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Research article

Dependence between Chinese stock market and Vietnamese stock market during the Covid-19 pandemic

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ABSTRACT

The study aims to investigate the tail dependence between Chinese stock market and Vietnamese stock market in the context of the Covid-19 pandemic. Using the data on the Ho Chi Minh City Stock Exchange (VNI) and the Shanghai Stock Exchange (SSEC) representing for Vietnam and China stock markets, the study reveals the tail dependence across three periods including: pre-pandemic, during the chaos of the pandemic, and the period of adaptation to the pandemic. Using the copula method including Normal, Clayton, Plackett, Frank, Student, Symmetrised Joe-Clayton copulas, the research results confirm that there is no dependent relationship between the stock market between the two countries in the pre-pandemic. During the pandemic, the Vietnamese stock market is heavily dependent on Chinese stock market, especially the upper tail dependence. During the period of adaptation to the pandemic, this dependence relationship still exists but less than that in the pandemic.

1. Introduction

The Covid-19 pandemic, which originated in Wuhan - China at the end of 2019, has spread to many countries in Asia, America, Europe, and the whole world as well as has become a global pandemic. Facing this context, the World Health Organization declared the Covid-19 pandemic as a global pandemic on January 23rd, 2020 that affects health, economic growth, trade, and supply chains around the world.

As the first country affected by the pandemic, China has implemented social distancing measures in many cities across the country to prevent the spread of the pandemic. Being a country located next to China to the south, Vietnam started detecting the first cases on January 23rd, 2020 through the case of two Chinese fathers and sons traveling in Vietnam. This event made Vietnam become an epidemic country and economic performance gradually adapt to the impacts of the pandemic (Tran, 2022).

Vietnam and China are among the few countries in the world that still maintain a socialist-oriented political system. Since the end of the cold war, many countries in the world have collapsed with their socialist-oriented institutions, but Vietnam and China have firmly stood and continued to build their socialist-oriented countries. It can be said that the two countries have relatively similar economic and political institutions in Asia, and especially close borders, so many economic, political activities are relatively closely linked both in the past and the present.

Vietnam stock market was established in 2000 with its first stock market of Ho Chi Minh City Stock Exchange (VNI) in Ho Chi Minh city, a largest city in the country. At present, VNI has become an important securities trading and capital mobilization channel to meet medium and long-term capital needs for businesses, with a market capitalization of about VND 4.92 million billion and about 126% of GDP (SSC, 2021). