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Portfolio Diversification Benefits of Malaysia's Stock Indices with Commodities: An Analysis Based on the MGARCH-DCC and Wavelet Techniques

(Manfaat Kepelbagaian Portfolio Indeks Saham Malaysia dengan Komoditi: Analisis Berdasarkan Teknik MGARCH-DCC dan Wavelet)

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ABSTRACT

This research examined the potential for diversifying Malaysian Islamic and conventional stock indexes with other commodities, such as crude oil, Bitcoin, and gold, with time-varying differences or investors' varied investment horizons, which researchers had previously overlooked. Methods like the Multivariate GARCH-Dynamic Conditional Correlation (MGARCH-DCC) and the continuous wavelet transformation (CWT) were employed since they are time-varying and time scale-dependent. Crude oil, Bitcoin, and gold are shown to be leading the stock indices in our vector error correction model (VECM) analysis, implying that changes in the price of these commodities influence the stock indices. The findings also indicate that investors exposed to Malaysian stock indexes and investing in Bitcoin may benefit from significant diversification advantages across almost all investment horizons. However, the MGARCH-DCC result shows that Bitcoin is highly unpredictable. As a precaution, Malaysian investors should choose gold as a diversification instrument which is more stable. The wavelet model demonstrates that investors in Malaysia's Islamic and conventional indices may benefit from the gold holding for durations ranging from 1 to 64 days and 128 days beyond. The findings highlight the importance of using contemporary techniques to identify diversification opportunities for investors with varied investment horizons or holding stocks for various times.

Keywords: Diversification benefits; Malaysian stock indexes; conventional stock index returns; CWT; Bitcoin.

ABSTRAK

Penyelidikan ini memeriksa peluang kepelbagaian indeks saham Islam dan konvensional Malaysia dengan komoditi lain, seperti minyak mentah, Bitcoin, dan emas, dengan perbezaan masa yang berlainan atau ufuk pelaburan pelbagai yang sebelum ini diabaikan oleh penyelidik. Kaedah seperti Multivariate GARCH-Dynamic Conditional Correlation (MGARCH-DCC) dan transformasi wavelet berterusan (CWT) telah digunakan kerana kajian bergantung kepada perbezaan masa dan skala masa. Minyak mentah, Bitcoin dan emas ditunjukkan mendahului indeks saham dalam analisis model pembetulan ralat vektor (VECM), membayangkan bahawa perubahan dalam harga komoditi ini mempengaruhi indeks saham. Penemuan juga menunjukkan bahawa pelabur yang terdedah kepada indeks saham Malaysia dan melabur dalam Bitcoin mungkin mendapat manfaat daripada kelebihan kepelbagaian yang ketara merentas hampir semua ufuk pelaburan. Walau bagaimanapun, keputusan MGARCH-DCC menunjukkan bahawa Bitcoin sangat tidak dapat diramalkan. Sebagai langkah berjaga-jaga, pelabur Malaysia harus memilih emas sebagai instrumen kepelbagaian yang lebih stabil. Model wavelet menunjukkan bahawa pelabur dalam indeks Islam dan konvensional Malaysia mungkin mendapat manfaat daripada pegangan emas untuk tempoh antara 1 hingga 64 hari dan 128 hari seterusnya. Penemuan kami menyerlahkan kepentingan menggunakan teknik kontemporari untuk mengenal pasti peluang kepelbagaian bagi pelabur yang mempunyai ufuk pelaburan yang berbeza-beza atau memegang saham untuk pelbagai masa.

Kata kunci: Faedah kepelbagaian; indeks saham Malaysia; indeks saham konvensional; CWT; Bitcoin

INTRODUCTION

Stock indices rely on knowledge and information, and the technology explosion has changed these stock markets around the globe. Investors can keep track of information in real-time and respond immediately to events worldwide. The exclusion of national economies from world activities is no longer relevant. This is because external affairs will directly affect the other markets in a different region. Investors are using a variety of portfolio diversification techniques to minimise the risk exposure caused by the unpredictability and volatility of globalisation on investment values. To achieve lower-risk rates, these methods need minimal asset correlations. Previous research has shown that commodity and stock market correlations are extremely low. The low correlation and attractive return expectations of commodities markets provide investors with invaluable resources for diversification. Consequently, investors' involvement in commodities markets has risen since the year 2000, and they typically participate in commodities markets by direct or indirect investment in the commodities market.

The term "financialisation of commodities markets" has arisen due to investors' increasing involvement in commodities markets. Commodities markets have been vulnerable to possible disruptions from stock markets because of financialisation and portfolio diversification by global investors. The growing interdependence between stock and commodities markets means that both markets are moving in the same direction with a high correlation, consequently making it difficult for investors to enjoy the advantages of cross-market diversification. Besides that, fund managers and investors also worry about the various investment horizons over the investing cycle, with market returns differing in duration and based on time ranges linked to specific investment horizons (Gencay, Selcuk & Whitcher 2001). The 2008 global financial crash has demonstrated that the world capital systems are far more interlinked than traditionally known (Mishkin 2011).

Nevertheless, commodities markets still provide significant advantages for the diversification of portfolios. Research on the correlation of commodities markets with stock indices is abundant in developed countries but limited in emerging countries, such as Malaysia, which has a distinct culture, laws, and regulations. Thus, the purpose of this study is to evaluated the relationship between Malaysian stock market indices and commodities markets to contribute to the body of knowledge on stock index diversification. Emerging nations' economies are also more volatile than developed countries' economies, owing to their high reliance on export-related activities (Fan et al. 2009). Past research on the correlation between commodity markets and stock indexes that primarily focus on developed nations may be skewed and could be questioned.

The KLCI Shariah Index was introduced in 1991 to promote interest in equities investments that adhere to Islamic principles (Hussin et al. 2012). Thomson Reuters (2018) reported that the global Islamic finance industry expanded its assets to USD 2.4 trillion in 2017, or 6 % utilising the Compound Annual Growth Rate (CAGR) from 2012 to 2017. It is worth researching the correlation of Shariah's index with commodities markets by analysing them at various intervals to understand the riskiness and future portfolio diversification gains for interested investors.

Besides commodities, cryptocurrencies have emerged to become another alternative investment instrument. Among the cryptocurrencies commonly used in the market, Bitcoin ranks first in scale and value exchanged. By investing USD 1,000 in Bitcoins in July 2010, a return of USD 8.3 million will be produced in 2017 (Narayan et al. 2019). Due to its high return, Bitcoin has captured the attention of investors worldwide looking for a safe haven for their investment portfolio.

This research investigated the diversification of Malaysian stock indices with gold, crude oil, and Bitcoin by considering their correlations and volatility. This study's sample period spanned more than eight years, from 1 September 2011 to 28 June 2019. Utilizing contemporary analytic techniques, such as the MGARCH-DCC, we should decide which commodities and indices investors may invest in. It will benefit the Malaysian economy in the long term by assisting investors in identifying commodities and indices relevant to their portfolios. The benefits of portfolio diversification for different investment horizons or stock holding periods were also shown using wavelet models.

In summary, the study sought to meet the requirements of interested investors seeking to diversify their investments in commodities and stock indices by contemplating both the time-varying and time-scale dependence of the selected variables, which were previously overlooked. Therefore, the study aims to ascertain if Malaysian stock indices influence commodity price fluctuations and whether historical stock indices' values help with commodity price prediction. Additionally, we are interested in identifying which exogenous variable is more exogenous across various time horizons. Besides that, to diversify their portfolios, investors also need to know which stock indices and commodities to invest in and finally, does the gain from portfolio diversification varies for investors across various investment horizons or stockholding times. The results of each research objective were anticipated to have substantial consequences on investors' portfolio allocation and investment horizon choices. Using modern approaches, the study seeks to get detailed and comprehensive information for strategic portfolio allocations to investors who wish to minimise risk in their portfolios via diversification in Malaysia stock indexes, Bitcoin, gold, and crude oil. Through this study, we can grasp the insights of the relatively modern approaches used in this research, which enable us to comprehend the opportunities for

portfolio diversification across various investment horizons that support diverse investors.

The following sections of the article are arranged as follows. The following section delves into the literature on commodities, stock market indices and portfolio diversification regarding time-varying and scale dependency. It also briefly covers the theoretical foundation assumed in this study. Next section discusses the methods to accomplish the article's goals, followed by the discussion on the methodical examination of evidence and results. Subsequently, the findings are discussed via logical explanation and historical observations in the literature. At the end of this article, a list of references is provided.

LITERATURE REVIEW

Most investment funds have identified commodities as profitable diversification instruments due to their weak associations with traditional assets and a high co-movement of commodity prices with inflation (Gorton & Rouwenhorst 2006; Büyükşahin et al. 2010). These features may inspire investors to select commodities as a safe haven instrument during a volatile period for conventional equity markets, particularly if macro-economic shocks continue to operate in opposite directions on commodities and stock prices. Current developments in commodities markets have instigated scepticism about such opinions. After almost four decades of real average drops in prices, commodities prices have witnessed a globally unprecedented and constant increase in prices in the last decade. The increased prices phenomenon is mainly contributed by increased demand from developing markets in Asia, a declining United States (US) currency, low interest rates, shifts in biofuel programs, and a sluggish supply reaction. Simultaneously, the trading activity in commodities markets by investment firms, hedge funds, and exchange-traded funds has increased considerably since 2000 (Helbling 2008).

