Quantitative Easing and Tightening Effects on Volatility Transmission in ASEAN's Emerging Financial Markets

Teera Kiatmanaroch[a]
Ornanong Puarattanaarunkorn[b]
Khon Kaen University

Abstract: This study examines the volatility transmission among four emerging financial markets in the ASEAN region, comprising Thailand, Malaysia, Indonesia and the Philippines, during quantitative easing (QE) and quantitative tightening (QT) policies. A copula-based GARCH model is used to investigate the relationship among the volatility of stock market returns in these four countries and to explore the relationship among their exchange rate returns. Daily data were divided into two periods: the QE period covered 23/3/2020–15/3/2022, and the QT period covered 16/3/2022–13/2/2023. The findings show the relationship among the volatility of stock market returns across four countries, revealing that upper-tail dependence is more prominent during periods of QE than QT. Furthermore, the volatility of exchange rate returns across countries tends to correlate more during periods of QT. This study provides empirical evidence of integration among the financial markets of the four countries, and findings that are valuable for portfolio management. Investors seeking yields in ASEAN's emerging financial markets should closely monitor the Federal Reserve's monetary policy, particularly during periods of QT, which pose a higher risk of unexpected negative returns.

Keywords: ASEAN stock market, copula, exchange rate, GARCH, volatility transmission
JEL classification: C22, C58, G15

1. Introduction

In March 2020, the US Federal Reserve (FED) adopted an unconventional monetary policy measure called quantitative easing (QE) to mitigate the economic effects of the COVID-19 pandemic. Subsequently, in 2022, the FED transitioned to quantitative tightening (QT) to address inflation. These policies significantly impacted global stock markets (Beirne et al., 2020; Canuto, 2022; World Bank Group, 2020). The QE policy created liquidity in international financial markets, instilled confidence among investors, and stimulated investments in stock markets. Both advanced and emerging economies benefited from capital inflows (Beirne et al., 2020; Cortes et al., 2022). Conversely, the QT policy reduced the liquidity of the US dollar in the global economy and led

[a] Department of Agricultural Economics, Khon Kaen University, Khon Kaen, 40002, Thailand. E-mail: teera@kku.ac.th
[b] Faculty of Economics, Khon Kaen University, Khon Kaen, 40002, Thailand. E-mail: pornan@kku.ac.th (Corresponding author)
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to the appreciation of the US dollar (International Monetary Fund, 2022). The FED's ongoing tightening of monetary policy, marked by incremental interest rate hikes, has adversely affected emerging markets and developing economies (EMDEs), leading to currency depreciation against the US dollar, and a reduction in domestic consumption and investment. Additionally, it has influenced stock market investments, resulting in lower equity prices (Arteta et al., 2022). The changing monetary policies of the US can considerably impact economies, currency exchange markets, and stock market investments in emerging markets and other nations.

The FED's implementation of QE and QT policies impacted global financial markets and currency valuations through several mechanisms. QE, characterised by central banks increasing money supply through large-scale asset purchases, typically leads to lower interest rates, increased liquidity, and often results in higher stock prices and weaker domestic currencies, with the dollar depreciating. Conversely, QT, involving the reduction of money supply, generally results in tighter monetary conditions or higher interest rates, potentially leading to lower stock market valuations and stronger domestic currencies, with the dollar appreciating.

The MSCI index, developed by Morgan Stanley Capital International (MSCI) to reveal the performance of diverse stock markets across different periods provides information that guides stock market investments and portfolio management. Figure 1 shows the MSCI Price Index in US Dollars (closing price) for MSCI World, MSCI Emerging Markets, and MSCI Frontier Markets from January 2016 to February 24, 2023. It covers the performance of each market group during the period marked by the FED's implementation of both QE and QT measures. Specifically, from October 2017 to August 2019, the FED implemented QT measures following the completion of the QE3 program (Smith & Valcarcel, 2023). Following the COVID-19 pandemic crisis, an unlimited QE measure was introduced on March 23, 2020, to tackle the economic downturn (Rebucci et al., 2022). As the crisis eased, the FED initiated QT measures, raising the policy rate by 0.25% in March 2022, with plans for subsequent interest rate hikes to address domestic inflation concerns (Arteta et al., 2022). Figure 1 shows that the announcement of the unlimited QE policy substantially increases investments across all market groups. Conversely, during the QT policy periods, the price index of Emerging and Frontier markets demonstrated a downward trend. Arteta et al. (2022) observed that Emerging and Developing Economies (EMDEs) were affected by an increase in the US interest rates after March 2022. This resulted in a decrease in the stock market index and currency depreciation in each country.

Figures 2 and 3 show the stock market indices and exchange rate data of four emerging market countries in ASEAN, comprising Thailand, Malaysia, Indonesia and the Philippines, during the period from March 2020 to February 2023, respectively. Figure 2 displays daily closing prices for stock market indices in these four countries, showing a decline before March 23, 2020. This decline was influenced by the World Health Organization's (WHO) declaration of the COVID-19 situation on March 11, 2020, which led to a worldwide economic slowdown (ASEAN, 2020). The FED's announcement of unlimited QE on March 23, 2020 (Rebucci et al., 2022) was followed by an immediate rise in all stock market indices. This reaction reflected the impact of the FED's policy on investments, despite the ongoing challenges posed by the COVID-19 pandemic.

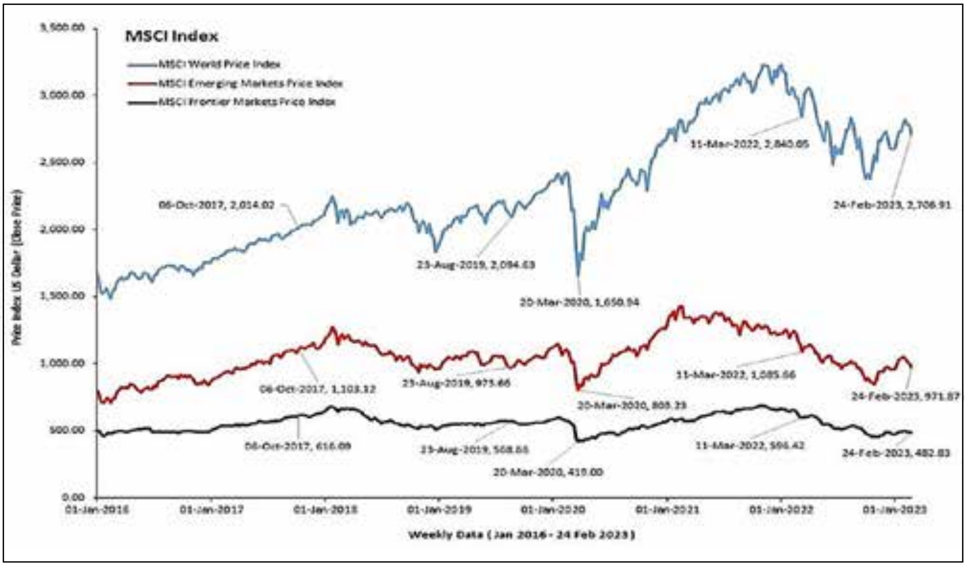

Figure 1. MSCI price index in US dollars (January 2016 to February 2023)
Source(s): Authors.

