) to agricultural commodities across various quantiles in price distribution. The properties of asset characteristics (Safe-haven, Hedge, and Diversifier) are investigated with the bivariate CQ approach. The samples we used in this study are categorized into sections for different economic events (crisis) and whole time series to see the variety of results throughout the period. The daily data from selected indices and agricultural commodities futures prices cover the period from 2000 to 2020. This period interval can capture two major crises in the financial market (Global Financial Crisis (GFC) and COVID-19), which are beneficial for our research.

The CQ (developed by Han et al. (2016)) we used in this paper is very helpful in observing the cross-quantile dependence and directionality between the variables at different quantiles representing different market states. This approach can examine the cross-quantile dependencies with more accuracy than the traditional method (GARCH, DCC, and MSV). Another advantage of the CQ, it can estimate the results in large long lags, which can observe the prediction between variables in any period prices (daily, weekly, monthly). Furthermore, this methodology can be applied to generate other illustrations such as heatmap results (times significant occurred on cross-quantiles) and rolling window directional predictability (time-varying CQ), which is conceptually appealing and easy to interpret.

Following this advantage, we conduct our study in 2 main steps of the methodology. First, we generate the heatmap results of cross-quantile significance between the SET Index and potential agricultural commodities with daily, weekly, and monthly trading lags. We also investigate the different results between the overall gross and crisis period samples (GFC and COVID-19). In the second step, we simulate the rolling window framework by using a 100-day fixed window for every 100 days of trading on the markets and 20 days window for the crisis period sample. Finally, the summary of these rolling window estimates is shown in percentage terms as the probability of being a safe-haven role occurred to SET Index.

Overall heatmap results show that most agricultural commodities futures seem to be a weak safe-haven asset to the SET Index as there is an absence of negative predictability on the low cross-quantiles except wheat, oat, and canola which can perform the negative correlate in the lower left corner at least 1 case in any lags. Meanwhile, gold index, agricultural Index, wheat, corn, canola, soybean, cocoa, and Australian wool could be used as a hedge by either a negative or no predictability at the most cross quantiles. These results are likely to be consistent with empirical studies from Candila and Farace (2018); Ji et al. (2020); Kaur and Dhiman (2021) which showed the absence and negative causality between agricultural commodity and the stock market, especially on emerging or Asian market.

Consequent to overall results, we also monitor the safe-haven role of these assets during crisis periods (GFC and COVID-19). The results from the crisis period sample are different from the overall. There are correlations among variables in the crisis period sample, such as negative results for gold and precious metal during COVID-19. Some agricultural futures, such as Australian wool, perform a negative role at GFC while performing a positive during the COVID-19 period, and vice versa for palm oil. The potential assets have a more positive relationship with SET Index during the GFC period. Only wheat can perform a strong safe-haven role in both GFC and COVID-19 periods. During the COVID-19 pandemic, gold index, precious metal index, corn, and sugar could be excellent hedging assets with SET Index. And the rest, the assets, for instance, rough rice, corn, canola, soybean, sugar, cotton, and Thai rubber, are virtually weak safe-haven to the SET Index.

We also generate the rolling window framework to observe the dynamic or time-varying CQ. The probability that occurred from these results is summarized as a percentage table to confirm the result of being safe-haven role. We found that CQ results are time-varying and change through time. The potential assets (commodity indices and agricultural futures) can perform well with more negative predictability than positive predictability. At the same time, outperformance assets (such as commodity index, agricultural commodity index, rough rice, wheat, corn, oat, canola, and soybean) can show good performance of negative correlation with the SET Index during a crisis period, either GFC or COVID-19 period.

For investment implications, we generate the general pairwise portfolio results like return, Sharp ratio, volatility (SD), and overall trade liquidity of selected potential assets (Safe-haven and Hedge asset) from the preceding CQ approach, such as wheat, corn, oat, canola, soybean, and sugar. The results suggest that including Agricultural futures in the stock market can make the portfolio substantially less volatile (SD) and have a negative loss, especially during the extreme downturn compared to pure SET Index performances. Apart from the return/loss and volatility, we also observe the trading liquidity (volume) from an active market in Thailand and 24-hour worldwide markets such as CME and ICE. The results showed the seasonal movement of assets. And confirm the constant number of trading agricultural futures in the markets.

Based on our study, investors, financial advisors, and any economic actors are recently having empirical evidence that some agricultural commodities could perform well to be safe-haven and hedge against the extreme downturn in the Thai stock market. So, these well-perform assets are suggested to be held or added in investors' portfolios for hedging risk during a crisis period. On the other hand, few assets, such as barley and lumber, which seem to act in the same direction (positive) with SET Index at low quantiles or overall, will be considered diversifiers in a portfolio. Moreover, many financial institutions can scrutinize these assets more thoroughly due to their benefits, especially in hedging investors' losses from the stock market. They can also apply the asset's performance to develop Commodity funds in the market. However, the choice selected by investors or financial institutions will vary under each asset's different characteristics. Some of them should be observed closely in the short-term during a crisis, such as a commodity index, cereal products, or cocoa, while the assets like gold, wheat, oat, corn, canola, and soybean can be held through a period

Recommendations for Future Research

In this study, we only selected the suitable variables for our study, which are most active in the market for a long time and adequate for our period observation. Many new entry products are interesting to be traded on the market, such as high-quality products (ex. Thai White rice), other fruits and vegetables, live cattle, lean hog, seeds for planting, and ingredients for alcohol fermentation (ex. wine and beer). So, future research can bring up these assets to observe their characteristics in the stock market. The next recommendation of our study is to work directly on the asset pair correlation between agricultural futures and the stock market. No other factors can affect their correlation or predictability, such as the inflation rate. These factors can be applied with another method of CQ analysis as Partial CQ to get more insight and investigation. And the last point, we only investigate the relationship with the overall SET Index of the Thai stock market. So, the future study can observe the different markets, which may be other countries (especially in emerging or Asian markets) or minor in Thailand (ex. SET100, SET50, SETWB, ASEAN market)

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