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# Asymmetric correlation and hedging effectiveness of gold & cryptocurrencies: From pre-industrial to the 4th industrial revolution<sup>☆</sup>



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## ABSTRACT

This paper examines the long-run and short-run asymmetric effects of gold and cryptocurrency returns on the Thai stock market. Employing daily data on gold prices from 2000 to 2019 and on cryptocurrency (Bitcoin) from 2013 to 2019 in a linear and non-linear Autoregressive Distributed Lag (ARDL) framework, we investigate and contrast the hedging effectiveness of gold and bitcoins for equities. This study also evaluates whether hedging potential of gold or cryptocurrency remains equally strong in bearish and bullish conditions of the stock market. Our key findings on stock and gold returns reveal that the effects of gold on the stock market are asymmetric in most of the cases. Negative asymmetry is more likely to occur regardless of stock market conditions. On the other hand, there is very limited evidence showing the meaningful effect of cryptocurrency. The robustness of the ARDL bounds test of co-integration provides evidence for a strong long-run relationship in all cases. Contrary to the existing literature, our results suggest that neither gold nor cryptocurrency acts as a good instrument for hedging in the stock market. Correlations between stock/gold and stock/cryptocurrency pairs are found to be positive in most cases. Our findings imply that adding gold or cryptocurrency to a stock portfolio does not enhance its risk-adjusted return.

## 1. Introduction

The global financial crisis and associated events and most recently the outbreak of COVID-19 have shaken developed and emerging economies. The upheavals in the international financial system are now more persistent and recurrent. The international financial integration and synchronisation of business cycles are considered fundamentals for the market turbulence and spillover (Rejeb and Arfaoui, 2016; Nasir and Du, 2018; Huynh, 2019). To benefit from risk-return trade-off through international portfolio diversification, investors are now particularly attentive to the interdependence between stocks and alternative assets (Bekaert et al., 2014). There is also a great interest in the nature of asset dependencies for asset pricing, portfolio allocation and financial policy formulation. The portfolio return can be influenced by misallocation, especially during market turmoil. Asset dependencies, therefore, are vital to verify how the assets can affect each other and how strongly they are interlinked. According to the diversification

principle, the probability of investment losses could be diminished by investing in assets with low correlations.

As a result of globalisation, the emerging countries which are often very dependant on commodities, have become highly integrated with the rest of the world. Emerging stock markets are vulnerable to several global shocks with severe commodity price fluctuations (oil price shocks), increased financial instability and a potential slowdown in the global economy. Therefore, risk management has become crucial, particularly during extreme market conditions, as investors seek protection. Traditionally, a good place of safety against macroeconomic risk is the gold market (Erb and Harvey, 2006; Reboredo, 2013). In developed stock markets, gold is reported to be a good safe-haven asset during the peak of the recent financial crisis (Ciner et al., 2013; Flavin et al., 2014; Bredin et al., 2015; Junttila et al., 2018; Baek, 2019). However, this does not hold for all stock markets. There is empirical evidence showing that gold is a poor safe-haven or is not a safe-haven for emerging stock markets (see, e.g. Baur and McDermott, 2010; Beckmann et al., 2015;

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Bekiros et al., 2017). Co-movements between stock and commodity markets have intensified following the rapid financialisation of commodities (Tang and Xiong, 2012; Delatte and Lopez, 2013; Adams and Glück, 2015). The substantially eased investment in gold makes gold increasingly acts like stocks (Bekiros et al., 2017).

The proposition that gold has played a comparatively minor safe-haven role in emerging stock markets reinforces the need for an alternative. In this context, a major development has occurred through the financial innovation in the age of the 4th Industrial revolution, specifically, the cryptocurrencies and bitcoins. It has brought a new phenomenon amongst international investors who now sell precious metals and buy Bitcoin (Rehman and Apergis, 2018). Nevertheless, there is very limited evidence showing meaningful effects of cryptocurrencies on stocks. Concomitantly, it raises some vital questions on the effectiveness of cryptocurrencies in portfolio diversification and hedging, particularly in the emerging stock market. Furthermore, the linearity assumption introduced in the existing literature may overlook asset connections. Positive and negative shocks of gold/Bitcoin prices may affect stock market differently where there are asymmetric effects of gold/Bitcoin on the stock market. This provides the rationale for the subject study and to investigate the notion that whether cryptocurrency can be a better safe-haven asset for emerging stock market. Studies of correlation between stock markets and alternative assets are often conducted for a single asset either gold (as an old asset) or cryptocurrency (as a new asset), mostly focusing on developed markets. A comprehensive study that includes old and new assets and focuses on a developing market has not been conducted hitherto. This study will address the gap and investigate how emerging stock market, old and new alternative assets are associated. This paper is applying both linear and nonlinear approaches to examine correlation and hedging effectiveness of gold and Bitcoin for emerging stocks.

Contextualising on the debate on the role of gold which is a pre-industrial age asset in the era of 4th industrial revolution and cryptocurrencies which are new instruments of the modern age, using daily data on Thai stocks, gold prices, and cryptocurrency (Bitcoin), this study finds that correlations between stock/gold and stock/cryptocurrency pairs are positive in most of the cases. This study also reveals that the hedging ability of gold and cryptocurrency against an adverse movement in the stock market is more complicated than the linear relation explored in the previous studies. After splitting the entire sample period into different market states, estimates of stock and gold returns reveal that the effects of gold on the stock market are indeed asymmetric in most cases, except for one period of the bull market from May 2004 to October 2007. Negative asymmetry is more likely to occur regardless of stock market conditions. An asset might be suitable for investment from a risk perspective if the asset correlates negatively with another asset, hence putting both of them together significantly reduces the risk. A diversifier, a hedge and a safe-haven asset were differentiated by Baur and Lucey (2010) and Ratner and Chiu (2013). Diversification implies putting an asset with whom it has a weak positive correlation. A weak (strong) hedge is a non-correlated (negative-correlated) asset with another asset on average. An asset that is uncorrelated (negatively correlated) to another asset in times of stress is a weak (strong) safe-haven. From the risk perspective, gold and cryptocurrency are suitable for diversification purpose only. Neither gold nor cryptocurrency acts as a good instrument for hedging in the emerging stock market. Our key results further suggest that putting gold or cryptocurrency to a stock portfolio does not enhance its risk-adjusted return. These findings also contribute to the understanding of market behaviour that stock market is imperfect, and investors can suffer losses in the emerging stock market, instead of pursuing alternative safe-haven assets to reshape their portfolios. It is advisable to investors to not pursue hedging asset without thorough consideration. Furthermore, stock/gold and stock/Bitcoin dependencies are not uniform throughout the bearish and bullish markets. This is also in line with traditional wisdom that the universe of investable assets is driven by rising

macroeconomic factors, such as economic expectations or anticipated inflations.

The remainder of this paper is organised as follows: Section 2 reviews relevant literature. Section 3 explains the rationale for using the chosen methodology and dataset. Section 4 presents and discuss the empirical results. Section 5 concludes and provide policy implications.