Wang et al. (2013) investigated the presence of a safe haven effect of global commodities on stock prices in a few nations. According to the study, the safe haven effect has been prominent in most nations since the 2008 financial crisis. A safe haven asset is neither connected to nor adversely associated with another asset or portfolio during an economic downturn or financial crisis (Baur & Lucey 2010).

Mensi et al. (2013) utilised the daily data from 2000 to 2011 to examine the connection and volatility between commodities market indices and the S&P500 using the VAR-GARCH approach. They examined whether past S&P500 results have a predictive value for the current performance and if the preceding S&P500 index has a projecting value for the present commodity values. As expected, a strong connection was found between commodities and stock markets. The findings demonstrate the need to integrate commodities into the equity-based fund to enhance its risk-adjusted performance.

By utilising the monthly time series data, Patel (2013) explored the correlation of gold prices with Indian stock market indexes. Patel used Johansen's cointegration technique in his research and derived two conclusions: (1) According to Johansen's cointegration test, gold prices and all stock market indexes have a long-term connection, (2) The Granger causality analysis indicates that the price of gold consists of essential data for predicting Indian stock markets.

Karim et al. (2021) investigated how the correlation between oil and BRICS stock market returns reacts across various investment horizons by utilising the data from 2006 to 2020. The wavelet and MGARCH-DCC reveal that Russia, Brazil, and South Africa stock markets are much more correlated with oil price returns across investment horizons and are more volatile, notably during the Covid-19 period. The research also discovered that the stock market returns of China and India are less correlated with the oil price return and less volatile. The finding also shows that the oil price return leads the BRICS stock markets return, and the two are positively correlated.

Only a small number of empirical research has been undertaken on the gold and cryptocurrency markets, and there are limited comparative evaluations of their positions relative to stock market indices that have been conducted (Bouri et al. 2017a). Guesmi et al. (2018), for example, used the GARCH-based frameworks, which are inappropriate for comparing the tails of the distribution of Bitcoin returns to those of stock market indexes. Additionally, Guesmi et al. (2018) did not employ a time-varying method to assess Bitcoin's position, nor did they compare Bitcoin's safe-haven capacity to gold and commodities indices.

In summary, the studies on Bitcoin and commodities and their potential impact on portfolio diversification with stock markets indices are constrained (particularly for the Islamic stock market index) and inadequate, with no clear findings. Therefore, these subjects merit an additional investigation.

The theory identified for the study was proposed by Markowitz and referred to as the portfolio diversification principle. Markowitz developed the Modern Portfolio Theory (MPT), which states that the portfolio's volatility should be less than the weighted average securities volatility if the portfolio is constructed among assets that show low correlations return (Markowitz 1959).

The earlier version of the MPT presumes the normality assumption of portfolio variances. However, according to Markowitz, the normally distributed variance is insufficient to quantify risk. Thus, to account for asymmetric and fat-tailed distributions, several efforts have been made to improve the model to nearly reflect the real-world trend. To get a better outcome, we used a few modern techniques, such as the MGARCH-DCC and wavelet method. Moreover, the benefit of utilising

the wavelet approach is that there are no pre-requisite distribution assumptions, making it deliver a more realistic result (In and Kim 2013). Additional details on the methods used to achieve the study goals are provided in the next section.

METHODOLOGY

DATA

The data utilised in this research consisted of the daily data of Malaysian Morgan Stanley Capital International (MSCI) Islamic and conventional stock indexes, Bitcoin, gold, and crude oil prices from 1 September 2011 to 28 June 2019. All data were obtained from DataStream.

TIME-SERIES TECHNIQUES

Our study applied the error correction models to inspect the relationship between the Malaysian stock indices and other selected variables. After the establishment of the cointegrating relationship, many past studies applied either the vector error correction model (VECM) approach and/or variance decomposition (VDC) methodology to analyse the lead-lag connection (Granger causality). Our research used the following approach to analyse the granger causality relationship. First, we needed to run the unit-root test and evaluate the VAR order, followed by the Johansen cointegration test. We could not depend on the cointegration test to identify the leading and lagging variables. Hence, we used the VECM to find the correct short-term and long-term Granger causalities (Masih et al. 2009). Nonetheless, the VECM cannot express the relative exogeneity or endogeneity of the variables. Usually, the variance decomposition (VDC) process is the most suitable tool for evaluating the exogeneity and endogeneity of variables. However, the statistical program that we used (Microfit 5) has a drawback of only up to 150 measurements (or time horizon) that can be regressed. In the meantime, our data consisted of 2,042 daily observations. Using the Microfit 5 to regress our data would only produce an outcome that spans five months of evaluation, which would be inappropriate for us to draw a definitive conclusion. Due to the time-series statistical program restriction, we decided to employ the Maximal Overlap Discrete Wavelet Transformation (MODWT) to analyse the lead-lag relationship between the variables by considering the time scale impact of the calculation. We needed to determine the relative exogeneity of the variables across different time horizons to determine which variable has the most significant influence on others. By identifying the variable, stakeholders may carefully monitor it and, if required, take appropriate action.

MAXIMUM OVERLAP DISCRETE WAVELET TRANSFORMATION

The series variance can be decomposed into identical scale-by-scale intervals through squared wavelet coefficients generated by Discrete Wavelet Transform (DWT) and MODWT. Given the superiority of MODWT in generating wavelet estimators with higher precision than DWT (Percival 1995; Gallegati 2008), this research opted to use MODWT for wavelet decomposition.

MODWT extends the assessment of wavelet variance by adding estimators and confidence intervals for wavelet covariance and wavelet correlation (Whitcher et al. 2000). The wavelet covariance measures the extent of the relationship between X and Y across different time scales. Gallegati (2008) states that the wavelet covariance at wavelet scale j between X and Y, may be defined as $\gamma_{XY,j} = \mathrm{Cov}\left[\tilde{\omega}_{j,t}^{X}\tilde{\omega}_{j,t}^{Y}\right]$. The following equation offers the calculation of an unbiased estimator of the wavelet covariance established upon MODWT after satisfying the perimeter conditions.

$$\tilde{\gamma}_{XY,j} = \frac{1}{\tilde{N}_j} \; N-1 \sum_{t=L_{J-1}}^{N-1} \tilde{\omega}_{j,t}^{X}\tilde{\omega}_{j,t}^{Y}$$

Next, the MODWT cross-correlation coefficients, $\tilde{\rho}_{\hat{o},XY,j}$ for scale j and lag τ may be measured by dividing wavelet cross-correlation $\tilde{\gamma}_{\hat{o},XY,j}$, and the square root of wavelet variances X ($\tilde{\sigma}_{X,j}$) and Y($\tilde{\sigma}_{Y,j}$) as in the following equation:

$$\tilde{\rho}_{\hat{o},XY,j} = \frac{\tilde{\gamma}_{\hat{o},XY,j}}{\tilde{\sigma}_{X,j}\tilde{\sigma}_{Y,j}}$$

The value of wavelet cross-correlation coefficients $\tilde{\rho}_{\hat{o},XY,j}$ is identical to a standard unconditional cross-correlation coefficient and should lie between 0 and 1 across different time scales.

The asymptotic wavelet variance Vj of the MODWT estimator could be determined by the spectrum $S_{\omega X,j}$ of scale j wavelet coefficients. Following this, a confidence interval of 100(1 − 2p) % of MODWT estimator robust to non-Gaussianity for $\tilde{\upsilon}_{X,j}^{2}$ could be constructed as Gallegati (2008) suggested. Accordingly, 128 observations were considered to be sufficient for a good approximation of wavelet coefficients under the large sample theory (Gallegati 2008).

MULTIVARIATE GARCH - DYNAMIC CONDITIONAL CORRELATION

The MGARCH-DCC method, as recommended by Pesaran and Pesaran (2010), was used explicitly to fulfil the third objective of this research. The multivariate *t* and normal distributions were used to generate the most efficient result. The MGARCH analysis requires us to

compute conditional cross-asset correlations through MGARCH-DCC with the following formulation:

$$\tilde{\rho}_{ij,t-1}(\phi) = \frac{q_{ij,t-1}}{\sqrt{q_{ii,t-1}q_{jj,t-1}}}$$

Where $q_{ij,t-1}$ are presented by

$$q_{ij,t-1} = \bar{\rho}_{ij}(1-\phi_1-\phi_2) + \phi_1 q_{ij,t-2} + \phi_2 \tilde{r}_{i,t-1}\tilde{r}_{j,t-1}$$

In the above equation, $\bar{\rho}_{ij}$ stands for the (i,j)th unconditional correlation, while ϕ_1 and ϕ_2 represent the parameters with the condition of $\phi_1 + \phi_2 < 1$, and $\tilde{r}_{i,t-1}$ denotes the standardised asset returns. The study estimates $(1-\lambda_{i1}-\lambda_{i2})$ were used to evaluate the nature of the mean reversion process. Several validation experiments were performed to verify our models for robustness checks. One might refer to Pesaran and Pesaran (2010) for more detailed information about the MGARCH model.

CONTINUOUS WAVELET TRANSFORMATION (CWT)

The fourth research question of our study could be resolved by employing a CWT. For instance, few researchers have applied the CWT to finance and economic research, such as Abdullah and Masih (2016). The CWT transforms the original series from a single time-domain variable to multiple series captured from time and frequency domains. Under the CWT strategy, there is no need to specify the number of wavelets, giving it a competitive advantage over the DWT / MODWT approaches. The CWT maps a two-dimensional diagram of series similarities that lets us quickly identify and deduce trends or concealed information effortlessly. The CWT analysis is often simpler to understand than a discreet method since its redundancy helps improve the visibility of the traits. The CWT results assisted us in identifying the areas with a high or low correlation of variables under review across various time horizons. Therefore, the study is more straightforward and more uncomplicated to be understood.

For both MODWT and CWT, this study employed the least asymmetric wavelet filter of length L=8 represented as LA(8) as suggested by Daubechies (1992). The wavelet filter produced eight coefficients. Based on previous studies, LA(8) is sufficient to cater for time-series data (In & Kim 2013). Further, LA(8) offers a smoother wavelet coefficient than other classes of wavelet filters, such as the Haar filter.

RESULTS AND DISCUSSION

DESCRIPTIVE OF DATA

Figure 1 shows the raw time-series data for all variables that were chosen. The graph illustrates that the Bitcoin price is very volatile, with the price rising and falling dramatically in a short period in 2017. We also see a decline in oil and gold prices, indicating a lack of demand for these commodities. Meanwhile, the Malaysian indices had risen higher before drifting sideways for a few years before recording a downturn in 2018 and beyond. Malaysia's indices were trending higher from 2011 onward, indicating a rising economy, as shown by both Islamic and conventional indices. However, the indices began to indicate a poor performance by 2016 due to Malaysia's sluggish economic climate.

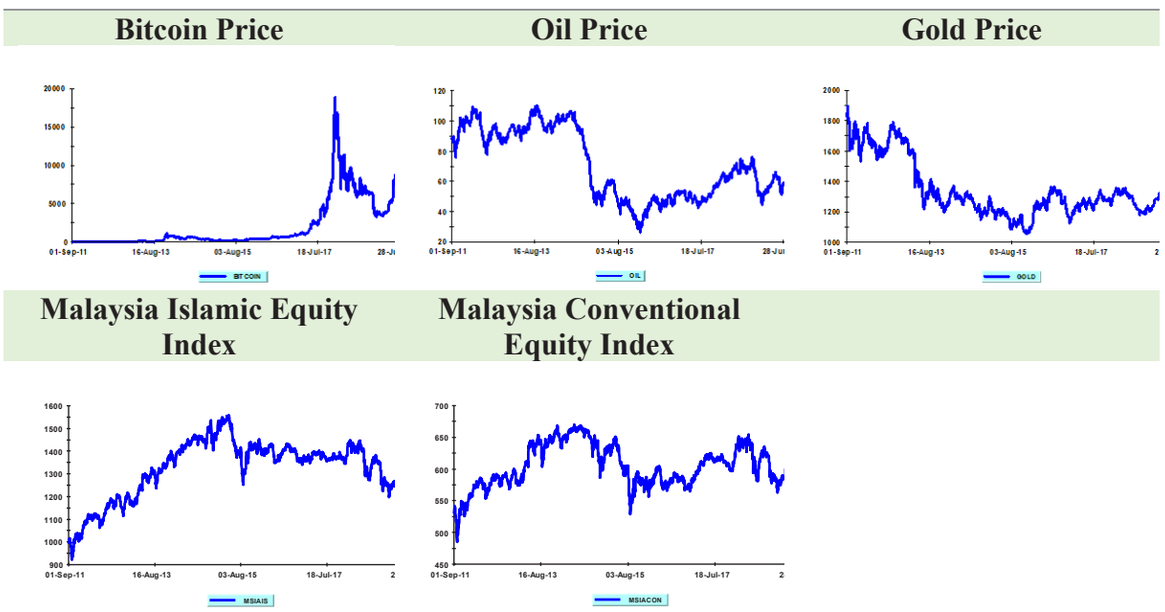

FIGURE 1. Dynamics of raw time-series data

Table 1 displays the descriptive statistics for the returns series, expressed as rt = ln(Pt/Pt 1), where rt is the series return calculated using the natural log and Pt is the price index at time t. Bitcoin's average return outperformed the Malaysian stock indices and other commodities. Besides that, Bitcoin is the most volatile asset compared to gold, crude oil, and Malaysian stock indices. Consequently, Bitcoin seems more lucrative than the Malaysian stock indices and other commodities regarding risk return.

EMPIRICAL RESULTS OF STANDARD TIME-SERIES TECHNIQUES

Based on the ADF test, we validated the unit roots of all variables and discovered that they should be utilised as I(1). We also found that the best VAR order is the one for AIC and SBC. To determine the exogeneity and endogeneity of the variables, we utilised a vector error correction analysis method (Table 2) using one cointegrating vector. According to Table 2, Bitcoin, crude oil, and gold prices are exogenous, while Malaysia's Islamic and conventional stock indices are endogenous. This seems to imply that Malaysia's stock indices will be affected by Bitcoin, crude oil, and gold prices. Investors interested in Malaysia stock indices should regularly follow the price movements of Bitcoin, crude oil, and gold so that they may take appropriate action if necessary. The error correction model distinguishes between the short-term and long-term Granger causalities. The term error correction refers to long-term connections between variables. The 'F'-test of the joint significance or insignificance of the lags of each of the 'differenced' variables provides the short-term impact of each variable. The diagnostic of all error correction model equations seems to imply that the equations are fairly specified.

The percentage of variance breakdown indicated by its previous shocks may decide the variable's relative exogeneity and endogeneity. Nonetheless, even though our entire horizon was 2,042, our methods to verify the variance decomposition limit our horizon to 150. The Maximum Overlap Discrete Wavelet Transformation (MODWT) was then used to determine the lead-lag connection between the selected exogenous variables.

EMPIRICAL RESULTS OF MODWT

Figure 2 shows the cross-correlation of MODWT-based wavelets between Bitcoin and crude oil across all intervals and the associated estimated confidence intervals against time leads and lags across all scales. Each scale is correlated with a distinct period. The individual cross-correlation function corresponds to wavelet scales λ_1 …, λ_8 that are correlated with changes of 1-2, 2-4, 4-8, 8-16, 16-32, 32-64, 64-128, and 128-256 days from the bottom to top. The red lines delimit the wavelet cross-correlation at the 95 percent confidence range. If the curve on the left side of the graph is significant, the first variable is leading. It is the reverse if the curve is prominent on the right side of the graph. It is deemed as significant positive wavelet cross-correlation if both 95 percent confidence levels are above the horizontal axes; if both 95 percent confidence levels are below the horizontal axes, it is

TABLE 1. Descriptive statistics

Variable	Mean	Standard Deviation	Min	Max	Skewness	Kurtosis	Number of observation
BITCOIN	0.00156	0.0256	-0.2883	0.2105	-0.9530	20.2262	2042
OIL	-0.00009	0.0091	-0.0466	0.0505	0.0270	3.2838	2042
GOLD	-0.00005	0.0041	-0.0441	0.0236	-0.7989	9.5063	2042
MSIAIS	0.00006	0.0026	-0.0164	0.0140	-0.1811	3.5893	2042
MSICON	0.00002	0.0025	-0.0161	0.0169	-0.3093	4.1339	2042

TABLE 2. VECM of bitcoin and other variables

Dependent Variable	**Bitcoin**		**Crudeoil**		**Gold**		**Msais**		**Msacon**	
ECM (-1)	-0.004	(0.004)*	-0.0013	(0.001)*	-0.00115	(0.0007)*	0.002	(0.0004)	0.002	(0.0004)
Chi - square SC(1)	3.941	(0.047)	14.4002	(0.000)	1.0476	(0.306)	12.170	(0.000)	16.16	(0.000)
Chi - square FF(1)	3.641	(0.056)	5.0066	(0.025)	2.1506	(0.143)	0.493	(0.483)	0.006	(0.941)
Chi - square N(2)	34211	(0.000)	910.24	(0.000)	7560.3	(0.000)	1167	(0.000)	1555	(0.000)
Chi - square Het(1)	30.908	(0.000)	0.0198	(0.888)	34.3201	(0.000)	51.21	(0.000)	68.31	(0.000)

Notes: SEs are provided in parentheses. Chi-squared statistics for serial correlation (SC), functional form (FF), normality (N), and heteroskedasticity (Het) are used as diagnostics.

* Denote significance at the 5% level.