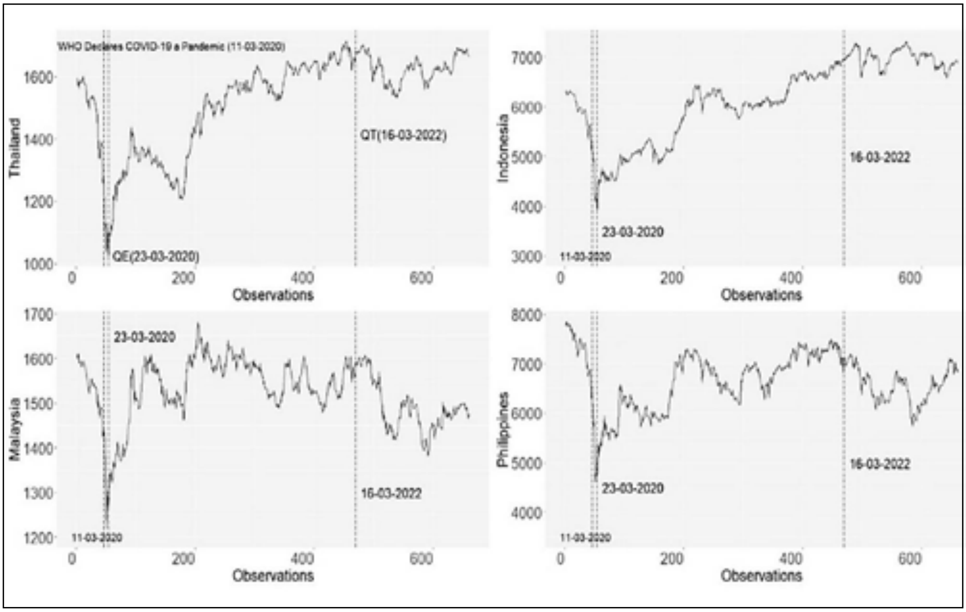

Figure 2. Stock market indices of ASEAN emerging markets
Source(s): Authors.

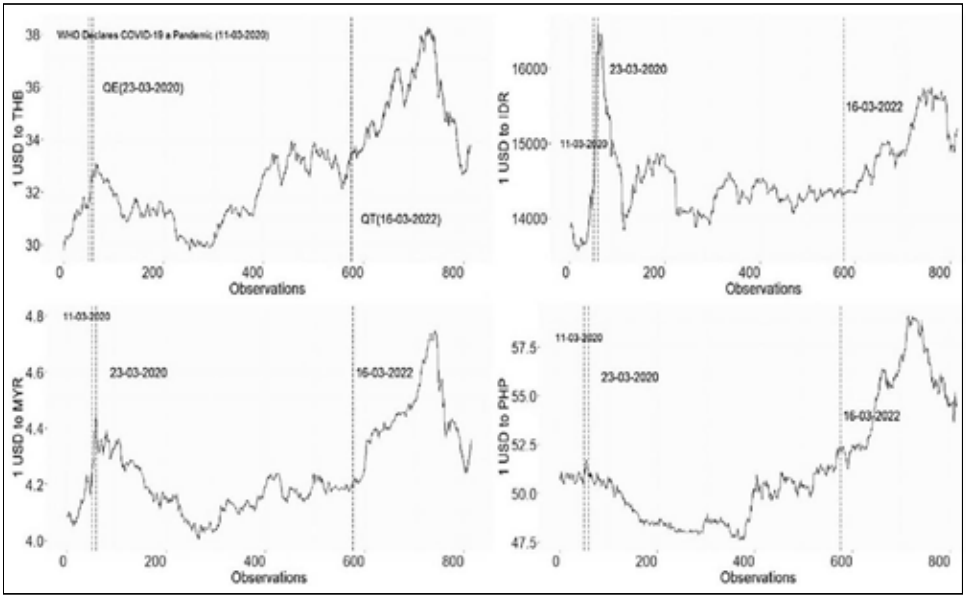

Figure 3. Exchange rates of ASEAN emerging markets
Source(s): Authors.

The plan to increase the policy rate was announced on March 16, 2022. Subsequently, fluctuations, including both increases and decreases, were observed in the stock market indices of Thailand, Malaysia, Indonesia and the Philippines. However, over the period from March 16, 2022 to February 13, 2023, these indices did not consistently show an upward trend.

Figure 3 shows daily exchange rates for Thailand (one US dollar to Thai baht [THB]), Malaysia (one US dollar to Malaysian ringgit [MYR]), Indonesia (one US dollar to Indonesian rupiah [IDR]), and the Philippines (one US dollar to Philippine peso [PHP]). Following the announcement of the unlimited QE policy, all four currencies immediately appreciated against the US dollar. Subsequently, after the FED's interest rate hike policy announcement, these currencies promptly depreciated against the US dollar.

From the above discussion, the implementation of QE and QT policies by the Fed evidently affected the financial markets of emerging ASEAN countries. Therefore, this study explores the volatility transmission among emerging financial markets in the ASEAN region during the QE and QT policy periods. Specifically, it investigates the stock and foreign exchange market relationships among four emerging market economies in ASEAN (Thailand, Malaysia, Indonesia and the Philippines), based on the MSCI All Country World Index (MSCI ACWI Index) market allocation (MSCI, 2023). Daily data from both the stock and exchange rate markets were used. We divided the data into two periods: The first period spans from March 2020 to March 2022, coinciding with the QE policy, while the second period covers March 2022 to February 2023 and corresponds to the QT policy. A copula-based Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) model was employed to analyse these relationships.

This study highlights several key findings regarding stock market volatility in the four countries during these two periods. First, the relationship among volatilities varies between periods. During the QE period, all four markets showed a positive relationship in terms of volatility, with most market pairs showing a stronger relationship in the upper tail than in the lower tail. Significantly, during the QE period, the upside risk relationships among certain market pairs were stronger than the downside risk relationships. During the QT period, the stock market volatility in all four markets shows a consistent directional change. Significantly, for market pairs, such as Thailand-Malaysia, Thailand-Indonesia, Thailand-Philippines and Malaysia-Indonesia, the upper tail dependence (τ_U) decreases while the lower tail dependence (τ_L) increases compared to the QE period. This indicates that during the QT period, investors in these markets collectively face increased exposure to downside risk compared with the QE period. Therefore, when comparing periods with substantial dollar liquidity and QE measures with periods with QT measures, investors must concentrate on dealing with uncertain negative returns. Consequently, the insights from this study are valuable for making investment decisions in each market and effectively managing investment portfolios.

Second, regarding the exchange rate relationship across all four countries, during the implementation of the FED's QT policy, the volatility in exchange rate changes between Thailand-Malaysia, Thailand-Indonesia, Thailand-Philippines, Malaysia-Indonesia, Malaysia-Philippines and Indonesia-Philippines showed a consistent directional shift. Moreover, the level of correlation increased compared to the QE policy period, suggesting a trend of closer alignment in capital movement volatility among countries during the QT policy. This underscores the importance of investors closely monitoring the direction and alignment during this period.

This study stands out from prior research by analysing both periods of QE and QT policies. It reveals the distinct impacts on the relationships among ASEAN emerging economies' stock markets and the exchange rate relationships for each country under both QE and QT regimes. These findings will be beneficial to investors in managing their investment risks in each country. When dollar liquidity in the market decreases due to the FED's QT policy, investors who diversify their investments into various stock markets must be cautious, as they face the simultaneous occurrence of two events: the depreciation of each country's currency and the challenge of uncertain negative returns in stock market investments.