## 2. Literature review

Since the global financial crisis 2008–2009, there has been increasing interest in the safe-haven property of gold against stock markets. Many studies focusing on developed economies, for instance, Ciner et al. (2013) investigated asset dependencies. They concluded that gold acts as a safe-haven for US stocks in the 90 s and the recent global financial crisis. Furthermore, there is empirical evidence to support the superiority of the selection of gold as a safe-haven asset for US equity funds (Flavin et al., 2014). Bredin et al. (2015) illustrated further evidence that gold is a safe-haven asset for stocks in the long-run up to one year. Recently, Baek (2019) explored the relationship between gold, stock and bond markets in the US. The interactions amongst them are investigated regarding extreme returns, predictive power, causality and co-integration. The results showed that the causality of gold returns with stock and bond returns is unidirectional. Nevertheless, there is no cointegration between the variables. The researchers also discovered that subsequent short-term stock returns can be predicted by the gold returns. Remarkably, gold returns are more likely to deteriorate under extreme market with bond returns than with stock returns. The results imply that during temporary market downturns, gold will best act as a safe-haven asset for stocks. Furthermore, there is an attempt to clarify the safe-haven property of gold at sectoral levels in developed stock markets. Empirical evidence remains to confirm that gold is a safe-haven asset for both aggregate and sector levels. Junttila et al. (2018) examined the safe-haven properties of gold while focusing on the US stock market returns at both aggregate and sector levels. The results revealed that the correlations between gold and stock market returns have changed considerably, especially in energy sector stocks. During the crisis, the correlations between gold futures and aggregate US stocks were found to be negative, supporting the safe-haven hypothesis of gold. Moreover, gold futures can be used as cross-hedging for stocks in the energy sector effectively, specifically during stock market crises. Although in some studies less important role of gold in stock markets have been reported and the insignificant effect has not been observed. Baur and Lucey (2010) argued that the safe-haven property of gold only holds in short-run. Lucey and Li (2015) revealed that gold is not the strongest or best safe haven for stocks when compared to other precious metals such as palladium, silver and platinum.

Contrary to the results on developed stock markets, research on the hedging of extreme price fluctuations in emerging markets indicates that gold is not a safe-haven or is only a weak safe-haven. For instance, Beckmann et al. (2015) found a strong hedge of gold for stock markets in Russia and Indonesia, but no safe-haven function was observed. There is evidence showing that gold serves as a poor safe-haven asset for stock markets in China, Egypt, Korea, South Africa, Turkey and Thailand (Beckmann et al., 2015). Furthermore, Baur and McDermott (2010) and Bekiros et al. (2017) argued that gold does not act as a safe-haven for the BRIC countries. However, Wen and Cheng (2018), argued that the safe-haven property of gold prevails. They investigated the safe-haven properties of gold and US dollar against emerging economies<sup>1</sup> stocks by employing Copulas approach to measure low-high tail dependence between the markets and downside portfolio risk. Although safe-haven properties of gold and the US dollar

<sup>1</sup> Brazil, Chile, China, the Czech Republic, India, Malaysia, Russia, South Africa and Thailand.

were found, gold was not the strongest safe-haven asset against emerging stocks. The results revealed that the US dollar was superior to gold in most cases, particularly in China and Thailand.

In comparison to the above-discussed studies on gold, the literature on assessing the safe-haven role of cryptocurrencies for stock markets is relatively limited. Perhaps, due to the reason that the cryptocurrencies<sup>2</sup> have just started to exist since the inception of Bitcoin in 2009. Yet, the apparent failure of central banks and governments during the global financial crisis 2008–2009 and European sovereign-debt crisis 2010–13 have made cryptocurrencies increasingly popular amongst investors (Balcilar et al., 2017). There is a significant increase in the number of businesses that agree to accept Bitcoin as a medium of exchange. The popularity of bitcoin has continued to increase, although it has suffered from numerous hacks, bad creditability, and government restrictions. Bitcoin has gained popularity as an investment asset, besides being a fairly recent invention. With approximately 5234 types, cryptocurrencies have now reached a market capitalisation of \$170 billion, and Bitcoin holds 64.71% of the total market share. Consequently, many academic papers have focused on Bitcoin.

There is no strong evidence to support hedging effectiveness and safe-haven property of Bitcoin for stock at the aggregate market level. For instance, Bouri et al. (2017a) evaluated Bitcoin's potential for diversification, hedging, and being safe-haven asset against bonds, stocks, gold, the US dollar and oil. Their analysis included European and Asia Pacific stocks (US, UK, Germany, Japan, and China) and employed a Bivariate DCC model and regression analysis. The results indicated that Bitcoin can be used as a diversifier only on some occasions and it is a poor hedger. Furthermore, that the Bitcoin occasionally acts as a potential safe-haven asset and this property is time-variant. However, Bitcoin can serve as a good hedge and safe-haven asset for stocks at the sectoral level. Bouri et al. (2017b), examined the potentials of Bitcoin for diversification, hedging, and being safe-haven asset against general commodity index and energy commodity index. Their empirical results revealed that Bitcoin serves as a good hedge and safe-haven for energy commodities, but it is not good for non-energy commodities. In the pre-crash 2013, there was evidence showing the hedging and safe-haven properties of Bitcoin. Nevertheless, in the post-crash period, Bitcoin only serves as a diversifier. Moreover, there is empirical evidence showing hedging effectiveness of Bitcoin against the stock when the risk of stock return is measured by the implied volatility index. On a broader note, studies like Bouri et al. (2017c) analysed hedging property of Bitcoin against global uncertainty. They measured global uncertainty using implied volatility index that is created from fourteen emerging and developed stock markets. Their findings showed that Bitcoin does act as a hedge against global uncertainty.

All in all, gold has not found to play a major role in diversification in emerging stock markets. In other words, gold does not act as a good hedge or safe-haven asset for emerging stock. To achieve the benefits from international portfolio diversification, alternative safe-haven assets for emerging stock markets are required to be examined. Existing literature provides us reasons to expect that cryptocurrency can be a better safe-haven asset for emerging stocks. Furthermore, it is discernible from the literature mentioned above that many existing studies focused on either Bitcoin or gold as a single diversifier, hedge or safe-haven asset against the stock. Hence, a comparative study of old and new assets is needed. Furthermore, it is vital to focus on emerging markets which do have idiosyncratic characteristics and as the studies on the role of gold as safe-haven suggest, there is a contrast between emerging and developed markets. The nexus between cryptocurrencies and the stock market as well as precious metals such as gold is vital when it comes the question of diversification (Huynh et al. (2020a) and Huang and Kilic (2019)). Concomitantly, investigation of the

interconnection amongst gold, cryptocurrency and stock is intriguing. Especially, the movements in precious metals' prices could be considered as the sources of economic uncertainties, which stimulates the potential shocks in stock markets (Huynh, 2020). Last but not least, the techniques often used by the studies acknowledged above considered that correlation changes as discrete events. Modelling these techniques to determine the dependency of financial assets during extreme markets (bullish or bearish) is not appropriate. From this perspective, the Autoregressive Distributed Lag (ARDL) and Nonlinear ARDL models are more suitable for analysis on the subject.<sup>3</sup> To comprehend asymmetries, the nonlinear ARDL model offers insight into the correlations in different market conditions.

### 3. Data & methodology

#### 3.1. Data

This study examines asymmetric correlations and hedging effectiveness of gold and cryptocurrencies for the Thai stock market. Interest in the subject market stems from Thailand's development journey based on rapid industrialisation with significant economic growth over the last few decades, characterised by its more volatile records in the recent past (Wadud and Ahmed, 2016). In particular, we attempt to investigate the effects of global assets on the various stock market conditions, to further understand the benefits of international portfolio diversification. The Asian crisis brought a sudden cessation in Thailand's economic growth in the late 1990s. The country suffered from large declines in output and then succumbed to a regime with increased uncertainties in the new millennium. These uncertainties were stemming from global events and recessions as well as Thailand's own changing domestic scenarios.<sup>4</sup> Stock Exchange of Thailand (SET) has been widely recognised as the main emerging market in Southeast Asia. The SET has shown remarkable development, despite domestic instability and global uncertainty. It also continues to be an attractive investment venue for local and foreign investors. Capital inflows to the stock market have been continuously increasing after financial liberalisation in 1992. In 2019, SET was considered the highest market capitalisation of newly listed companies in Southeast Asia (the stock exchange of Thailand, 2019). The World Federation of Exchanges (2018) ranked SET amongst the world top 10 largest returns market, 21st biggest in terms of the number of listed companies, 23rd largest market by capitalisation and 23rd largest by value traded. As far as we know, the study on hedging and safe-haven assets has received very little attention in the context of the Thai stock market. Therefore, the subject study will address this caveat in the existing body of knowledge by drawing on recent data, old, and new assets classes which will provide the basis for further research in other emerging stock markets.

We use the daily closing price of the Thai stock market index and gold price of the London Bullion Market Association (LBMA). The data covers the period from 2000 to 2019. Daily data of Bitcoin covers the period of 2013 to 2019. All data is taken from the Thomson Reuters DataStream database.

Table 1 shows descriptive statistics of the return on assets, with return measured as the difference in the log of prices. Bitcoin is found to be the riskiest asset, which has the largest fluctuations, compared to the Thai stock market and gold. The value of the gold return is less volatile than the stock market return, indicating that gold is the least volatile

<sup>3</sup> Recent studies, for instance, Bahmani-Oskooee and Nasir (2020) and Bahmani-Oskooee et al., (2020) have jointly employed ARDL and Nonlinear ARDL models.

<sup>4</sup> Since the introduction of Thailand's constitutional monarchy in 1932, Thailand experienced 26 general elections and 19 coups, including 12 successful. To-date, Thailand has had the highest number of coup attempts than almost any other country in the world.

<sup>2</sup> Cryptocurrencies are virtual or digital currencies that use cryptography for security.

**Table 1**  
Descriptive statistics.

	Stock	Gold	Bitcoin
Mean	0.024	0.032	0.224
Median	0.000	0.015	0.000
Maximum	10.577	6.865	33.558
Minimum	-16.063	-10.162	-26.891
Std. Dev.	1.253	1.064	4.942
Skewness	-0.753	-0.372	0.077
Kurtosis	14.450	9.272	10.408
Jarque-Bera	28,484.430	8669.268	3982.207
Probability	0.000	0.000	0.000
Correlation	1.000	-0.028	-0.006

Note. The total number of daily stock and gold returns are 5126 observations and for Bitcoin 1741.

asset. Positive skewness value is found for Bitcoin, while negative skewness is observed in the cases of stock and gold returns. The fat tails in return distributions are demonstrated by high kurtosis statistics for all asset returns. In the stock market, the leptokurtic phenomenon is more apparent than in gold and Bitcoin. Jarque-Bera statistic test results indicate that asset return distributions are non-normal. Lastly, the results from Pearson linear correlation show negative values in both cases of stock/gold and stock/Bitcoin returns which preliminarily indicate that gold and Bitcoin have a potential for risk hedging for Thai stock market.

### 3.2. Identifying market phases

Figs. 1 displays the return series of the Thai stock market. We follow the procedure of Pagan and Sossounov (2003) and Yaya and Gil-Alana (2014) for splitting the series into phases of bull and bear. It is introduced as follows:

- (1a) The initial turning points in raw data will be determined by local peaks (troughs) as the ones that occur when they are the highest (lowest) values on either side of the date in eight months.
- (1b) Turn alternation will be identified by choosing the highest of multiple peaks (or the lowest of multiple troughs).
- (2a) Turns between the start and end of the series within six months will be eliminated.
- (2b) Peaks (or troughs), which are lower or higher at both ends of the series, will be eliminated.
- (2c) Cycles which take less than sixteen months to complete will be eliminated.
- (2d) Phases that are less than four months in length (unless fall or rise exceeds twenty per cent) will be eliminated.

These measures define the final turning points (peaks and troughs) and establish the periods of bulls and bears accordingly. Table 2 indicates the dates of each time period. We obtain fifteen phases for Thailand. Starting and ending points are taken as troughs and the time

**Table 2**  
Bull and bear market phases.

Market Phase	Period
Bear	4/1/2000 - 11/10/2000
Bull	12/10/2000 - 12/1/2004
Bear	13/1/2004 - 17/5/2004
Bull	18/5/2004 - 29/10/2007
Bear	30/10/2007 - 29/10/2008
Bull	30/10/2008 - 1/8/2011
Bear	2/8/2011 - 4/10/2011
Bull	5/10/2011 - 21/5/2013
Bear	22/5/2013 - 3/1/2014
Bull	4/1/2014 - 13/2/2015
Bear	14/2/2015 - 7/1/2016
Bull	8/1/2016 - 24/1/2018
Bear	25/1/2018 - 27/12/2018
Bull	28/12/2018 - 1/7/2019
Bear	2/7/2019 - 31/12/2019

**Table 3**  
ADF & PP Unit Root Testing.

Variables	Augmented Dickey-Fuller Level (P-Value)	1st Difference (P-Value)
Stock	-19.8014(0.0000)	-37.1304(0.0000)
Gold	-73.3287(0.0001)	-36.5318(0.0000)
Bitcoin	-16.6171(0.0000)	-21.3302(0.0000)

  

	Phillips-Perron Level (P-Value)	1st Difference (P-Value)
Stock	-70.2611(0.0001)	-918.4026(0.0001)
Gold	-73.3257(0.0001)	-908.2437(0.0001)
Bitcoin	-41.5212(0.0000)	-465.2058(0.0001)

plots confirm that. Currently, the stock market remains in its bearish state. We found that the longest market phase is in bull phase whereas the shortest period has been found in the bear phase.

### 3.3. An autoregressive distributed lag (ARDL) model

The traditional econometric approaches, such as Vector Autoregression (VAR) model or the co-integration treatments, cannot deal with the issue of a different order of integration. Unlike previous studies that have used VAR or cointegration techniques, we adopted an autoregressive distributed lag (ARDL) model and bounds testing approach based on the seminal work of Pesaran et al. (2001). The ARDL model has a major advantage of allowing us to deal with data that have different orders of integration, which are usually present when a structural breaks problem occurs. Another major issue is the endogeneity i.e. when there is a correlation between the explanatory variable and the error term. Unobserved heterogeneity or omitted variables, in a broad sense, can cause endogeneity. Endogeneity issue



Figs. 1. Time series plot of the daily Thai stock market index (2000–2019).



has gained growing interest amongst academics. Effectively addressing endogeneity issues and using adequate estimation techniques are important to have reliable results (Ullah et al., 2020). In this regard, Pesaran and Shin (1999) stated that if the ARDL model is free of residual correlation, endogeneity is less of a problem. Our results from the diagnostic test, the LM statistics do not indicate autocorrelation in the error term as reported in Tables 4, 5, 8, and 9. Therefore, endogeneity is not a problem for our model. Nonetheless, Pesaran and Shin (1999) have also mentioned that both serial correlation and endogeneity issues are corrected by the appropriate lag order in the ARDL model. The ARDL model can be specified as follows:

$$y_t = \alpha + \sum_{i=1}^p \gamma_i y_{t-i} + \sum_{j=1}^k \sum_{i=0}^{q_j} X_{j,t-i} \beta_{j,i} + \varepsilon_t \quad (1)$$

An ARDL is a least-squares (LS) regression that includes lags of the dependant variable and explanatory variables. The current value of the stock market return is represented by  $y_t$ , where its number of lags is represented by  $p$ ; past values of stock market return, current and past values of gold and Bitcoin returns are represented by  $X_j$ , where the number of lags of past values of stock market return is represented by  $q_j$ ; and the number of lags of current and past values of gold and Bitcoin returns is represented by  $q_k$ . Some of the explanatory variables in the model may skip lagged terms ( $q_j = 0$ ). Those variables are called fixed or static regressors. The explanatory variables are called dynamic regressors, with at least one lagged term. In our analysis, past values of stock market return, current and past values of explanatory variables (gold return, Bitcoin return) function as dynamic regressors of the current value of the stock market return.

### 3.4. Bounds test for co-integration

#### Long-run relationship

The dynamic relationship between the dependant variable and explanatory variables can be estimated by an ARDL model, and it can be transformed into a long-run representation (Pesaran et al., 2001) as follows:

$$\theta_j = \sum_{i=1}^j \beta_{j,i}^{\wedge} / 1 - \sum_{i=1}^p \gamma_i \quad (2)$$

$\theta_j$  estimates long-run coefficients, indicating the long-run response of the dependant variable to a change in explanatory variables.

#### Co-Integrating Relationship

It is postulated by Pesaran and Shin (1999) that the ARDL models can estimate co-integrating systems without the need to pre-specify  $I(0)$  or  $I(1)$  where the variables can be either  $I(0)$  or  $I(1)$ . Unlike other methods of estimating co-integrating relationships, the ARDL representation does not need lag-length symmetry. Thus, there can be a different number of lags for each variable. By transforming Eq. (1) to differences, and substituting long-run coefficients from Eq. (2), co-integrating regression of the ARDL model is specified as follows:

$$\Delta y_t = - \sum_{i=1}^{p-1} \gamma_{i*} \Delta y_{t-i} + \sum_{j=1}^k \sum_{i=0}^{q_j-1} \Delta X_{j,t-i} \beta_{j,i*} - \varnothing^{\wedge} EC_{t-1} + \varepsilon_t \quad (3)$$

where

$$EC_t = y_t - \alpha - \sum_{j=1}^k X_{j,t} \theta_j^{\wedge}$$

$$\varnothing^{\wedge} = 1 - \sum_{i=1}^p \gamma_i^{\wedge}$$

$$\gamma_{i*} = \sum_{m=i+1}^p \gamma_m^{\wedge}$$

$$\beta_{j,i*} = \sum_{m=0}^{q_j} \beta_{j,m}^{\wedge}$$

Standard error of the coefficients of cointegrating relationship is represented by  $\varepsilon_t$  and it can be measured from the standard errors of original regression using the delta method (Pesaran and Shin, 1999).

### 3.5. Nonlinear ardl model

Even though, the ARDL model proposed by Pesaran et al. (2001) is more flexible than other methods a linear adjustment process is required; that is, positive and negative returns of gold/Bitcoin have symmetrical effects on the stock market. The adjustment mechanism, however, may be nonlinear where the stock market reacts differently to both positive and negative returns. A nonlinear ARDL (NARDL) model, which is an asymmetric extension of linear ARDL model, was recently developed by Shin et al. (2013). We follow Shin et al. (2013) to apply the NARDL model, and consider this asymmetrical long-run regression:

$$y = \alpha_0 + \delta^+ q_t^+ + \delta^- q_t^- + \alpha_1 x_1 + \zeta_t \quad (4)$$

where the long-run parameters related to positive and negative returns are  $\delta^+$  and  $\delta^-$ .  $q_t$  is decomposed as

$$q_t = q_0 + q_t^+ + q_t^- \quad (5)$$

where the initial value is  $q_0$ , and the partial sum processes of positive and negative changes in  $q_t$  are  $q_t^+$  and  $q_t^-$ , defined as:

$$q_t^+ = \sum_{j=1}^t \Delta q_j^+ = \sum_{j=1}^t \max(\Delta q_j, 0)$$

$$q_t^- = \sum_{j=1}^t \Delta q_j^- = \sum_{j=1}^t \min(\Delta q_j, 0)$$

$q_t^+$  and  $q_t^-$  are applied to replace  $q_t$  around a single threshold value of zero. This allows differentiation of positive and negative changes in  $q_t$ . For this zero-threshold value, Shin et al. (2013) argue that 'in a wide variety of applications, the resulting partial sum processes maintain an intuitive and economically significant interpretation.' We follow the work of Shin et al. (2013), Bahmani-Oskooee and Fariditavana (2015, 2016) and most recently Nasir et al. (2020a, 2020b) to employ the NARDL model for our analysis.  $q_t$  in the linear ARDL model in Eq. (1) is replaced by  $q_t^+$  and  $q_t^-$  as follows:

$$\Delta y_t = \gamma_0 + \sum_{j=1}^k \gamma_{1j} \Delta y_{t-j} + \sum_{j=0}^p \gamma_{2j} + \Delta x_{t-j}^+ + \sum_{j=0}^n \gamma_{3j}^- \Delta x_{t-j}^- + \rho_0 y_{t-1} + n^+ x_{t-1}^+ + n^- x_{t-1}^- + \omega_t \quad (6)$$

The null hypotheses  $\delta^+ = \delta^-$ , where  $\delta^+ = -\eta^+ / \rho_0$  and  $\delta^- = -\eta^- / \rho_0$  evaluate long-run symmetry. The relevant null hypothesis of  $\sum_{j=0}^p \gamma_{2j}^+ = \sum_{j=0}^n \gamma_{3j}^-$  tests short-run additive symmetry. Hence,  $\gamma_{2j}^+$  and  $\gamma_{3j}^-$  capture the short-run adjustments to positive and negative returns.