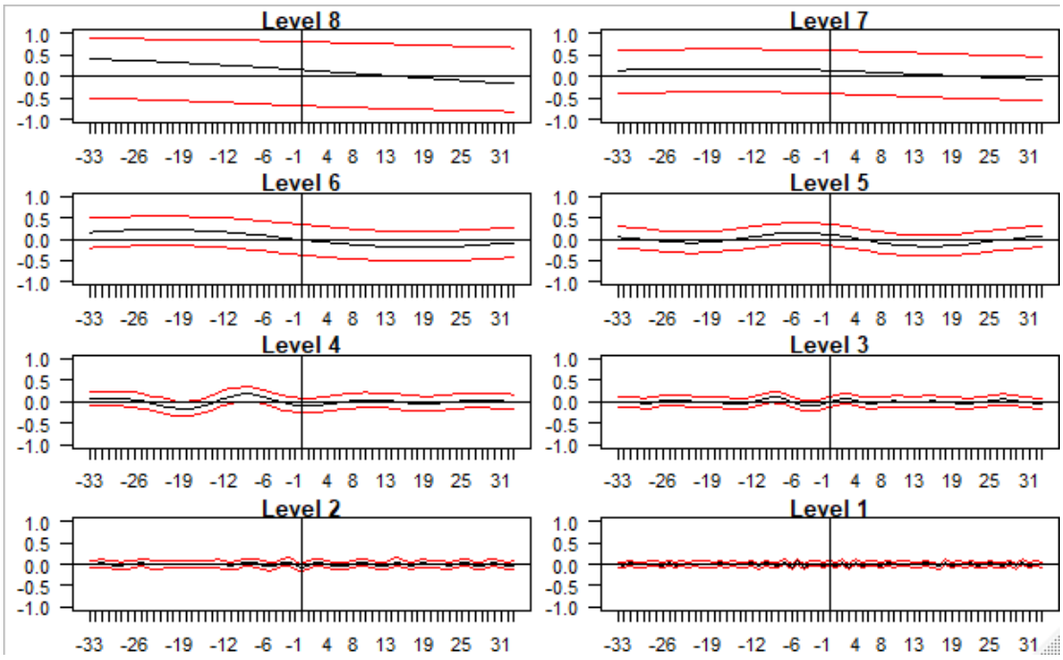

FIGURE 2. MODWT: Bitcoin price return vs. crude oil price return

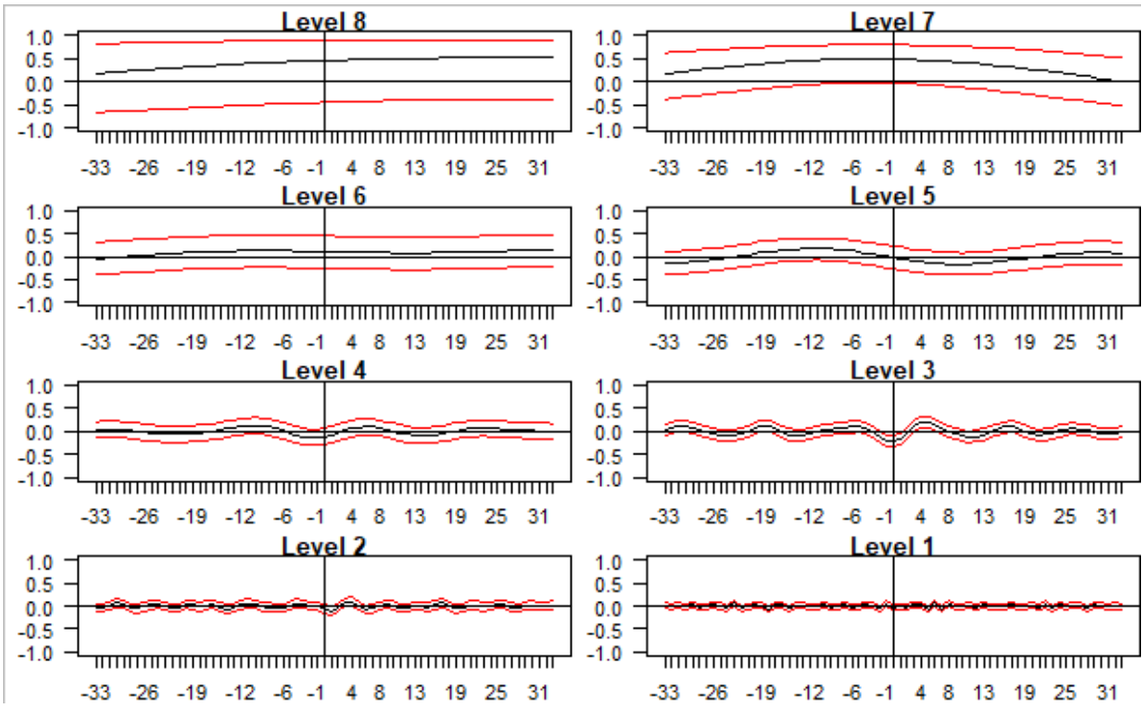

FIGURE 3. MODWT: Bitcoin Price Return vs. Gold Price Return

termed significant negative wavelet cross-correlation. We may conclude from this figure that:

1. At wavelet level 1 and 2, there is no substantial proof of the lead-lag connection between these two variables.
2. At wavelet level 3, 4, 5 6, 7, and 8, we can note that the graph slants to the left, suggesting that Bitcoin price return leads crude oil price return.

We might assume here that, at lower levels, there is no direct connection between Bitcoin price return and

the crude oil price return, but at higher levels, Bitcoin leads crude oil. While Bitcoin leads crude oil in the long run, the two variables are least correlated, as shown in Table 5. Therefore, the opportunity for diversification benefits between the two assets class is high. However, according to experts, Bitcoin is not a preferred safe-haven instrument. Cheah and Fry (2015) note that Bitcoin is a risky instrument with no intrinsic significance. Therefore, investors are urged to take special care if they select Bitcoin as part of their portfolio assets.

Figure 3 indicates the cross-correlation of the wavelet between the Bitcoin price return and the gold price return. We extracted the following details from Figure 3:

1. At wavelet levels 1, 2, 4, 6, and 7, there is no direct proof of the lead-lag interaction between the two variables.
2. At wavelet levels 3 and 8, we will note that the graph tilted to the right shows that the gold price return leads the Bitcoin price return.
3. The line tilted to the left-hand side at level 5. This may suggest that Bitcoin leads gold at this level.

We assume that the finding is inconclusive on certain levels (1, 2, 4, 6, and 7) since we cannot establish the lead-lag association between the two variables. However, at level 5, we have identified that Bitcoin leads gold but at a higher level (level 8), gold leads Bitcoin, which is in line with our assumption that gold as one of the world's most valuable commodities could affect Bitcoin price return. Our result is also compatible with Eichengreen (1992) who found that gold is a safe haven for investing. Gold is also known as a buffer against inflation and a way to improve portfolio diversification and wealth (Eichengreen 1992). Meanwhile, Dyhrberg (2016) notes that the features of Bitcoin are analogous to gold as both properties respond similarly to external shocks. These instruments have identical hedging capabilities and react to positive and negative news in the same direction.

The cross-correlation of the wavelet of crude oil price and gold price is shown in Figure 4. The following is the detailed information that we deduced from the graph in Figure 4:

1. There is no apparent lead-lag connection between these two variables at wavelet levels 1, 2, 3, 4, 5, and 6.
2. The graph is slanted to the left at wavelet levels 7 and 8, implying that the crude oil price leads the gold price.

In the long run, we can conclude that crude oil leads gold. This is consistent with our expectations, given that crude oil is the world's largest transacted commodity and a source of fuel and energy. According to Zhang and Wei (2010), crude oil has a more substantial and extensive impact on global economic development than gold. In addition, they discovered a substantial independent linear Granger causal relationship between the crude oil and gold markets. Notably, the crude oil price change linearly and Granger affects the gold price fluctuation, but not the other way around, implying that a rise in crude oil price drove up the gold price in the first few years of the twenty-first century, but this is not the case in the reverse direction (Zhang & Wei 2010).

The significance of conducting VECM analysis is to investigate the short-term and long-term causality between assets. Once the causality relationship is established, the MODWT analysis is conducted to estimate the time scale dependent on wavelet covariance and wavelet correlation variables before proceeding to MGARCH-DCC. The results of VECM show that movements in Bitcoin, crude oil, and gold prices will have an impact on Malaysia's stock indexes. Through MODWT, we discovered that in the long run, the price of crude oil might impact the price of gold, and the price of Bitcoin can influence the price of crude oil. However, MODWT and VECM cannot detect highly correlated and volatile variables that investors should avoid. As a result, MGARCH-DCC was used to assist investors in making better judgments.

EMPIRICAL RESULTS OF MGARCH-DCC

We used MGARCH-DCC instead of Constant Conational Correlation to evaluate the chosen commodities' diversification advantages with Malaysia stock indices. We did preliminary tests for the normal and t distributions to determine which of the two best matches our scenario. Referring to Rahim and Masih (2016) and Mohamad and Masih (2013), their research used t-DCC Multivariate Volatility models to address the fat-tailed features of return distribution as their key focus. Our evaluation of the approach yields a similar result, where the maximised log-likelihood for the multivariate t-distribution is 40952.1 (please refer to Table 3), which is more than the value achieved under the multivariate normal distribution model, 40482.7. In addition, the estimated degrees of freedom for the t-distribution is less than 30, indicating that the t-distribution is a more suitable model for capturing the fat-tailed nature of the variable distributions. As a consequence, we relied on the multivariate *t*-distribution results presented in Table 3. The MGARCH-DCC model in this paper was estimated by fitting individual GARCH(1,1) specifications. Therefore, for the robustness test, we used the CWT approach as presented in Figures 10 to 15.