The remainder of this paper is organised as follows: Section 2 reviews the relevant literature on financial integration and volatility transmission in ASEAN and non-ASEAN markets. Section 3 describes the methodology used, including the ARMA-GARCH model and copula model. Section 4 details the data used in this research. Section 5 presents and analyses the results, and discusses the findings. Finally, Section 6 concludes the research.

2. Literature Review

Financial market integration has become a significant phenomenon in the global economy with markets moving together worldwide. Patel et al. (2022) explored financial market integration in which markets move together and exhibit similar behaviour in risk-adjusted returns. This concept encompasses various market types such as bonds, commodities, stocks and foreign exchange, along with phenomena such as volatility transmission and contagion effects during crises. Chai and Rhee (2005) highlighted that the conditions for financial integration require free movement of capital and integrated financial services, while Click and Plummer (2005) illustrated the advantages of regional stock market integration for external investors, including enhanced convenience, reduced transaction costs and increased liquidity. However, such an integration may also lead to correlated movements, potentially reducing the diversification benefits for investors outside the region.

In the ASEAN region, various aspects of the relationship between different markets have been studied, particularly exchange rates and stock markets. Rufino (2018) and Jantarakolica and Jantarakolica (2018) found evidence of exchange rate integration among ASEAN countries. Rufino (2018) employed pairwise Granger causality to analyse exchange rate relationships among seven countries (Brunei Darussalam, Indonesia, Japan, Korea, the Philippines, Singapore and Thailand), revealing dependencies between currency pairs. Jantarakolica and Jantarakolica (2018) used CCC-MGARCH to study exchange rate volatility among Malaysia, Singapore and Thailand, revealing evidence of integration between Thailand-Singapore, Thailand-Malaysia and Singapore-Malaysia exchange rates. Similarly, Shahrier (2022) detected ASEAN-5 exchange rate co-integration during the COVID-19 pandemic through vector error correction model (VECM), revealing interdependence among Indonesia, Malaysia, the Philippines, Singapore and Thailand. Collectively, these findings offer evidence of exchange rate integration among ASEAN member countries.

Research on stock market integration in the ASEAN region has yielded mixed results. Click and Plummer (2005) analysed data from five major ASEAN stock indices and concluded that while the stock markets in Malaysia, the Philippines, Singapore and Thailand exhibit integration, it remains partial. Using the monthly closing prices of ASEAN stock indices and non-ASEAN markets, Janor and Ali (2007) found that, while some ASEAN markets are integrated, others are linked to non-ASEAN markets. However, the study noted that complete integration is hindered by factors, such as national borders. Both studies provide evidence of stock market integration but suggest that it remains incomplete.

Furthermore, previous studies have examined volatility transmission across ASEAN stock markets using advanced models such as GARCH and copula to analyse volatility dynamics and dependence structures. Sriboonchitta et al. (2014) used daily data from the stock markets of Indonesia, the Philippines, and Thailand, and revealed that market pairs, such as Indonesia-Philippines, Indonesia-Thailand and Philippines-Thailand, exhibited co-movement and tail dependence. Duong and Huynh (2020) used weekly data from the stock markets of Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam, and showed that all market pairs exhibited dependence, with the relationship between Vietnam and the other markets being relatively weak. Furthermore, Pongkongkaew et al. (2020) discovered dynamic co-movement in the stock markets of the five countries − Indonesia, Malaysia, the Philippines, Singapore and Thailand. These studies consistently found evidence of volatility transmissions across stock markets in the ASEAN region, and noted significant global events that affected financial markets during their observation periods. Similarly, Mulaahmetovic (2022) discussed various events during the global financial crisis (2007–2008) and noted that quantitative easing measures by the FED significantly impacted on global financial markets. This observation highlights the importance of considering external factors and monetary policies when studying financial market integration in the ASEAN region.

This literature review reveals substantial evidence of financial market integration in the ASEAN region, particularly in exchange rates and stock markets. The integration appears to be partial and influenced by both regional and global factors such as financial crisis, the COVID-19 pandemic, and unconventional policies by the FED. However, a gap in the existing literature has been identified: no previous studies compare the relationships between emerging ASEAN financial markets during the periods of QE and QT policy implementation by the FED. Specifically, it remains unclear how these two policies affect market relationships in similar or different ways. Therefore, this study aims to examine volatility transmission among the financial markets of emerging ASEAN countries: Indonesia, Malaysia, the Philippines and Thailand.

3. Methodology

3.1 ARMA(p,q)-GARCH(1,1) Model

This study uses an ARMA(p,q)-GARCH(1,1) model to analyse the volatility in each time-series dataset, including stock market index and exchange rate returns. The ARMA (p,q)-GARCH (1,1) model is shown in Equations (1)–(3), which represent the general equations of the model.

$$y_t = \mu + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{j=1}^{q} b_j \varepsilon_{t-j} + \varepsilon_t \tag{1}$$

$$\varepsilon_t = z_t \sqrt{h_t}\,, z_t \sim D(0,1) \tag{2}$$

$$h_t = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{3}$$

Equation (1) represents the mean equation where y_t represents stock market index returns and exchange rate returns at time t. Here, μ is the constant term, while a_i and b_j are autoregressive coefficients and moving average coefficients, respectively. Here, p and q indicate the lag orders of the autoregressive and moving averages, respectively. Finally, ε_t denotes the innovations or residuals of the time series data.

Equations (2) and (3) represent the variance equation, where ε_t appears as the product of h_t, the conditional variance, and z_t, the standardised residuals. In this context, z_t is defined as a random variable exhibiting an independent and identically distributed (i.i.d.) process, accommodating diverse data distributions D, such as normal, skewed normal, Student t and skewed Student t. As the exact data distribution pattern is unknown, we chose to test various data distributions that could measure normality, tail distribution and kurtosis.

Equation (3) illustrates the GARCH(1,1) process with the conditions $\omega > 0$, $\alpha_1 \geq 0$, and $\beta_1 \geq 0$. These conditions confirm that the values of h_t are positive and adhere to the properties outlined in Equation (2). Additionally, $\alpha_1 + \beta_1 < 1$ verifies that the data analysed using the GARCH(1,1) process exhibit stationarity and conform to the characteristics of the GARCH(1,1) model. Regarding the terms $\alpha_1 \varepsilon_{t-1}^2$ and $\beta_1 h_{t-1}$, α_1 indicates the magnitude of the persisting impact resulting from short-term shocks, while β_1 signifies the level of persistence of the impact arising from long-term shocks. Considering the value of $\alpha_1 + \beta_1$, if the sum is close to 1, it implies that the effects of shocks will persist in the long term (Chang & McAleer, 2012).

3.2 Copula Model

The random variable from the appropriate ARMA(p,q)-GARCH(1,1) model of each time-series dataset is used for the relationship analysis using a copula model that examines the interdependence between random variables. Copulas require the data to be transformed into a uniform distribution within the [0,1] interval. The marginal distribution of each variable, whether identical or different, must be known. Furthermore, random variables are assumed to follow an i.i.d. process (Patton, 2006). To validate this assumption, the Kolmogorov-Smirnov (K-S) test is used to confirm the uniform distribution of the random variables, while the Box-Ljung test was employed to empirically assess the i.i.d. property.

Following Sklar's theorem (Sklar, 1959), as explicated by Nelsen (2006), a copula function is employed to model the dependence structure between the marginal distribution functions of the random variables and their joint distribution.