## 4. Empirical results

### 4.1. The linear ardl model

The stationary existence of the variables is tested before conducting the ARDL model to exclude the potential for  $I(2)$  variables. This is because the presence of  $I(2)$  variables incur unreliability of the model. We applied two unit root tests i.e. the Augmented Dickey-Fuller test (Dickey and Fuller 1979, ADF) and the Phillips and Perron test (1988, PP). Table 3 reports the results of unit root tests, revealing that none of the variables is  $I(2)$ . All three variables are stationary at level. Therefore, we proceed to apply the ARDL model.

To examine the connections between stock/gold and stock/Bitcoin returns under different market conditions, the entire period is divided into fifteen sub-periods according to bearish and bullish phases. Thereafter, we run the linear ARDL model for each period on differencing the logarithms of prices. A maximum of eight lags are imposed on each variable, and the optimum number of lags is chosen by AIC (Akaike Information Criterion). Table 4 demonstrates the results of stock and gold short-run coefficient estimates, suggesting that the gold

**Table 4**  
Linear ARDL model: Stock and gold short-run coefficient estimates.

Stock/Gold	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull
Stock-1	0.021(0.281)	0.072(2.099)**	-0.028(-0.258)	-0.105(-3.195)*	0.024(0.387)	-0.008(-0.203)	0.110(0.730)	0.006(0.123)	0.040(0.269)	0.023(0.524)
Stock-2	0.126(1.780)***	0.058(1.675)***	0.129(1.198)	0.155(4.118)*	0.025(0.390)	0.075(1.817)***	-0.163(-1.095)	-0.110(-2.452)**	-0.244(-1.614)	0.056(1.265)
Stock-3	-0.068(-0.957)	-0.042(-0.594)	-0.182(-1.722)***		0.013(0.201)	0.062(1.507)	0.266(1.734)**	-0.210(-4.727)*	0.266(1.734)**	-0.069(-1.551)
Stock-4	0.162(2.328)**	-0.097(-1.401)			0.197(3.071)*		-0.238(-1.334)	0.046(1.104)	0.376(1.837)***	-0.125(-3.026)*
Stock-5	-0.097(-1.401)	-0.230(-3.396)*								
Stock-6	-0.127(1.855)***									
Stock-7	0.136(1.008)	-0.079(-1.403)	0.368(1.993)**	0.121(3.228)*	-0.100(-1.573)	0.043(1.036)	0.417(3.087)*	0.137(3.713)*		
Stock-8	0.107(1.892)***	0.021(0.363)		0.155(4.118)*						
Gold-1										
Gold-2										
Gold-3		-0.081(-1.430)								
Gold-4		-0.135(-2.389)**								
Gold-5		-0.045(-0.799)								
Gold-6		0.108(1.912)***								
Gold-7										
Gold-8										
<b>Diagnostic tests</b>										
LM test	0.425	1.784	0.154	0.048	0.004	14.748	0.396	3.382		
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable		
CUSUMQ	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable		
Stock/Gold	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull
Stock-1	0.025(0.321)	0.060(1.018)	-0.017(-0.257)	0.029(0.631)	-0.016(-0.224)	0.065(0.655)	-0.096(-1.019)			
Stock-2				-0.030(-0.645)						
Stock-3				-0.003(-0.072)						
Stock-4				-0.110(-2.400)**						
Stock-5										
Stock-6										
Stock-7										
Stock-8										
Gold	0.037(0.412)	0.034(0.673)	-0.114(-1.739)***	-0.065(-1.718)**	0.031(0.356)	0.044(0.566)	-0.187(-2.219)**			
Gold-1				0.081(2.133)**	0.169(1.960)**	-0.003(-0.043)				
Gold-2						-0.015(-0.190)				
Gold-3						0.041(0.528)				
Gold-4						0.174(2.122)**				
Gold-5						0.172(2.169)**				
Gold-6						-0.136(-1.665)***				
Gold-7										
Gold-8										
<b>Diagnostic tests</b>										
LM test	0.850	0.018	0.016	0.963	2.345	5.259	2.713			
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable			
CUSUMQ	Stable	Stable	Stable	Stable	Stable	Stable	Stable			

The 1, 5, and 10% significance levels are indicated by \*, \*\*, and \*\*\*, respectively. The values of t-test are numbers in parentheses. LM test is the Lagrange multiplier. CUSUM is the cumulative sum of recursive residuals. CUSUMQ is the cumulative sum of squares of recursive residuals.

**Table 5**  
Linear ARDL model: Stock and Bitcoin short-run coefficient estimates.

Stock/Bitcoin	Bear	Bull	Bear	Bull	Bear	Bull	Bear
Stock-1	0.028(0.377)	0.053(0.908)	-0.020(-0.290)	0.025(0.577)	-0.121(-1.753)***	0.122(1.392)	-0.043(-0.483)
Stock-2			0.013(0.191)		-0.009(-0.123)		
Stock-3			-0.130(-1.939)***		-0.061(-0.753)		
Stock-4			0.101(1.475)				
Stock-5							
Stock-6							
Stock-7							
Stock-8							
Bitcoin	-0.011(-0.800)	0.006(0.675)	-0.005(-0.307)	-0.001(-0.160)	0.038(3.010)*	-0.003(-0.248)	-0.011(-0.860)
Bitcoin-1		0.013(1.477)					
Bitcoin-2							
Bitcoin-3							
Bitcoin-4							
Bitcoin-5							
Bitcoin-6							
Bitcoin-7							
Bitcoin-8							
<b>Diagnostic tests</b>							
LM test	0.371	0.033	0.332	6.216	1.927	1.941	0.804
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable
CUSUMQ	Stable	Stable	Stable	Rather Stable	Stable	Stable	Stable

The 1, 5, and 10% significance levels are indicated by \*, \*\*,\*\*\*, respectively. The values of *t*-test are numbers in parentheses. LM test is the Lagrange multiplier. CUSUM is the cumulative sum of recursive residuals. CUSUMQ is the cumulative sum of squares of recursive residuals.