Table 4 illustrates the estimated unconditional volatilities of the five variables (diagonal components) and the unconditional correlations (off-diagonal elements). The numbers in the diagonal components in parentheses represent the unconditional volatility ranking (from the highest to the lowest). Based on the unconditional volatility, Bitcoin and crude oil prices continue to gain a more significant proportion of speculative transactions,

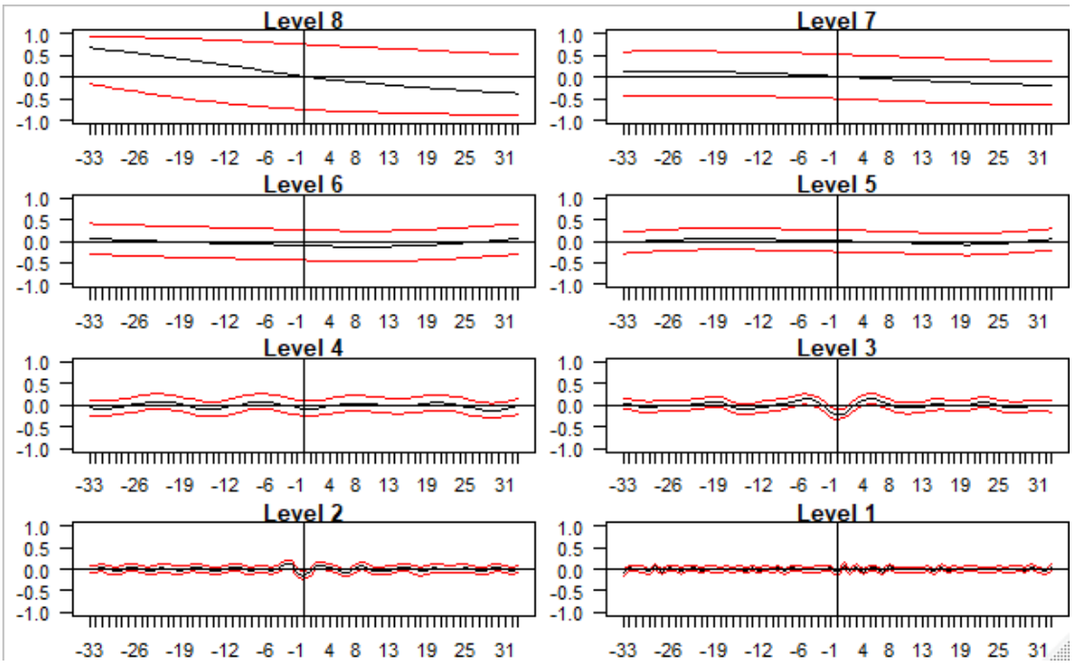

FIGURE 4. MODWT: Crude oil price return vs. gold price return

TABLE 3. Assessments of λ_{i1} and λ_{i2}, and δ_1 and δ_1

		Multivariate Normal Distribution		Multivariate t Distribution	
		Estimate	T-Ratio	Estimate	T-Ratio
Lamda 1 (λ1)	Bitcoin	0.87164	58.1815	0.81479	44.8543
	Crudeoil	0.93055	87.7832	0.94119	96.4115
	Gold	0.93867	85.4692	0.96603	137.6576
	Msais	0.90787	60.1908	0.94033	105.1807
	Msicon	0.90446	71.1281	0.92770	94.0840
Lamda 2 (λ2)	Bitcoin	0.11394	9.1908	0.17332	10.6318
	Crudeoil	0.057808	7.2994	0.04808	6.5912
	Gold	0.051906	6.1722	0.02935	5.2633
	Msais	0.063834	6.899	0.04871	7.4533
	Msicon	0.071026	8.4042	0.05933	8.0862
Delta 1 (δ1)		0.92004	37.3812	0.98639	839.277
Delta 1 (δ2)		0.015989	5.8246	0.00000	0.00000
Maximised log-likelihood		40482.7		40952.1	
Degree of freedom (df)		-		5.8355	

TABLE 4. Projected unconditional volatility matrix for all variables

	Bitcoin		Crudeoil		Gold		Msais		Msacon	
Bitcoin	0.0255	(1)	0.0132		0.0487		0.0017		0.0094	
Crudeoil	0.0132		0.009	(2)	0.111		0.0363		0.041	
Gold	0.0487		0.111		0.0041	(3)	0.0078		0.0027	
Msais	0.0017		0.0363		0.0078		0.0026	(4)	0.8841	
Msacon	0.0094		0.041		0.0027		0.8841		0.0024	(5)

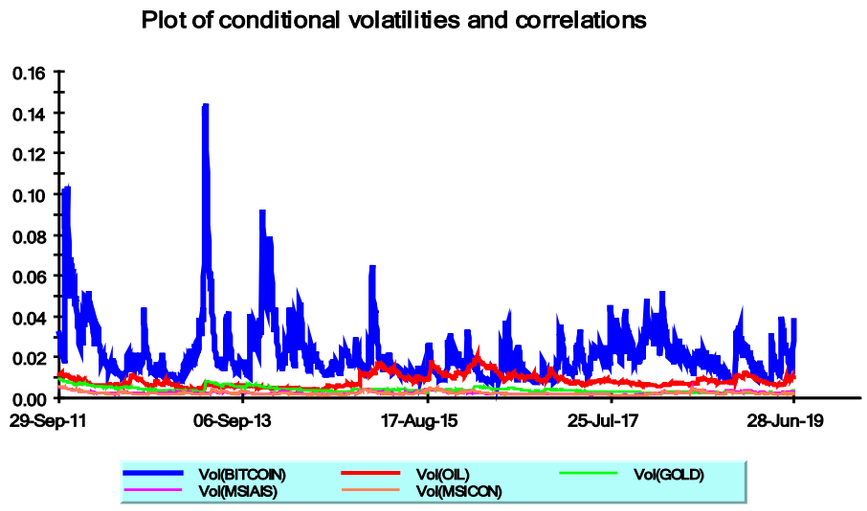

FIGURE 5. Conditional volatilities of all variables

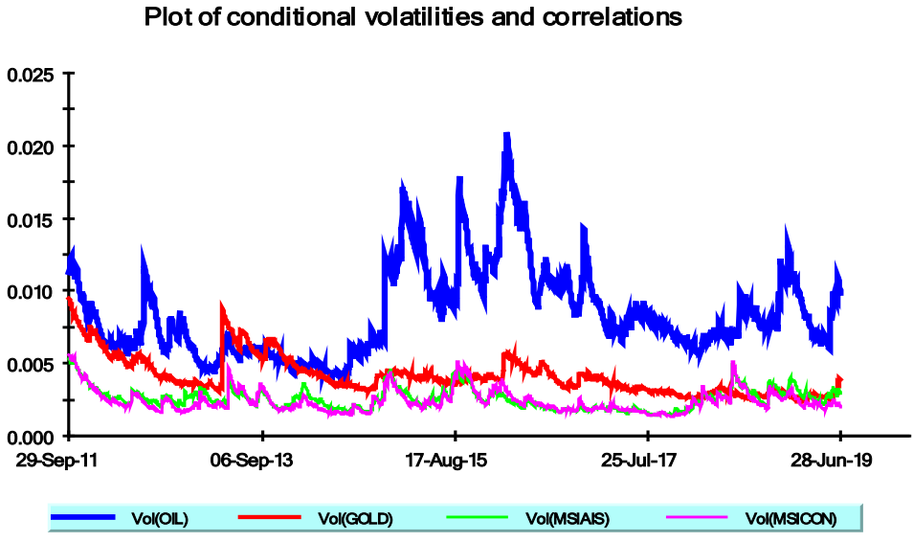

FIGURE 6. Conditional volatilities of all variables except bitcoin

as shown in Table 4. Malaysia's conventional stock index has the lowest volatility in the Southeast Asian capital market, indicating that the Malaysian economy is safe and robust. Bloomberg (2014) named Malaysia, South Korea, and China as the top emerging-market nations with 5 % or above GDP growth rates.

The correlation between commodities and stock indices is vital for the third objective of this study. A succinct assessment of the unconditional correlations listed in Table 5 reveals that the Bitcoin price return has the lowest correlations with almost all variables under consideration. We ordered the unconditional correlations to understand the relative correlation between variables better, as shown in Table 5 (from the highest to the lowest).

These rankings highlight the lowest correlation with the Bitcoin price return for almost all variables under analysis (indicated by the notation 'a' in Table 5). The outcome indicates that Bitcoin should be included in a portfolio allocation to gain from diversification. Bitcoin's isolation from the impact of economic and financial factors (Corbet et al. 2018) makes it a powerful diversifier, notably during the stock market plunges (Bouri et al. 2017b). However, the Bitcoin price return is the most volatile, as shown in Table 4, and thus, investors should consider gold as an option because gold is the second least correlated with other variables. Gold can also be used as a nearly ideal hedging device toward inflation (Worthington & Pahlavani 2007). The performance of conventional and Islamic market indices

in Malaysia also has a rather low correlation with gold as shown in Table 5, and hence, gold is the safest alternative for diversification of portfolios. However, Bitcoin and gold have many similarities and can be considered as diversifying commodities. First, for starters, Bitcoin and gold are non-political in nature and are governed as commodities, particularly in the US, where Bitcoin is categorised as a commodity by the Commodity Futures Trading Commission (CFTC). Second, no central body can regulate or modify gold and Bitcoin mining or trades (Baur et al. 2018), making both inflations resistant. Third, neither Bitcoin nor gold generates cash flows; they are generated via a process known as "mining". The availability of Bitcoin is restricted to not more than 21 million coins, as specified in its practice. Fourth, gold and Bitcoin respond to good and bad news in an inverted asymmetric manner (Bouri et al. 2017b). Table 5 also reveals that the crude oil price return has the lowest correlation with Bitcoin. Any trader with a crude oil exposure who wants a full diversification benefit would then be advised to invest in Bitcoin.

Before moving on to the next phase, we had to confirm that our results were reliable and that our test was accurate within a certain threshold of significance. For the robustness test, our results are shown in Table 6. The Kolmogorov–Smirnov test statistic is 0.0533 and the *p*-value associated with the test is 0.0303 which is less than the critical value of 5%. Therefore, we cannot reject the null hypothesis that integral probability transformations are distributed uniformly. Due to the presence of serial correlation, our LM was equal to 30.1331 (p-value = 0.003), which is statistically significant at a 5% critical level, rejecting our null hypothesis that the model t-DCC is appropriately specified. Nevertheless, the diagnostic test more or less well specified the model and demonstrates that MGARCH models possess asymptotic features that are unaffected by serial correlations. We expect that serial correlation would not have a negative impact on model specification.

Until now, our studies and assumptions on volatilities and correlations have been made on an unconditional basis. We may use the sample period's average volatility and correlation on an unconditional basis. However, the notion that volatility and correlation would stay constant during an 8-year cycle defies logic. Volatility and correlation are more likely to be dynamic, and this characteristic was addressed by the MGARCG-DCC model utilised in this study.

We began by examining the volatility of the temporal dimension. As shown in Figure 5, we map the conditional volatilities of the five variables. We found during those eight years under observation that Bitcoin price return had the most significant volatility relative to others. During this period, the lowest volatility is the Malaysia conventional stock index return (CSIR) and the highest volatility is Bitcoin. Figure 5 also illustrates that investing in Bitcoin is risky due to its excessive volatility compared to other factors. Meanwhile, Figure 6 shows that the Malaysia CSIR is the least volatile variable in contrast to the others and the Islamic Stock Index Return comes next (ISIR).

We assessed the correlation between Bitcoin price return and Malaysia Islamic and conventional stock index return through conditional correlations as identified in Figure 7. The chart shows that Bitcoin's correlation with Malaysia stock indices return was an upward trend from 2013 through 2019. Before that, from 2011 until 2013, the correlation is in a downward trend indicating a high diversification opportunity exists from 2011 until 2013 but reduce afterwards. The correlation of Bitcoin with Malaysia ISIR is higher compared to the conventional index, and therefore, it makes the conventional index a better choice for a diversification portfolio with Bitcoin.

Crude oil price return has the second-lowest correlation with Malaysia ISIR, making crude oil a suitable candidate for diversification instrument (refer to Table 5). We can see in Figure 8 that the correlation between crude oil and Malaysian indices has been

TABLE 5. Ranking of unconditional correlations for all variables

Bitcoin (BITCOIN)	Crude oil (OIL)		Gold (GOLD)		Malaysia ISIR (MSAIS)		Malaysia CSIR (MSACON)	
GOLD	GOLD		OIL		MSACON		MSAIS	
OIL	MSACON		BITCOIN	a	OIL		OIL	
MSAIS	MSAIS		MSAIS		GOLD		BITCOIN	a
MSACON	BITCOIN	a	MSACON		BITCOIN	a	GOLD	

TABLE 6. Robustness testing

	Coefficient	*p*-value
LM test	30.1331	0.003
	Test statistic	Critical value
Goodness of fit1	0.0533	0.0303

[1]Kolmogorov-Smirnov Goodness-of-Fit Test

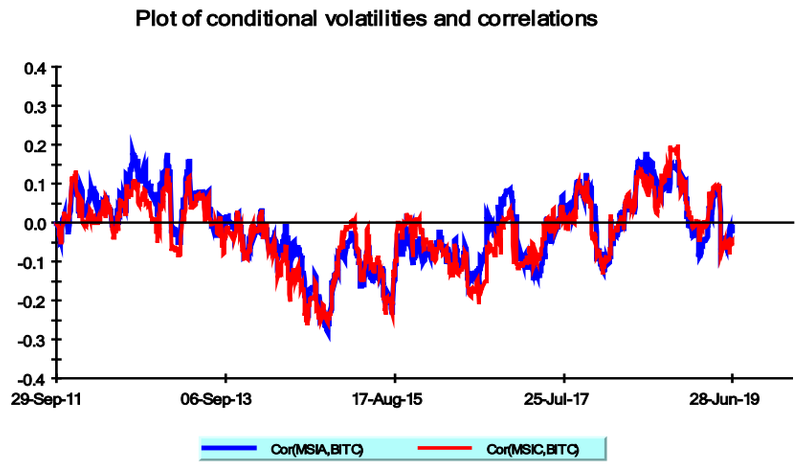

FIGURE 7. Conditional correlation of bitcoin price return with Malaysia Islamic and conventional indices return

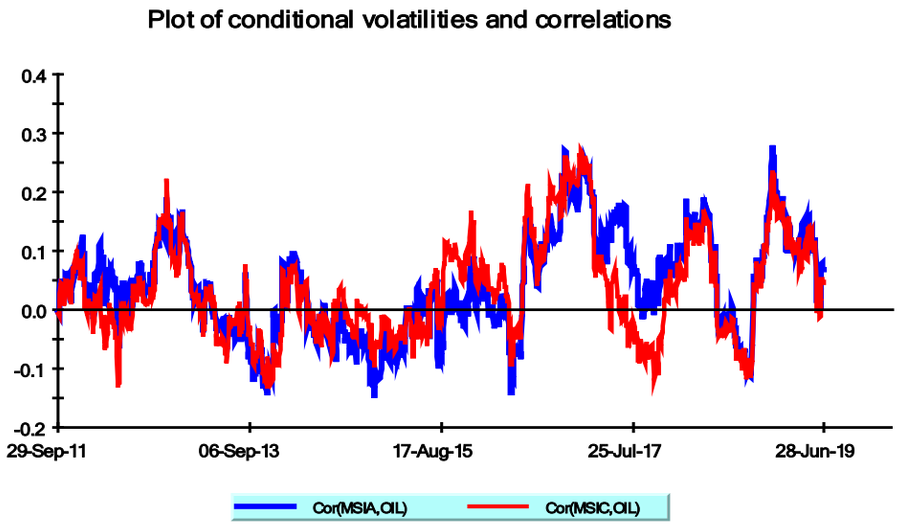

FIGURE 8. Conditional Correlation of Crude Oil Price Return with Malaysia Islamic and Conventional Indices Return

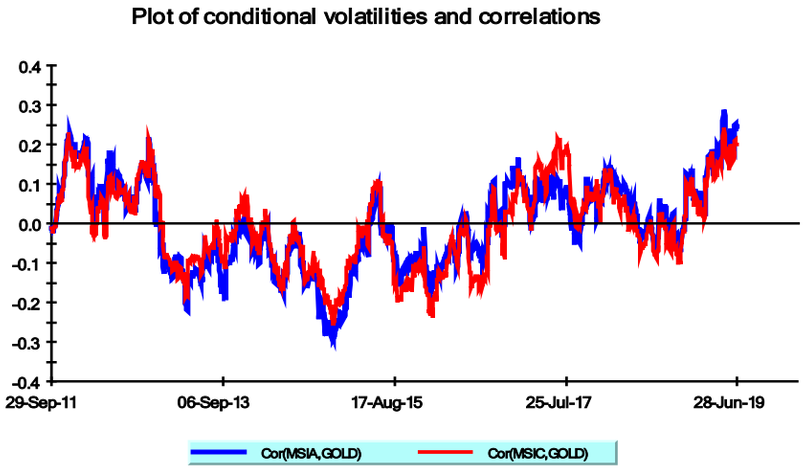

FIGURE 9. Conditional correlation of gold price return with Malaysia Islamic and conventional indices return

TABLE 7. Horizontal axis date

Horizontal Axis	Date
200	June 2012
400	March 2013
600	December 2013
800	September 2014
1000	July 2015
1200	April 2016
1400	January 2017
1600	October 2017
1800	July 2018
2000	May 2019