Let *X* and *Y* be continuous random variables with a joint function for (*X,Y*).

$$H(x,y) = \Pr[X \leq x, Y \leq y] \tag{4}$$

Then, the marginal distributions of *X* and *Y* are $F(x) = H(X,\infty)$ and $G(y) = H(\infty,Y)$, respectively.

Following Sklar's theorem,

$$H(x,y) = C\big(F(x), G(y)\big) \tag{5}$$

where C is a copula.

If *H* has continuous marginals *F* and *G*, then, the copula in Equation (5) is:

$$C(u,v) = H\big(F^{-1}(u), G^{-1}(v)\big) \tag{6}$$

where $F^{(-1)}(u)$ and $G^{(-1)}(v)$ are quantile functions. Given a parametric c_θ, then, the joint density c_θ is obtained from:

$$c_\theta = \frac{\partial^2 C_\theta(F(x), G(y))}{\partial x \partial y} \tag{7}$$

where θ represents the copula parameter. To estimate the copula parameter, the maximum pseudo-log likelihood method by Genest et al. (1995) is used because the exact marginal distributions of the random variables are unknown. This approach involved generating pseudo-observations $F_n(x_i)$ and $G_n(y_i)$ by transforming the marginal distribution functions *F* and *G* into uniform [0, 1] values through the empirical distribution, $F_n(x) = \frac{1}{n+1}\sum_{i=1}^{n} I(x_i \leq x), G_n(x) = \frac{1}{n+1}\sum_{i=1}^{n} I(y_i \leq y)$. Moreover, Equation (7) can be expressed as follows:

$$c_\theta = \frac{\partial^2 C_\theta(F_n(x), G_n(y))}{\partial x \partial y} \quad (8)$$

The copula parameter θ is estimated using the maximum pseudo-log likelihood method. The pseudo-log likelihood function is as follows:

$$L(\theta) = \sum_{i=1}^{n} \log[c_\theta(F_n(x_i), G_n(y_i))] \quad (9)$$

This study uses various bivariate copula families to capture potential dependence structures among random variables. Employing the CDVine package in R (Brechmann & Schepsmeier, 2013), we access the copula families for this analysis. Gaussian and Student t-copulas are used for symmetric dependence structures, whereas Archimedean copulas, including Clayton, Gumbel, Frank, Joe, BB1, BB6, BB7 and BB8, are employed for asymmetric structures. The selection of the most appropriate copula family for each pair of variables is guided by the Akaike Information Criterion (AIC) proposed by Akaike (1973). Additionally, the strength of the relationship within each copula family is evaluated using the Kendall's Tau correlation coefficient (τ).

4. Data

This study uses a dataset from ASEAN emerging markets: Thailand, Malaysia, Indonesia and the Philippines. Daily data on stock market indices and exchange rates (local currency per US dollar) for these countries were collected from Thomson Reuters Eikon database.

The study examines data from March 2020 to February 2023, comprising the daily closing prices of stock market indices. Thailand uses the SET Index, Malaysia uses the FTSE Bursa Malaysia KLCI Index, Indonesia uses the Jakarta SE Composite Index, and the Philippines uses The Philippine Stock Exchange PSEi Index. Daily bid price data for the forex spot rate are used for the exchange rates.

The data were divided into two periods: one during QE and the other during QT. An unlimited QE policy aimed at addressing economic issues from the COVID-19 pandemic, was announced on March 23, 2020 (Rebucci et al., 2022). To manage inflation and address economic concerns in the United States, the QT policy was implemented starting with a 0.25% increase in the policy rate in March 2022 (Arteta et al., 2022). The FED officially announced this plan on March 16, 2022 (The Federal Reserve, 2022). The data analysis divides the period into two periods: The QE period covers March 23, 2020 to March 15, 2022, and the QT period covers March 16, 2022 to February 13, 2023.

This study investigates two main aspects: 1) the relationship among the volatility of stock market index returns, and 2) the relationship among the volatility of exchange rate returns. The return rate (R_t) for both stock market indices and exchange rates can be calculated using the formula $R_t = \ln(P_t) - \ln(P_{t-1})$, where P_t is the data for stock market indices (or exchange rates) at time t, and $P_{(t-1)}$ is the data at time t–1. The descriptive statistics for R_t are presented in Tables 1 and 2.

Table 1. Descriptive statistics of daily return for stock market indices

	Thailand		Malaysia		Indonesia		Philippines	
	QE	QT	QE	QT	QE	QT	QE	QT
Maximum	0.0647	0.0188	0.0353	0.0396	0.0970	0.0222	0.1235	0.0348
Minimum	-0.0956	-0.0273	-0.0382	-0.0271	-0.0514	-0.0583	-0.0733	-0.0390
Median	0.0008	0.0002	0.0001	-0.0003	0.0012	0.0007	-0.0001	0.0012
Mean	0.0009	0.0001	0.0004	-0.0003	0.0012	0.0000	0.0009	-0.0001
Standard deviation	0.0122	0.0071	0.0091	0.0081	0.0125	0.0092	0.0167	0.0138
Skewness	-0.7650	-0.4329	0.0573	0.3633	0.8754	-1.5432	1.2503	-0.1807
Kurtosis	12.8810	1.2436	1.9575	2.8904	9.8376	8.3933	9.6060	0.1339
JB test	2,834.38[a]	17.14[a]	63.94[a]	66.56[a]	1681.29[a]	609.10[a]	1660.11[a]	1.11
ADF test	-22.63[a]	-12.84[a]	-20.97[a]	-15.01[a]	-22.06[a]	-14.61[a]	-22.63[a]	-13.77[a]

Note(s): JB denotes Jarque-Bera and ADF denotes augmented Dickey-Fuller. [a] denotes statistical significance at the 1% level.

Table 1 displays the descriptive statistics of the stock market indices returns in the four countries. Periods of QE and QT include 415 and 193 observations, respectively. In the QT period, mean values decreased across all countries, with notable declines in Malaysia (-0.0003) and the Philippines (-0.0001), both showing negative values. Similarly, the standard deviation values decreased in all four markets, indicating reduced volatility in stock market index returns following QT measures. Significantly, Indonesia and the Philippines reveal shifts from positive to negative skewness values between periods, suggesting a left-skewed dataset and heightened downside risks in the QT period. The p-values of the Jarque-Bera test indicate that the data significantly deviate from a normal distribution, except for the Philippines in the QT period, whereas the ADF test indicates all data series' stationarity.

Table 2 presents the descriptive statistics of the exchange rate returns. The QE period contained 517 observations, and the QT period contained 239 observations. The statistical summary shows that the mean of exchange rates for Malaysia and Indonesia changed from negative to positive from the QE period to QT period, while that of Thailand and the Philippines remained positive in both periods. In the QT period, exchange rate return volatilities rose in Thailand, Malaysia and the Philippines, as evidenced by higher standard deviation values compared to the QE period. Conversely, the Indonesian market volatility decreased during the QT period. Thus, Thailand, Malaysia and the Philippines experienced increased uncertainty in exchange rate returns during the QT period. The skewness values during the QT period clearly indicate that all foreign exchange rate markets faced downside risk. The p-values of the Jarque-Bera test indicate that the data significantly deviate from a normal distribution, except for Thailand in the QT period, whereas the augmented Dickey-Fuller (ADF) test indicates all data series' stationarity.