return has significant short-run effects on stock market return in most cases. However, the roles of gold tend to be insignificant in bearish markets. The short-run effects of gold on the stock market are not significant during bear phases in the first period from January 2000 to October 2000 and the ninth period from May 2013 to January 2014. We note that gold returns are related to stock returns positively and significantly in most cases. Nonetheless, the effects of gold on the stock market are negative and significant during the bull market from October 2000 to January 2004 and bear market from July 2019 to December 2019. This supports the hedging and safe haven hypothesis of gold. However, negative relations have been found only in two out of fifteen sub-periods considered. It would seem that gold can serve as a weak safe haven against the Thai stock market as negative relation has been found in some bear markets. All in all, the linear ARDL model indicates that a positive (negative) return of gold leads to a positive (negative) return on stocks. In other words, stocks and gold reveal positive relations in most of the time period considered and therefore the results decline the hedging and safe haven properties of gold. Our findings are consistent with [Baur and McDermott \(2010\)](#) who tested a safe haven property of gold for stock concerning different stock market conditions that do not confine to specific crisis periods. Their findings indicated that gold is not a safe haven for extreme levels of global uncertainty proxied by the conditional volatility of a world stock market index. Similarly, [Beckmann et al. \(2015\)](#) concluded that gold serves as a poor safe-haven asset for stock markets in China, Egypt, Korea, South Africa, Turkey and Thailand. Our results are also confirmed the findings by [Bekiros et al. \(2017\)](#) who suggested that gold is neither a hedge nor a safe haven asset for stocks in BRIC markets. This result is not surprising because the accelerated financialization of commodity markets ([Huynh et al., 2020b](#)), including the gold market, has significantly increased investments in gold, making the gold asset

behave more and more like stocks. Our findings are contrary to [Wen and Cheng \(2018\)](#) as they argued that safe haven properties of gold for emerging stock markets exist. However, as the results suggest, gold is not the strongest safe-haven asset against the Thai stock market.

**Table 5** reveals the results of stock and Bitcoin short-run relationship. In most cases, Bitcoin has no significant effect on the stock market. We also find that the relationship between stock and Bitcoin is significantly positive during the bear market from January 2018 to December 2018. The results indicate that Bitcoin does not act as a good hedging and safe-haven asset for stock. However, a low positive coefficient of Bitcoin (0.038) implies that Bitcoin is probably suitable for diversification purpose. Our results are partly verified by [Bouri et al. \(2017a\)](#) who found that Bitcoin can serve as an effective diversifier. They also indicated that a safe haven role of Bitcoin for Asia Pacific stocks has not been found. However, Bitcoin acts as a safe haven asset for stock with weekly data. The daily fluctuations in the price of Bitcoin and its speculative nature seem to undermine Bitcoin's daily safe haven property compare to its weekly safe haven. They argued that the reason that Bitcoin properties vary with time horizons is partly because the hedge and safe haven returns are driven by different factors at different time horizons.

**Tables 4 and 5** report several diagnostic tests. The LM statistics, distributed as  $\chi^2$  with 4 degrees of freedom with a critical value of 9.48, do not indicate autocorrelation in the error term in all the cases, except the case of stocks and gold during the bull market from October 2008 to August 2011. The cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMQ) are used to test for the stability of coefficient estimates ([Brown et al., 1975](#)). Overall, the findings indicate that the coefficients of the variables are stable in all cases.

The Bounds test method is employed to investigate the relationship



**Table 6**  
Linear ARDL model: Bounds test for co-integration analysis: Stock and gold.

Market Phase	F-statistic	Critical Value Bounds		
		Significance	I0 Bound	I1 Bound
Bear	13.116	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	173.971	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	20.552	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	569.014	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	126.256	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	363.459	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	7.108	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	63.443	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	76.687	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	128.848	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	122.806	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	73.313	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	107.687	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	44.490	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	67.332	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840

between variables over the long run. This is completed by performing an F-test for the joint significance of the coefficients of variables related to lagged levels. Co-integration implies that the variables move together, and they do not diverge from the long-run equilibrium. In other words, a short-run phenomenon is any disequilibrium between variables. Table 6 demonstrates the results of the calculated F-statistics from the bounds test for co-integration analysis with unrestricted constant and no trend for all fifteen market phases. The results for the stock market and gold returns show that the F-statistic is above the upper bound critical value and therefore the null hypothesis of no long-run relationship can be rejected in all cases. The results indicate that the stock and gold markets have long-run relationships in both bull and bear market phases. The existence of co-integrating relationships also

**Table 7**  
Linear ARDL model: Bounds test for co-integration analysis: Stock and Bitcoin.

Time Period	F-statistic	Critical Value Bounds		
		Significance	I0 Bound	I1 Bound
Bear	83.181	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	130.376	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	26.363	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	262.214	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	42.101	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bull	50.880	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840
Bear	70.905	10%	4.040	4.780
		5%	4.940	5.730
		1%	6.840	7.840

implies that the nexus amongst the variables has been substantial over the sample period. Table 7 shows the results of Bounds Test for co-integration analysis between stocks and Bitcoin. Long-run relationships between the variables are found in all bull and bear market phases, implying that Bitcoin plays crucial roles in influencing the stock market in the long-run. In the case of stocks and Bitcoin, we now combine the long run with the short-run results. While the findings suggest long-term adjustments, they do not demonstrate a short-term relationship.

Applying the linear ARDL model, in the case of stock and Bitcoin returns we are unable to find a meaningful short-run relation. Nevertheless, the linear assumption introduced in the linear ARDL model may cause the absence of evidence for their connections. Positive and negative shocks of gold price may affect stock market differently where there are asymmetric effects of gold on the stock market. This means that in the following section, the NARDL model is used to distinguish positive and negative returns using the partially positive and negative sums described in Eqs. (4) and (5) and implemented in the NARDL model in Eq. (6).

4.2. The nonlinear ardl model

Similar to the linear ARDL model, we placed a limit of eight lags on each variable to estimate the NARDL model in Eq. (6) and use AIC to choose the optimum number of lags. Tables 8–9 detail the findings of the short-run relations and some diagnostic tests. The results of long-run relations are shown in Tables 10–11. The short-run effects of gold/Bitcoin's positive and negative returns on the stock market are indicated respectively by the significance and sign of  $\gamma_{2j}^+$  and  $\gamma_{3j}^-$ .

The findings in Table 8 demonstrate that in most cases, positive and negative returns of gold affect the stock market significantly in the short run. The null hypothesis of short-run symmetry  $\sum_{j=0}^p \gamma_{2j}^+ = \sum_{j=0}^n \gamma_{3j}^-$  is rejected for most cases suggesting that short-run positive and negative returns of gold have asymmetrical effects on the stock market.