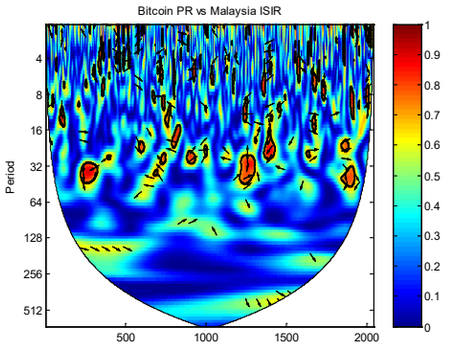

FIGURE 10. CWT – Bitcoin vs. MSAIS

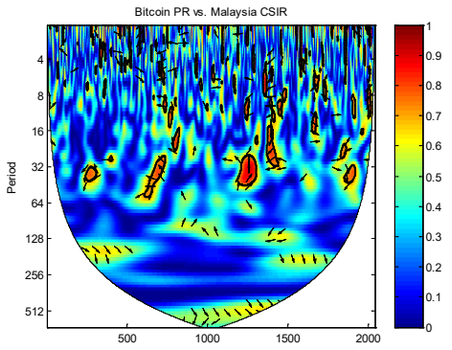

FIGURE 11. CWT – Bitcoin vs. MSACON

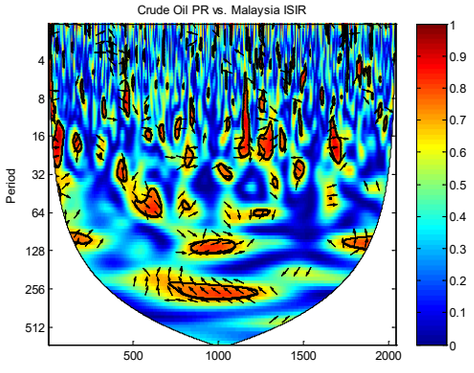

FIGURE 12. CWT – Crude oil vs. MSAIS

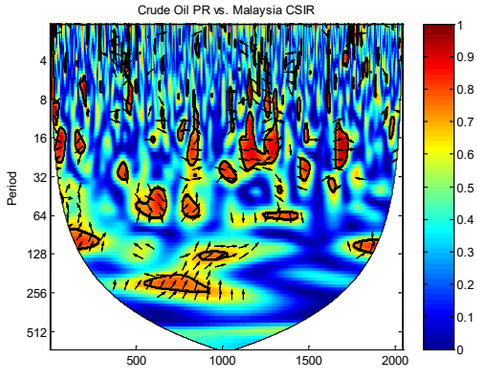

FIGURE 13. CWT – Crude oil vs. MSACON

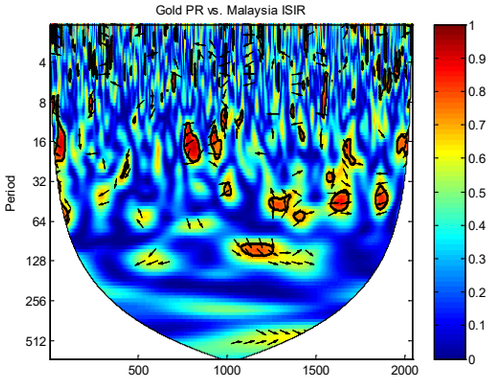

FIGURE 14. CWT – Gold vs. MSAIS

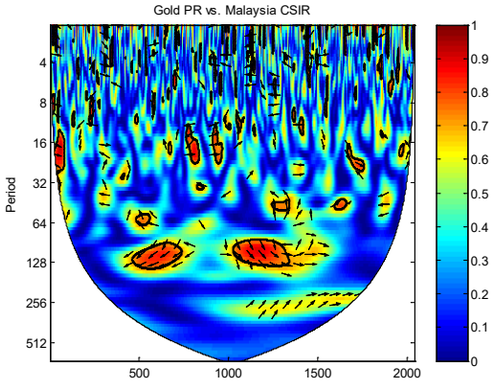

FIGURE 15. CWT – Gold vs. MSACON

declining from 2011 to 2014. From 2014 onward, the correlations show an upward trend until 2016. The upward trend indicates a low opportunity for future diversification benefits between Malaysia stock indices and crude oil. The variables are highly volatile and move in the ranges of 2.5 to -0.1 from 2016 to 2019, indicating unstable conditions during those years. From Figure 8, we also notice that the correlation of Islamic and conventional indices with crude oil is almost identical, with a slightly lower correlation for ISIR.

Meanwhile, the gold price return has the weakest correlation with Malaysia CSIR. An investor with a gold exposure portfolio would be better suited to diversify in Malaysia CSIR than Malaysia ISIR (refer to Table 5). This is because Malaysia's ISIR volatility and correlation are higher than Malaysia's CSIR. Figure 9 shows that the correlation between gold and Malaysian stock indexes had decreased from 2011 to 2014. This suggests an increase of opportunity for diversification benefit between gold price return and Malaysia stock indices return in those years. The correlation moves in an upward pattern afterwards, indicating a low opportunity for diversification.

EMPIRICAL RESULTS OF CWT

Figures 10 to15 show the estimated CWT and phase difference for the selected variables stretching from 1 to 8 (about two business years or 512 days). The number of trading days is shown on the horizontal axis, while the investment horizon is represented vertically. The curving line below represents the 5 % significance threshold determined by Monte Carlo simulations. As seen on the right, the picture follows a colour coding with the power ranges ranging from blue (low correlations) to red (high correlations).

Investors who wish to diversify by investing in Malaysia's conventional and Islamic stock indices should be aware of the correlation between the variables. The charts in Figures 10 and 11 show that investors may maintain their portfolio as long as they believe it is suitable to get a diversification benefit since there is no short- or long-term correlation between Bitcoin and Malaysia indices. Our findings support Bouri et al. (2017a) claim that Bitcoin has long been viewed as a safe haven from the global financial system's instability and sovereign risk.

For investors interested in owning crude oil and Malaysia stock indices portfolios, the investment should be held for one month (between 1 day to 32 days) to reap diversification benefits. They will be exposed to a high correlation if their investment lasts beyond one month or more than 32 days (see Figures 12 and 13). We also discovered that crude oil has a stronger correlation with Malaysia CSIR than Malaysia ISIR. Malaysia's economy is more vulnerable to fluctuations in crude oil prices than Bitcoin prices because Malaysia is a net exporter of crude oil and highly reliant on it for revenue.

Malaysia's stock indices exposure to gold prices is very similar to the Bitcoin price exposure for a period within 64 days. Referring to Figures 14 and 15, we note that the correlation between the gold price return and Malaysia stock indices is weak for investment holding periods from day 1 to day 64 for the most part. Nevertheless, the correlation between the variables under consideration is strong, especially with CSIR for scale durations ranging from 64 to 128 days, limiting the portfolio's diversification advantage. The investor will gain a diversification advantage for the lower scale, which exceeds the 128-day investment holding period, as the correlation between the Malaysian stock indexes return and the gold price return is low. The result is in line with our MGARCH-DCC test as shown in Table 5 (which indicates that the indices' correlation with gold is the lowest, especially for CSIR). Hussin et al. (2013) also found similar results in their study, noting that Malaysia's stock indices were not affected by gold prices or vice versa, indicating that gold could be a diversifier for Malaysia's stock indices.

CONCLUSION

This study seeks diversification opportunities for Malaysian conventional and Islamic stock index returns, and the returns of Bitcoin, gold, and crude oil prices. The study objectives were met using several relevant modern techniques, including the error-correction model, MODWT-based wavelet cross-correlations, CWT-based wavelet coherence, and MGARCH-DCC with data spanning more than eight years from 1 September 2011 to 28 June 2019.

Our study's objectives are to determine if Malaysian stock indices impact commodity price volatility and whether historical stock indices' values aid in commodity price prediction. We also want to know which exogenous variable is more exogenous across different periods. In order to diversify their portfolios, investors must understand which stock indexes and commodities to invest in, as well as how the benefit from portfolio diversification differs for investors across different investment horizons or stockholding timeframes.

Referring to the findings of the error-correction model, Bitcoin, gold, and crude oil prices are exogenous, whereas Malaysia's stock indices are endogenous. To summarise, Malaysian indices will be influenced by Bitcoin, gold, and crude oil prices. Based on the MODWT results, it can be assumed that Bitcoin leads crude oil at higher levels and that both variables would benefit from diversification in the long term. Meanwhile, we also discovered that gold leads Bitcoin in the long run, consistent with the expectation. Gold has long been regarded as a safe haven and one of the most valuable commodities. Therefore, the movement of the gold price will influence the Bitcoin price. According to the MGARCH-DCC results, Malaysia's conventional stock

index has the lowest volatility, indicating a balanced and robust economy. The Malaysian conventional stock index also has the lowest correlation with gold prices. Therefore, it is advised that investors exposed to Malaysia's conventional stock index invest in gold to gain from diversification. Gold has long been recognised as an essential hedging tool, and this finding is consistent with Hood and Malik's (2013) argument that gold may serve as a hedge and safe haven for the US stock market.

According to the CWT result, specific investment horizons may not provide substantial diversification benefits for Malaysian stock indices investors who have invested in crude oil and gold. Simultaneously, Bitcoin's investment offers significant diversification opportunities due to a relatively low correlation with Malaysian stock indices. However, due to its intense volatility, Bitcoin may be considered a high-risk diversifier. The low correlation between Bitcoin and Malaysian stock indexes may be attributed to Bitcoin's lack of similar price drivers with such variables (Bouoiyour et al. 2016). Bitcoin price is determined by variables other than economic and financial considerations, for example, the appeal (Kristoufek 2015), energy costs (Li & Wang 2017), customer secrecy (Ober et al. 2013), computer programming aficionados, and unlawful activities (Yelowitz & Wilson 2015). Instead, the advantages of portfolio diversification are more substantial if Malaysian individuals (particularly conventional index investors) engage in gold for a short-term investment holding. Stock holding durations of more than 64 days would result in high correlations between gold and Malaysian stock indices, resulting in minimal gains from portfolio diversification. Based on the finding, a more frequent assessment of portfolio allocations and investment horizons is recommended to find portfolio diversification opportunities.

Gold is known historically as a safe-haven instrument against inflation, economic recession or political turmoil. However, Bitcoin has started to draw investors' interest, particularly in developing countries, such as China and Latin America, where there are tight controls on capital movements, Bitcoin is used to transfer money abroad. This has been exacerbated by the government's control of the physical gold market, making Bitcoin an appealing gold alternative (Shahzad et al. 2019). As a result, we may infer that Bitcoin may play an essential role in the future as a safe haven tool for investors and other stakeholders.

Generally, the findings of this research reinforce prior empirical literature that Malaysia's stock indices are heavily correlated with commodities, resulting in fewer diversification gains over the long term. However, investors may still profit from diversification by considering time-varying correlations and diverse investment horizons.

The outcomes of this study have substantial consequences for Malaysian conventional and Shari'ah compliant investors, as understanding the correlation between the variables under consideration is essential for producing a high return investment. The findings of this study are also crucial for the government to allocate its scarce resources and for stock market policies at different investment horizons. The Malaysian government should consider any shocks to the variables under study when formulating macro-stabilisation policies for the stock market since failing to do so may result in a stock market crash and an economic crisis.

This research may be improved in the future by including new variables, such as silver, coffee, and other cryptocurrencies. Future research may compare the advantages of portfolio diversification between Malaysian stock indices and developed market stock indices, such as the US and the United Kingdom. More research on this topic could be done by looking at the relationships between the various sectors in Bursa Malaysia, such as the financial services, construction, health care, and the energy sector. By researching many sectors, more information could be provided on industry co-movements, enabling investors to reduce risk more effectively.

REFERENCES

Abdullah, A.M. & Masih, M. 2016. Diversification in crude oil and other commodities: A comparative analysis. *Asian Academy of Management Journal of Accounting and Finance* 12(1): 101-128.

Büyükşahin, B., Haigh, M. & Robe, M. 2010. Commodities and equities: ever a 'market of one'? *Journal of Alternative Investments* 12(3): 76–95.

Baur, D. & Lucey, B. 2010. Is Gold a hedge or a safe haven? An analysis of stocks, bonds and gold. *The Financial Review* 45: 217–229.

Baur, D.G., Hong, K. & Lee, A.D. 2018. Bitcoin: Medium of exchange or speculative assets? *Journal of International Financial Markets, Institutions and Money* 54: 177-189.

Bloomberg 2014. Best Emerging Market 2014: Countries. Available at http://www.bloomberg.com/visualdata/best-and-worst//best-emerging-markets-2014-countries, Bloomberg, 2014.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D. & Hagfors, L.I. 2017a. On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? *Finance Research Letters* 20: 192-198.

Bouri, E., Azzi, G. & Dyhrberg, A.H. 2017b. On the return-volatility relationship in the Bitcoin market around the price crash of 2013. Economics: The Open-Access, *Open-Assessment E-Journal* 11(2017–2): 1–16.

Bouoiyour, J., Selmi, R., Tiwari, A.K. & Olayeni, O.R. 2016. What drives Bitcoin price? *Economics Bulletin* 36(2): 843–850.

Cheah, E.T. & Fry, J. 2015. Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economics Letters* 130: 32-36.

Corbet, S., Meegan, A., Larkin, C., Lucey, B. & Yarovaya, L. 2018. Exploring the dynamic relationships between cryptocurrencies and other financial assets. *Economics Letters* 165: 28-34.

Daubechies, I. 1992. Ten Lts. *Society for Industrial and Applied Mathematics* 61: 198-202.

Dyhrberg, A.H. 2016. Bitcoin, gold and the dollar–A GARCH volatility analysis. *Finance Research Letters* 16: 85-92.

Eichengreen, B.J. 1992. *Golden Fetters: The Gold Standard and the Great Depression*, 1919–1939. New York, Oxford University Press.

Fan, J.P., Huang, J. & Zhu, N. 2009. *Distress without bankruptcy: an emerging market perspective*. Available at SSRN 1360873.

Gallegati, M. 2008. Wavelet analysis of stock returns and aggregate economic activity. *Computational Statistics and Data Analysis* 52(6): 3061-3074.

Gençay, R., Selçuk, F., & Whitcher, B. 2001. Differentiating intraday seasonalities through wavelet multi-scaling. *Physica A: Statistical Mechanics and its Applications* 289(3-4): 543-556.

Gorton, G., & Rouwenhorst, K.G. 2006. Facts and fantasies about commodity futures. *Financial Analysts Journal* 62(2): 47–68.

Guesmi, K., Saadi, S., Abid, I. & Ftiti, Z. 2019. Portfolio diversification with virtual currency: Evidence from bitcoin. *International Review of Financial Analysis* 63: 431-437.

Helbling, T. 2008. *The current commodity price boom in perspective*. International Monetary Fund, World economic outlook: Housing and the business cycle.

Hood, M., & Malik, F. 2013. Is gold the best hedge and a safe haven under changing stock market volatility? *Review of Financial Economics* 22(2): 47-52.

Hussin, M.Y.M., Muhammad, F., Abu, M.F. & Awang, S.A. 2012. Macroeconomic variables and Malaysian Islamic stock market: A time series analysis. *Journal of Business Studies Quarterly* 3(4): 1.

Hussin, M.Y.M., Muhammad, F., Razak, A.A., Tha, G.P. & Marwan, N. 2013. The link between gold price, oil price and Islamic stock market: Experience from Malaysia. *Journal of Studies in Social Sciences* 4(2): 161-182.

In, F. & Kim, S. 2013. *An Introduction to Wavelet Theory in Finance*. Singapore: World Scientific Publishing.

Karim, M.M., Chowdhury, M.A.F. & Masih, M. (2021). Re-examining oil and BRICS'stock markets: New evidence from wavelet and MGARCH-DCC. *Macroeconomics and Finance in Emerging Market Economies* 1-19.

Kristoufek, L. 2015. What are the main drivers of the Bitcoin price? Evidence from wavelet coherence analysis. *PLoS One* 10(4): e0123923.

Li, X., & Wang, C.A. 2017. The technology and economic determinants of cryptocurrency exchange rates: The case of Bitcoin. *Decision Support Systems* 95: 49–60.

Masih, M., A. Al-Elg & H. Madani 2009. Causality between financial development and economic growth: An application of Vector Error Correction and Variance Decomposition Methods to Saudi Arabia. *Applied Economics* 41(13): 1691–1699.

Markowitz, H.M. 1959. *Portfolio Selection: Efficient Diversification of Investments*. New York: Cowles Foundation Monograph 16.

Mensi, W., Beljid, M., Boubaker, A. & Managi, S. 2013. Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Economic Modelling* 32: 15–22.

Mohamad, S.F.S. & Masih, M. 2013. An application of MGARCH-DCC analysis on selected currencies in terms of gold Price. MPRA Paper 62349, University Library of Munich, Germany.

Mishkin, F.S. 2011. Over the cliff: From the subprime to the global financial crisis. *Journal of Economic Perspectives* 25(1): 49-70.

Narayan, P.K., Narayan, S., Rahman, R.E. & Setiawan, I. 2019. Bitcoin price growth and Indonesia's monetary system. *Emerging Markets Review* 38: 364-376.

Ober, M., Katzenbeisser, S., & Hamacher, K. 2013. Structure and anonymity of the bitcoin transaction graph. *Future Internet* 5(2): 237–250.

Patel, S.A. 2013. Causal relationship between stock market indices and gold price: Evidence from India. *IUP Journal of Applied Finance* 19(1): 99.

Percival, D.P. 1995. On estimation of the wavelet variance. *Biometrika* 82(3): 619-631.

Pesaran, B. & M.H. Pesaran 2010. *Time Series Econometrics Using Microfit 5.0: A User's Manual*. New York: Oxford University Press.

Rahim, A.M. & Masih, M. 2016. Portfolio diversification benefits of Islamic investors with their major trading partners: Evidence from Malaysia based on MGARCH-DCC and wavelet approaches. *Economic Modelling* 54: 425-438.

Shahzad, S.J.H., Bouri, E., Roubaud, D., Kristoufek, L. & Lucey, B. 2019. Is Bitcoin a better safe-haven investment than gold and commodities? *International Review of Financial Analysis* 63: 322-330.

Thomson Reuters 2018, *Islamic Finance Development Report 2018*: *Building Momentum* 1-44.

Wang, Y., Lin, C. & Li, Y. 2013. The Correlation and hedging effects between commodity and stock markets. *Journal of Applied Finance and Banking* 3(5): 269–297

Whitcher, B., Guttorp, P. & Percival, D.B. 2000. Wavelet analysis of covariance with application to atmospheric time series. *Journal of Geophysical Research: Atmospheres* 105(D11): 14941-14962.

Worthington, A.C. & Pahlavani, M. 2007. Gold investment as an inflationary hedge: Cointegration evidence with allowance for endogenous structural breaks. *Applied Financial Economics Letters* 3(4): 259-262.

Yelowitz, A., & Wilson, M. 2015. Characteristics of Bitcoin users: An analysis of Google search data. *Applied Economics Letters* 22(13): 1030–1036.

Zhang, Y.J. & Wei, Y.M. 2010. The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy* 35(3): 168-177.

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