Table 2. Descriptive statistics of daily return for exchange rate

	Thailand		Malaysia		Indonesia		Philippines	
	QE	QT	QE	QT	QE	QT	QE	QT
Maximum	0.0114	0.0152	0.0085	0.0105	0.0401	0.0107	0.0118	0.0148
Minimum	-0.0112	-0.0184	-0.0131	-0.0181	-0.0289	-0.0129	-0.0093	-0.0132
Median	0.0000	0.0003	0.0000	0.0004	0.0000	0.0003	0.0000	0.0002
Mean	0.0000	0.0000	-0.0001	0.0002	-0.0002	0.0002	0.0000	0.0002
Standard deviation	0.0035	0.0053	0.0025	0.0034	0.0042	0.0034	0.0029	0.0040
Skewness	0.0308	-0.1879	-0.6794	-1.7158	0.3715	-0.7809	0.4586	-0.0426
Kurtosis	0.8006	0.4041	3.4079	7.5122	24.7370	3.1543	1.5221	1.5009
JB test	13.23[a]	2.76	283.24[a]	651.00[a]	12928.29[a]	117.45[a]	66.22[a]	20.86[a]
ADF test	-20.08[a]	-14.60[a]	-20.59[a]	-12.73[a]	-22.65[a]	-13.64[a]	-23.28[a]	-13.35[a]

Note(s): JB denotes Jarque-Bera, and ADF denotes augmented Dickey-Fuller. [a] denotes statistical significance at the 1% level.

Furthermore, to assess the presence of time-varying volatility in the residuals, we conducted an autoregressive conditional heteroskedasticity Lagrange multiplier test (ARCH-LM). The results strongly indicate the presence of ARCH effects at lag 4 of all series data of the stock market indices and exchange rate returns. The p-value of the ARCH-LM test is less than 0.05. This significant finding suggests that the variance of the error terms is not constant over time or exhibits heteroskedasticity. Consequently, these results justify using the GARCH model to account for our data.

5. Empirical Results

5.1 Results of GARCH (1,1) Model

We employ an ARMA(p,q)-GARCH(1,1) model to characterise and model the time-varying volatility in each time-series dataset, including returns from stock market indices and exchange rates. Tables 3 and 4 display the results of selecting the ARMA(p,q)-GARCH(1,1) model for the stock market index and exchange rates return series, respectively. The results found that the estimated coefficients indicate that $\alpha + \beta$ for all data series are close to 1 in both periods, implying a long-run persistence of shocks on conditional variance. Additionally, when examining the standardised residuals for all data series, the results of both the Box-Ljung test and Kolmogorov-Smirnov test suggest the absence of a serial correlation and confirm a uniform distribution for these data. Therefore, the standardised residuals obtained from the ARMA(p,q)-GARCH(1,1) model are suitable for an analysis using a copula model.

Table 3. ARMA(p,q)-GARCH(1,1) model results for stock market index return series

	Thailand		Malaysia		Indonesia		Philippines	
Parameters	QE	QT	QE	QT	QE	QT	QE	QT
μ	0.000605 (0.00043)	0.000347 (0.00047)	0.000099 (0.00039)	-0.000131 (0.00053)	0.001113[a] (0.00037)	0.000546 (0.00054)	-0.000216 (0.00058)	-0.000132 (0.00100)
ar_1	–	–	–	–	0.106971 (0.24842)	–	–	–
ma_1	–	–	–	–	-0.254726 (0.24031)	–	–	–
ω	0.000002 (0.00001)	0.000003[b] (0.00000)	0.000001 (0.00000)	0.000022 (0.00003)	0.000017[a] (0.00001)	0.000005[a] (0.00000)	0.000042[b] (0.00002)	0.000000 (0.00000)
α	0.064297 (0.11453)	0.055869[a] (0.01545)	0.033480[c] (0.01717)	0.109626 (0.12619)	0.195254[a] (0.06387)	0.050296[a] (0.01400)	0.195094[b] (0.09249)	0.000000 (0.00101)
β	0.916726[a] (0.12121)	0.880009[a] (0.03407)	0.952017[a] (0.01947)	0.559988 (0.48201)	0.665800[a] (0.08487)	0.886828[a] (0.03387)	0.665342[a] (0.10951)	0.999000[a] (0.00098)
Skew	–	–	–	–	–	–	–	–
Shape	4.1906[a] (1.46971)	7.8558[b] (3.66726)	8.1441[a] (2.75946)	5.6177[a] (2.07035)	6.1237[a] (1.65718)	4.6086[a] (1.34500)	3.7830[b] (0.66539)	–
AIC	-6.4016	-7.0769	-6.6578	-6.8184	-6.2649	-6.7144	-5.6659	-5.6868
Box-Ljung test								
1st moment	0.9323	0.3430	0.4514	0.7125	0.3484	0.0843	0.1615	0.8430
2nd moment	0.0614	0.1693	0.2257	0.8271	0.3081	0.5192	0.4212	0.6353
3rd moment	0.8446	0.2576	0.6356	0.7013	0.4022	0.5319	0.3210	0.9862
4th moment	0.1666	0.1618	0.4229	0.7627	0.5973	0.9872	0.5074	0.4657
P-value of KS test	1	1	1	1	1	1	1	1

Note(s): [a,b,c] denote statistical significance at the 1%, 5% and 10% levels, respectively. KS denotes Kolmogorov-Smirnov. The values in parentheses are the standard errors.

Table 4. ARMA(p,q)-GARCH(1,1) model results for exchange rates return series

	Thailand		Malaysia		Indonesia		Philippines	
Parameters	QE	QT	QE	QT	QE	QT	QE	QT
μ	0.000074	0.000277	-0.000034	0.000492[a]	0.000041	0.000386[a]	-0.000084	0.000391
	(0.00019)	(0.00032)	(0.00009)	(0.00015)	(0.00009)	(0.00015)	(0.00008)	(0.00026)
ar_1	0.707470[b]	–	0.110076	0.754375[b]	0.085106	–	-0.072281	-0.099379
	(0.29392)		(0.58921)	(0.30673)	(0.27099)		(0.52944)	(0.37532)
ar_2	–	–	–	–	–	–	-0.388167	–
							(0.34282)	
ar_3	–	–	–	–	–	–	-0.103258[c]	–
							(0.05429)	
ma_1	-0.611541[c]	–	-0.068627	-0.660546[c]	-0.001714	–	-0.027546	0.238860
	(0.32834)		(0.59109)	(0.36198)	(0.27104)		(0.53183)	(0.36480)
ma_2	–	–	–	–	–	–	0.336190	–
							(0.36055)	
ω	0.000000	0.000000	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
α	0.026815[a]	0.035171	0.091944[c]	0.143709	0.204869[a]	0.237488	0.090042[a]	0.033228[b]
	(0.00535)	(0.04120)	(0.05369)	(0.25900)	(0.07570)	(0.24290)	(0.02288)	(0.01399)
β	0.970684[a]	0.949086[a]	0.858379[a]	0.855290[a]	0.794131[a]	0.761512[b]	0.908939[a]	0.965772[a]
	(0.00532)	(0.04631)	(0.05161)	(0.16373)	(0.06250)	(0.31408)	(0.01897)	(0.01370)
Skew	–	–	–	–	–	–	–	–
Shape	7.6158[a]	–	5.4819[a]	3.2298[b]	2.4579[a]	2.8432[a]	5.7785[a]	7.5358[c]
	(2.56830)		(1.40333)	(1.44050)	(0.18606)	(0.60903)	(1.15043)	(4.32556)
AIC	-8.5380	-7.6411	-9.3359	-9.0991	-8.9530	-8.7954	-9.0172	-8.2549
Box-Ljung test								
1st moment	0.8248	0.4249	0.9319	0.5555	0.4324	0.5529	0.9935	0.9899
2nd moment	0.7828	0.7472	0.7294	0.6714	0.6604	0.8748	0.07535	0.3591
3rd moment	0.7788	0.5494	0.4240	0.8114	0.1269	0.1962	0.9655	0.8146
4th moment	0.5000	0.5780	0.7373	0.2158	0.7268	0.9749	0.05269	0.1109
P-value of KS test	1	1	1	1	1	1	1	1

Note(s): [a,b,c] denote statistical significance at the 1%, 5% and 10% levels, respectively. KS denotes Kolmogorov-Smirnov. The values in parentheses are the standard errors.

5.2 Results of Copula

The analysis results of the relationship among the volatility of stock market indices and exchange rates are presented in Tables 5 and 6, respectively. Correlation values from the copula model are depicted in three aspects – overall concordance (τ), upper tail concordance (τ_U) and lower tail concordance (τ_L) – all expressed in Kendall tau. These values were derived from the copula parameters of the selected copula family with the lowest AIC value, which was validated using the Cramer-von Mises (CvM), KS and White tests. In these tests, a p-value > 0.05 indicates the suitability of the chosen copula family for the dataset.

5.2.1 Relationship among Volatility of Stock Market Indices

Table 5 illustrates the dependence among the volatility of stock market index returns in the forms of τ, τ_U and τ_L correlations obtained from the appropriate copula family.

In the QE period, positive τ values indicate co-movement among all four stock market indices, implying simultaneous changes in the same direction. Relationships between Thai-Malay, Thai-Indo, Malay-Indo, Malay-Phi and Indo-Phi show co-movement in overall (τ), upper (τ_U) and lower tail (τ_L) regions, implying extreme changes in one dataset correlate with similar changes in another. Thai-Phi exhibits correlation in overall and upper tail but independence in the lower tail. Incomplete co-movement is noted among all pairs, with τ, τ_U and τ_L values not equal to 1. The Thai-Malay pair shows the highest correlation across all values, with $\tau = 0.27$, $\tau_U = 0.27$ and $\tau_L = 0.23$.

In the QT period, the relationship among the volatility of the stock market index returns in all four markets shows a similar direction of change. Significantly, Thai-Malay exhibits the highest τ value at 0.33, Thai-Phi shows the highest τ_U value at 0.2 and

Table 5. Results of copula model for stock market index returns

Period	Pair-copula	Copula family	τ	τ_U	τ_L	AIC	Goodness of fit test		
							p-value of CvM	p-value of KS	p-value of WhiteTest
QE	Thai-Malay	Survival BB7	0.27	0.27	0.23	-95.42	0.42	0.5	–
	Thai-Indo	Survival BB1	0.24	0.07	0.21	-66.34	0.85	0.94	–
	Thai-Phi	Gumbel	0.109	0.25	0	-46.52	0.48	0.42	–
	Malay-Indo	BB7	0.23	0.25	0.12	-63.92	0.27	0.08	–
	Malay-Phi	Survival BB7	0.21	0.21	0.11	-59.35	0.43	0.47	–
	Indo-Phi	Survival BB7	0.19	0.1	0.17	-42.81	0.92	0.88	–
QT	Thai-Malay	Survival Gumbel	0.33	0	0.4	-56.95	0.57	0.59	–
	Thai-Indo	Survival Gumbel	0.23	0	0.29	-28.96	0.71	0.75	–
	Thai-Phi	BB1	0.26	0.2	0.14	-31.46	0.79	0.69	–
	Malay-Indo	Survival Gumbel	0.23	0	0.29	-28.21	0.55	0.47	–
	Malay-Phi	Survival BB8	0.24	0	0	-27.86	0.51	0.63	–
	Indo-Phi	Student t	0.18	0.05	0.05	-13.41	–	–	0.58

Thai-Malay has the highest τ_L value at 0.4. This suggests that Thai-Malay is the most closely related market pair compared to others in both periods, likely due to their shared borders.

In both periods, all four stock markets showed positive correlation (τ values), indicating that they tend to move in the same direction. This suggests a level of integration among these emerging ASEAN-4 markets. Particularly, the Thai-Malay pair consistently showed the highest correlation in both periods, indicating that geographical proximity can lead to stronger market relationships. While co-movement exists among markets, the correlations are not perfect (τ values are not equal to 1). This implies that diversification opportunities still exist for investors within the region, allowing them to manage risk across these markets. However, investors should be aware that markets are still integrated, which means a shared downside risk also exists.

The study results obtained from the copula model show us that the transition from QE to QT measures can change the structure of the stock market relationships in the opposite direction when considering the changing values of τ_U and τ_L. For example, during the QE and QT periods, the Thai-Malay has values of $(\tau_U^{QE} = 0.27, \tau_L^{QE} = 0.23)$ and $(\tau_U^{QT} = 0, \tau_L^{QT} = 0.4)$, respectively. These correlation results show that in the QT period, the τ_U value decreased, and the τ_L value increased compared to the QE period, which is the same for the Thai-Indo, Thai-Phi and Malay-Indo pairs (see Table 5). Conversely, for the Malay-Phi and Indo-Phi pairs, the values of τ_U and τ_L in the QT period are lower than those in the QE period. This reveals that during the QT period, investors in the Thai-Malay, Thai-Indo, Thai-Phi and Malay-Indo stock markets faced a higher level of downside risk in both markets than in the QE period. In the QE period, the relationships between Thai-Malay, Thai-Phi, Malay-Indo and Malay-Phi, the values of τ_U are greater than the values of τ_L. Thus, investors encounter higher upside risk when investing in both these markets.

From these findings, it can be concluded that monetary policy shifts can significantly impact stock market relationships in the region. The increased downside risk during QT for some market pairs suggests that investors and policymakers need to be particularly attentive to risk management during tightening periods. However, the persistent co-movement and varying degrees of correlation also indicate that diversification opportunities remain within the region. The study provides valuable insights for understanding market behaviour under different monetary policy regimes, which can inform both investment strategies and policy decisions in ASEAN.

5.2.2 Relationship among Volatility of Exchange Rates

Table 6 illustrates the dependence among the volatility of exchange rate returns for each country in the forms of τ, τ_U and τ_L correlations, obtained from the appropriate copula family. In both periods of QE and QT, positive τ values indicate correlated exchange rate volatilities among Thailand (USD-Baht), Malaysia (USD-Ringgit), Indonesia (USD-Rupiah), and the Philippines (USD-Peso), moving in the same direction.

In the QE period, Malay-Indo showed τ, τ_U and τ_L values of 0.28, 0.03 and 0.03, respectively, indicating a co-movement in the overall relationship between the datasets,

Table 6. Results of the copula model for exchange rate returns

Period	Pair-copula	Copula family	τ	τ_U	τ_L	AIC	Goodness of fit test		
							p-value of CvM	p-value of KS	p-value of WhiteTest
QE	Thai-Malay	Survival Clayton	0.16	0.16	0	-47.33	0.57	0.86	–
	Thai-Indo	Gaussian	0.14	0	0	-24.11	0.72	0.76	–
	Thai-Phi	Gaussian	0.21	0	0	-56.73	0.4	0.52	–
	Malay-Indo	Student t	0.28	0.03	0.03	-101.09	–	–	0.48
	Malay-Phi	Frank	0.12	0	0	-15.23	0.06	0.06	–
	Indo-Phi	Gaussian	0.07	0	0	-3.68	0.11	0.21	–
QT	Thai-Malay	Frank	0.21	0	0	-20.23	0.09	0.22	–
	Thai-Indo	Frank	0.16	0	0	-12.15	0.43	0.23	–
	Thai-Phi	Student t	0.29	0.08	0.08	-49.94	–	–	0.59
	Malay-Indo	Gaussian	0.38	0	0	-90.06	0.55	0.68	–
	Malay-Phi	Gaussian	0.14	0	0	-9.71	0.31	0.25	–
	Indo-Phi	Frank	0.19	0	0	-17.7	0.5	0.39	–

and in their upper and lower tail regions. For Thai-Malay, both τ and τ_U were 0.16, showing a relationship overall and particularly in the upper tail. For Thai-Indo, Thai-Phi, Malay-Phi and Indo-Phi, only τ values were examined. Malay-Indo had the highest τ value at 0.28. Co-movement among all pairs was incomplete as τ, τ_U and τ_L values were not equal to 1.

In the QT period, Thai-Phi revealed τ, τ_U and τ_L values of 0.29, 0.08 and 0.08, respectively, indicating co-movement in overall relationships, and in upper and lower tail regions. Only τ values were found for other market pairs, and Malay-Indo had the highest τ value at 0.38. Significantly, Malay-Indo showed the highest τ correlation value in both time periods, possibly due to their shared border and closely interconnected economies compared to other countries.

During the QT period, exchange rate volatility among market pairs displayed a stronger relationship than during the QE period. The FED's QT policy led to a reduction in global economic liquidity in the US dollars (International Monetary Fund, 2022), likely resulting in more synchronised capital flows across market pairs. Consequently, a higher degree of co-movement existed in exchange rates than before. This differs from the QE policy period that is characterised by high liquidity in international financial markets, which benefits emerging economies through capital inflows (Beirne et al., 2020; Cortes et al., 2022).

These findings provide several key insights. The consistent positive correlation among all four exchange rates suggests a level of economic integration in the Southeast Asian region. The Malay-Indo pair showed the strongest relationship in both periods, highlighting the importance of geographical proximity and economic ties. Moreover, the increased co-movement during QT suggests that these markets efficiently respond to global economic conditions. This efficiency can be attractive to international investors looking for markets that quickly adjust to new information. However, incomplete co-movement (τ values not equal to 1) implies persistent diversification opportunities. Such insights are valuable for investors in risk management and for policymakers in crafting coordinated responses to global economic shifts, potentially fostering greater regional financial stability and attractiveness to international investment.

6. Conclusion

This study employs a copula-based GARCH model to examine: 1) the relationship among the volatility of stock market index returns, and 2) the relationship among the volatility of exchange rate returns (local currency per US dollar). The analysis is divided into two periods. The first spans March 2020 to March 2022, during the QE measures, while the second covers March 2022 to February 2023, during the QT measures. The data from emerging ASEAN markets, such as Thailand, Malaysia, Indonesia and the Philippines, were used in this study. The empirical findings showed volatility transmission among the financial markets of Thailand, Malaysia, Indonesia and the Philippines during both QE and QT periods.

The key findings of the study can be concluded as follows: for the relationship among the volatility of stock markets, in both periods, all four stock markets showed positive correlation, indicating that they tend to move in the same direction. This suggests a level of integration among these emerging ASEAN-4 markets. This can be seen as a positive development, as it may indicate increasing economic ties and potential for regional cooperation. While these markets demonstrate integration in terms of volatility transmission, they are not fully integrated as indicated by τ, τ_U and τ_L values not reaching the maximum level of 1. This implies that there are still diversification opportunities for investors within the region, allowing them to manage risk across these markets. Furthermore, new findings suggest that transitioning from QE to QT policies can change the relationship structure among stock markets in the opposite direction as evidenced by τ_U and τ_L values. The change in market relationships between QE and QT periods demonstrates that these markets can adapt to different monetary policy environments. This is an external policy from outside the region that directly affects the ASEAN stock markets. For risk management implications, this study provides insights into how risk profiles change under different monetary policy regimes. For instance, during the QT period, some market pairs showed higher downside risk. This information can help investors and policymakers better prepare for and manage risks associated with policy changes. Adjustments in portfolio diversification across countries are crucial for aligning with the varying monetary policy measures of the FED, especially during QT periods.

For the relationship among the volatility of exchange rate returns, in both periods, all four exchange rates (Thai baht, Malaysian ringgit, Indonesian rupiah, and Philippine peso against the US dollar) showed consistent positive correlation, indicating they move in the same direction. Moreover, the results show the incomplete co-movement (τ values not equal to 1) implying that there are still diversification opportunities for investors and businesses operating across these markets, which allows for risk management and potential arbitrage opportunities. Furthermore, in QT periods, the volatility of exchange rate returns for all four countries tends to exhibit a stronger correlation than in QE periods. This suggests that these markets become more synchronised when global liquidity tightens, and reveals that the exchange rates of all four countries are similarly affected by QT. Those responsible for setting monetary policy in each country should cooperate and coordinate policies across nations to maintain financial stability within the ASEAN region. The increased co-movement during QT suggests that these markets efficiently respond to global economic conditions.

This study differs from previous research in that it examines both the QE and QT periods implemented by the FED. It found that these monetary policy measures had varying impacts on the relationship among stock markets in ASEAN emerging markets and on the exchange rates of each country. Significantly, all four countries' financial markets experienced volatility transmission during both QE and QT periods. For the policy implication, these empirical findings offer valuable insights for investors to mitigate investment risks across countries. Specifically, during periods of reduced dollar market liquidity under the FED's QT policy, investors diversifying into various stock markets should be wary of potential currency depreciation and uncertain negative returns. Therefore, this study provides valuable insights for policymakers in these countries. Understanding the co-movement of their financial markets can inform coordinated policy responses to global economic changes, potentially leading to more stable regional economies. To stabilise financial markets within the ASEAN region and reduce the impact of exchange rate volatility, several policy measures have been proposed and implemented. These include the establishment of comprehensive macroeconomic and financial surveillance systems to enhance financial stability (ASEAN Secretariat, 2015). Such systems can help identify potential risks and vulnerabilities in the regional financial landscape, allowing for preemptive policy actions. Another mechanism is the promotion of currency swap agreements between ASEAN countries, which aims to reduce the impact of exchange rate volatility that can be contagious among ASEAN countries (Shahrier, 2022), and is part of the multilateral financial agreement between ASEAN+3 member countries (Sussangkarn, 2010). These agreements can provide short-term liquidity support and help stabilise exchange rates during periods of market stress.

Based on this study's findings, future research could use the time-varying copula models to gain deeper insights into ASEAN financial markets, as that could capture the dynamic nature of dependence structures. Furthermore, researchers could expand the scope to include other emerging and developed markets for comparison to obtain a broader view of the topic. Additionally, incorporating sectoral analysis, examining the effects of policy announcements, and integrating other economic variables could provide a more comprehensive understanding of market interdependencies.

References

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B.N. Petrov, & F. Csaki (Eds.), *Proceedings of the 2nd International Symposium on Information Theory* (pp. 267–281). Akadémiai Kiadó.

Arteta, C., Kamin, S., & Ruch, F.U. (2022). *How do rising U.S. interest rates affect emerging and developing economies? It depends* (Policy Research Working Paper No. 10258). World

Bank Group. https://documents1.worldbank.org/curated/en/099036212082239238/pdf/IDU032d1feef0db0d0480e0b3190f92d87c50de8.pdf

ASEAN. (2020). *Economic impact of COVID-19 outbreak on ASEAN* (ASEAN Policy Brief, April 2020). Association of Southeast Asian Nations, Jakarta Secretariat. https://asean.org/wp-content/uploads/2021/09/ASEAN-Policy-Brief-April-2020_FINAL.pdf

ASEAN Secretariat. (2015). *ASEAN economic community blueprint 2025*. The ASEAN Secretariat Jakarta. https://asean.org/book/asean-economic-community-blueprint-2025/

Beirne, J., Renzhi, N., Sugandi, E.A., & Volz, U. (2020). *Financial market and capital flow dynamics during the COVID-19 pandemic* (ADBI Working Paper No. 1158). SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3656848

Brechmann, E.C., & Schepsmeier, U. (2013). Modeling dependence with C- and D-Vine copulas: The R package CDVine. *Journal of Statistical Software, 52*(3), 1–27. https://doi.org/10.18637/jss.v052.i03

Canuto, O. (2022). *Quantitative tightening and capital flows to emerging markets* (Policy Brief, June 2022). Policy Press Center for the New South. https://www.policycenter.ma/sites/default/files/2022-06/PB_42-22%20(%20CANUTO%20).pdf

Chai, H.Y., & Rhee, Y. (2005). *Financial integration and financial efficiency in East Asia: A comparison with Europe*. Korea Institute for International Economic Policy. https://www.kiep.go.kr/boardDownload.es?bid=0034&list_no=5565&seq=2

Chang, C.L., & McAleer, M. (2012). Aggregation, heterogeneous autoregression and volatility of daily international tourist arrivals and exchange rates. *Japanese Economic Review, 63*(3), 397–419. https://doi.org/10.1111/j.1468-5876.2011.00563.x

Click, R.W., & Plummer, M.G. (2005). Stock market integration in ASEAN after the Asian financial crisis. *Journal of Asian Economics, 16*(1), 5–28. https://doi.org/10.1016/j.asieco.2004.11.018

Cortes, G.S., Gao, G.P., Silva, F.B.G., & Song, Z. (2022). Unconventional monetary policy and disaster risk: Evidence from the subprime and COVID–19 crises. *Journal of International Money and Finance, 122*, Article 102543. https://doi.org/10.1016/j.jimonfin.2021.102543

Duong, D., & Huynh, T.L.D. (2020). Tail dependence in emerging ASEAN-6 equity markets: Empirical evidence from quantitative approaches. *Financial Innovation, 6*(1), 1–26. https://doi.org/10.1186/s40854-019-0168-7

Genest, C., Ghoudi, K., & Rivest, L.P. (1995). A semiparametric estimation procedure of dependence parameters in multivariate families of distributions. *Biometrika, 82*(3), 543–552. https://doi.org/10.1093/biomet/82.3.543

International Monetary Fund. (2022). *Global financial stability report: Navigating the high-inflation environment*. https://www.imf.org/-/media/Files/Publications/GFSR/2022/October/English/text.ashx

Janor, H., & Ali, R. (2007). Financial integration of the ASEAN-5 markets: Financial crisis effects based on bivariate and multivariate cointegration approach. *Investment Management and Financial Innovations, 4*(4), 144–158.

Jantarakolica, T., & Jantarakolica, K. (2018). ASEAN-5 economic and exchange rate integration. In W.A. Barnett, & B.S. Sergi (Eds.), *Banking and finance issues in emerging markets* (International Symposia in Economic Theory and Econometrics, Vol. 25), (pp. 9–29). Emerald Publishing Limited.

MSCI. (2023). *MSCI ACWI Index market allocation*. https://www.msci.com/zh/our-solutions/indexes/acwi

Mulaahmetovic, I. (2022). Evaluating the effectiveness of quantitative easing measures of the Federal Reserve and the European Central Bank. *Asian Economic and Financial Review, 12*(3), 141–163. https://doi.org/10.55493/5002.v12i3.4436

Nelsen, R.B. (2006). *An introduction to copulas* (2nd ed.). Springer Science and Business Media. https://doi.org/10.1007/0-387-28678-0

Patel, R., Goodell, J.W., Oriani, M.E., Paltrinieri, A., & Yarovaya, L. (2022). A bibliometric review of financial market integration literature. *International Review of Financial Analysis, 80*, Article 102035. https://doi.org/10.1016/j.irfa.2022.102035

Patton, A.J. (2006). Modelling asymmetric exchange rate dependence. *International Economic Review, 47*(2), 527–556. https://doi.org/10.1111/j.1468-2354.2006.00387.x

Pongkongkaew, P., Wannapan, S., Chaitip, P., & Chaiboonsri, C. (2020). Modeling dependence structure of evidence from ASEAN-5 stock market patterns. *International Journal of Economics and Management, 14*(1), 81–94.

Rebucci, A., Hartley, J.S., & Jiménez, D. (2022). An event study of COVID-19 central bank quantitative easing in advanced and emerging economies. In H. Chudik, C. Hsiao, & A. Timmermann (Eds.), *Essays in honor of M. Hashem Pesaran: Prediction and macro modeling* (Advances in Econometrics, Vol. 43A) (pp. 291–322). Emerald Publishing Limited. https://doi.org/10.1108/S0731-90532021000043A014

Rufino, C.C. (2018). Long-run linkages of ASEAN+3 floating currencies. *DLSU Business and Economics Review, 27*(2), 1–14.

Shahrier, N.A. (2022). Contagion effects in ASEAN-5 exchange rates during the Covid-19 pandemic. *North American Journal of Economics and Finance, 62*, Article 101707. https://doi.org/10.1016/j.najef.2022.101707

Sklar, A. (1959). Fonctions de répartition à N dimensions et leurs marges. *Annales de l'ISUP, 8*(3), 229–231.

Smith, A.L., & Valcarcel, V.J. (2023). The financial market effects of unwinding the Federal Reserve's balance sheet. *Journal of Economic Dynamics and Control, 146*, Article 104582. https://doi.org/10.1016/j.jedc.2022.104582

Sriboonchitta, S., Liu, J., Kreinovich, V., & Nguyen, H.T. (2014). A Vine copula approach for analyzing financial risk and co-movement of the Indonesian, Philippine and Thailand stock markets. In V.N. Huynh, V. Kreinovich, & S. Sriboonchitta (Eds.), *Modeling dependence in econometrics* (Advances in Intelligent Systems and Computing, Vol. 251), (pp. 241–254). Springer.

Sussangkarn, C. (2010). *The Chiang Mai initiative multilateralization: Origin, development and outlook* (ADBI Working Paper No. 230). Asian Development Bank Institute. https://www.adb.org/sites/default/files/publication/156085/adbi-wp230.pdf

The Federal Reserve. (2022, March 16). *Decisions regarding monetary policy implementation*. [Press Release]. Board of Governors of the Federal Reserve System. https://www.federalreserve.gov/newsevents/pressreleases/monetary20220316a1.htm

World Bank Group. (2020, June). *Global economic prospects*. https://openknowledge.worldbank.org/entities/publication/d29e6c95-4753-58e8-b368-d03c78cacab5