**Table 8**  
Nonlinear ARDL model: Stock and gold short-run coefficient estimates.

Stock/Gold	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull
Stock-1	0.016(0.224)	0.057(1.653)**	-0.029(-0.265)	-0.1107(-3.248)*	0.011(0.180)	-0.003(-0.073)	0.025(0.140)	0.001(-0.025)		
Stock-2	0.138(1.954)**	0.127(1.172)	-0.185(-1.738)**				0.017(0.105)	0.037(0.819)		
Stock-3	-0.069(-0.965)						-0.229(-1.320)	-0.113(-2.527)**		
Stock-4	-0.057(-0.816)						-0.297(-1.676)	0.038(0.857)		
Stock-5	0.159(2.290)**							-0.181(-4.037)*		
Stock-6	-0.095(-1.368)							-0.060(-1.354)		
Stock-7	-0.235(-3.483)*							0.016(0.381)		
Stock-8	0.126(1.840)**							-0.104(-2.517)**		
Gold_POS	-0.004(-0.024)	-0.124(-1.797)**	0.364(1.959)**	-0.002(-0.049)	-0.028(-0.324)	0.034(0.828)	0.539(2.467)**	0.164(2.715)*		
Gold_POS-1	0.343(1.809)**			0.221(4.258)*			-0.490(-1.752)**	-0.024(-0.334)		
Gold_POS-2							0.339(1.140)	0.159(2.454)**		
Gold_POS-3							0.306(1.024)			
Gold_POS-4							-0.448(-1.493)			
Gold_POS-5							0.815(2.521)**			
Gold_POS-6							-0.172(-0.528)			
Gold_POS-7							0.621(2.323)**			
Gold_POS-8										
Gold_NEG	0.343(1.937)**	-0.073(-1.073)	0.370(1.994)**	0.219(4.915)*	-0.205(-2.406)**	0.035(0.836)	0.017(0.064)	0.125(2.300)**		
Gold_NEG-1		0.174(1.940)**			0.112(0.929)		0.782(2.363)**	0.114(1.252)		
Gold_NEG-2		0.015(0.180)			-0.023(-0.222)		-0.205(-0.586)	-0.181(-2.186)**		
Gold_NEG-3		-0.086(-1.028)			-0.084(-0.795)		-0.581(-1.624)	0.189(2.500)**		
Gold_NEG-4		-0.211(-2.534)**			0.301(2.889)*		0.687(1.893)**	0.088(1.318)		
Gold_NEG-5		-0.149(-1.826)**			-0.121(-1.400)		-0.388(-1.069)	-0.102(-1.561)		
Gold_NEG-6		0.205(3.179)*					0.249(0.674)	0.001(0.012)		
Gold_NEG-7							0.372(1.231)	0.183(2.864)*		
Gold_NEG-8							0.577(1.955)**	-0.117(-2.337)**		
<b>Diagnostic tests</b>										
LM test	1.546	1.533	0.142	0.405	0.996	14.641	2.505	0.086		
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable		
CUSUMQ	Stable	Stable	Stable	Rather Stable	Rather Stable	Rather Stable	Stable	Stable		
Stock/Gold	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull		
Stock-1	0.033(0.424)	0.056(0.948)	-0.009(-0.126)	0.023(0.502)	-0.013(-0.193)	0.016(0.165)		-0.127(-1.349)		
Stock-2	-0.052(-0.636)			-0.029(-0.620)						
Stock-3	-0.012(-0.154)			-0.006(-0.138)						
Stock-4	-0.027(-0.326)			-0.110(-2.398)**						
Stock-5	0.242(2.893)*									
Stock-6										
Stock-7										
Stock-8										
Gold_POS	0.097(0.733)	0.032(0.621)	-0.007(-0.071)	-0.134(-2.823)*	-0.076(-0.732)	0.093(0.985)		-0.304(-3.054)*		
Gold_POS-1	-0.273(-1.347)		-0.231(-1.886)**	0.140(2.379)**	0.234(1.657)**					
Gold_POS-2	-0.252(-1.150)									
Gold_POS-3	0.631(2.957)*									
Gold_POS-4	-0.658(-3.805)*									
Gold_POS-5										
Gold_POS-6										
Gold_POS-7										
Gold_POS-8										
Gold_NEG	-0.133(-0.927)	0.033(0.645)	-0.232(-2.353)**	0.006(0.128)	0.158(1.305)	-0.106(-1.132)		-0.039(-0.365)		
Gold_NEG-1	0.170(0.768)		0.204(1.835)**					-0.264(-2.196)**		
Gold_NEG-2	0.271(1.204)		-0.209(-2.193)**							
Gold_NEG-3	-0.902(-4.302)*					0.144(1.313)				

(continued on next page)

Table 8 (continued)

Stock/Gold	Bear	Bull	Bear	Bull	Bear	Bull	Bear	Bull
Gold_NEG-4	0.455(2.842)*							
Gold_NEG-5	-0.316(-2.363)**							
Gold_NEG-6								
Gold_NEG-7								
Gold_NEG-8								
<b>Diagnostic tests</b>								
LM test	0.065	0.030	0.000	1.549	1.694	3.115	0.143	
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable	
CUSUMQ	Stable	Stable	Stable	Rather Stable	Stable	Stable	Stable	

The 1, 5, and 10% significance levels are indicated by \*, \*\*, \*\*\*, respectively. The values of *t*-test are numbers in parentheses. LM test is the Lagrange multiplier. CUSUM is the cumulative sum of recursive residuals. CUSUMQ is the cumulative sum of squares of recursive residuals.

Expectedly, asymmetries are more likely to occur in bear markets compared to bull markets. Although negative asymmetries have been generally found in most cases, bear markets are more sensitive to negative shocks from the gold market than the bulls. We also find that there is a symmetrical effect in the bull market from May 2004 to October 2007. Insignificant effects have been found during bull markets from October 2008 to August 2011 and from January 2014 to February 2015.

Table 9 illustrates the nonlinear short-run coefficient estimates of stocks and Bitcoin. Unexpectedly, the results are not meaningfully different from the linear assumption. Even though negative asymmetry has been found in some cases there are insignificant effects of Bitcoin on stocks in most cases. Negative returns of Bitcoin are more influential in the bear markets than in the bulls. Moreover, diagnostic tests in Tables 8 and 9 indicate no autocorrelation in the error term in all the cases, except the case of stocks and gold during the bull market from October 2008 to August 2011. The stability tests indicate that the coefficients of the variables are stable in all cases.

Having identified evidence of short-run asymmetric effects of gold/Bitcoin's positive and negative returns on stocks, we turn next to examine if those short-run effects last in the long run. For this investigation, the F-test is used to create cointegration amongst the variables. The results in Tables 10 and 11 show that positive and negative returns of gold and Bitcoin do have significant long-run effects on the stocks for all the cases. These results are consistent with the linearity assumption in Section 4.1

Consequently, and contrary to the results from linear ARDL model, we find further evidence of meaningful stock and gold relations by applying nonlinear ARDL model. These asymmetric effects have been found in bear markets (January 2000 – October 2000, May 2013 – January 2014, February 2015 – January 2016, January 2018 – December 2018). Likewise, the nonlinear assumption is significant during the bear market (February 2015 – January 2016) in the cases of stocks and Bitcoin. This suggests that when studying the nexus between financial assets, particularly during turmoil periods, it is important to make a distinction between positive and negative returns (it allows for nonlinearity in the adjustment process). Notably, the results suggest that neither gold nor Bitcoin does act as a safe-haven asset for emerging stocks. Gold can serve as a weak safe-haven against emerging stocks as negative relation has been found in some bear markets. 5. Conclusion

It has been documented in the existing literature that when it comes to gold acting as a safe haven to hedge in stock markets, the relationships between stock and gold differ between emerging and developed markets. The investors need a financial instrument that is expected to retain or even gain value during periods of economic downturn. Such a safe-haven asset, potentially gold, should be uncorrelated or negatively correlated with the performance of macroeconomy which means that it may appreciate in the event of a market crash and economic meltdown. In this context, the subject paper examines hedging and safe haven properties of gold and Bitcoin for stocks using daily data from Thailand. We suggest that the lack of support for gold as a poor safe haven in emerging stock markets may be due to a linear adjustment mechanism which has often been assumed. We relaxed this unrealistic assumption and used both linear and non-linear ARDL models for analyses. If gold cannot be a safe haven or is only a poor safe-haven asset for emerging stocks, it emphasises that alternative safe-haven assets are needed. Considering the investment opportunities which the 4th industrial revolution has brought to us; we also examined hedging and safe haven properties of Bitcoin. We also assessed whether there is the equally hedging potential of gold or cryptocurrency in bearish and bullish markets.

In the light of empirical findings based on linear ARDL model, we conclude that there is no strong evidence of hedging and safe haven properties of gold and Bitcoin for the stock market. There are insignificant effects in some periods for stocks and gold, while insignificant effects have been found in most cases of stocks and Bitcoin. Correlations

**Table 9**  
Nonlinear ARDL model: Stock and Bitcoin short-run coefficient estimates.

Stock/Bitcoin	Bear	Bull	Bear	Bull	Bear	Bull	Bear
Stock-1	0.026(0.343)	0.054(0.911)	-0.047(-0.708)	0.025(0.576)	-0.032(-0.493)	0.119(1.358)	-0.045(-0.508)
Stock-2			0.037(0.565)				
Stock-3			-0.145(-2.198)**				
Stock-4							
Stock-5							
Stock-6							
Stock-7							
Stock-8							
Bitcoin_POS	-0.010(-0.727)	0.013(1.279)	-0.036(-1.709)***	-0.001(-0.161)	-0.001(-0.164)	-0.003(-0.321)	-0.011(-0.864)
Bitcoin_POS-1			0.026(0.852)				
Bitcoin_POS-2			-0.004(-0.124)				
Bitcoin_POS-3			-0.072(-2.319)**				
Bitcoin_POS-4			0.097(4.360)*				
Bitcoin_POS-5							
Bitcoin_POS-6							
Bitcoin_POS-7							
Bitcoin_POS-8							
Bitcoin_NEG	-0.010(-0.696)	-0.005(-0.400)	0.008(0.357)	-0.001(-0.162)	0.042(2.788)*	-0.004(-0.358)	-0.011(-0.910)
Bitcoin_NEG-1		0.018(1.433)	-0.036(-1.070)		-0.042(-2.740)*		
Bitcoin_NEG-2			-0.026(-0.734)				
Bitcoin_NEG-3			0.099(2.886)*				
Bitcoin_NEG-4			-0.033(-1.499)				
Bitcoin_NEG-5							
Bitcoin_NEG-6							
Bitcoin_NEG-7							
Bitcoin_NEG-8							
<b>Diagnostic tests</b>							
LM test	0.490	0.445	0.058	6.246	1.996	1.876	0.627
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable	Stable
CUSUMQ	Stable	Stable	Stable	Rather Stable	Stable	Stable	Stable

The 1, 5, and 10% significance levels are indicated by \*, \*\*,\*\*\*, respectively. The values of *t*-test are numbers in parentheses. LM test is the Lagrange multiplier. CUSUM is the cumulative sum of recursive residuals. CUSUMQ is the cumulative sum of squares of recursive residuals.

between stock/gold and stock/cryptocurrency pairs are found to be positive in most cases. However, gold can serve as a weak safe haven against emerging stocks as negative relation has been found in some bear markets. We were able to find further evidence supporting significant effects between stocks/gold and stocks/Bitcoin when the nonlinear ARDL model was applied. Expectedly, asymmetric effects are more likely to occur in bear markets compared to bull markets. Although negative asymmetries have been generally found in most cases, bear markets are more sensitive to negative shocks from the gold market than the bulls. This suggests that when studying the nexus between financial assets, particularly during turmoil periods, it is important to differentiate between positive and negative returns (it allows for nonlinearity in the adjustment process). We also conclude that positive and negative returns of gold and Bitcoin do have significant long-run effects on the stocks for all the cases. In contrast to the existing literature, mostly focusing on the developed markets, our results lead us to conclude that neither gold nor Bitcoin act as a good instrument for hedging in the emerging stock market. Hence, the issue of having safe-haven assets for investing in emerging stock markets remains unresolved in the age of 4th industrial revolution and cryptocurrencies.

To mitigate excessive risk, optimal portfolio allocation has to be

established by investors and fund managers. In the policy context, our findings imply that adding gold or Bitcoin to a stock portfolio does not enhance its risk-adjusted returns. The existence of convergence between the prices of stock, gold, and cryptocurrency, as well as their asymmetric relations, can be useful for forecasting purposes, economic modelling and policy formulation. The findings are useful to market participants and policymakers in understanding the role of gold and cryptocurrency in the stock market. They can consider the improvement of financial stability caused by global assets to implement their diversification strategies. Regulatory policies for stock market development should be reviewed regularly to investigate their effectiveness, to ensure the stock market remains efficient and risks are eliminated where possible. There are some limitations of the subject study which used stock market index and hence the composition of the index may potentially impact the results. For instance, if there are too many natural resource firms in the index, the observed difference in the relationship between gold and stock prices might have been found due to the exposure to resources. Although the impact on the results is not clear, it is worth mentioning. A way to resolve this issue in future research could be by using industry-specific indices to explain the role of gold.

**Table 10**  
Nonlinear ARDL model: Bounds test for co-integration analysis: Stock and gold.

Market Phase	F-statistic	Critical Value Bounds		
		Significance	10 Bound	11 Bound
Bear	9.770	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	253.139	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	13.647	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	379.963	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	82.582	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	240.823	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	6.478	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	41.286	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	7.774	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	86.292	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	77.350	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	50.040	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	70.803	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	35.995	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	47.743	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360

**Table 11**  
Nonlinear ARDL model: Bounds test for co-integration analysis: Stock and Bitcoin.

Market Phase	F-statistic	Critical Value Bounds		
		Significance	10 Bound	11 Bound
Bear	55.371	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	86.844	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	32.762	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	174.481	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	85.178	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bull	33.890	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360
Bear	47.313	10%	3.170	4.140
		5%	3.790	4.850
		1%	5.150	6.360

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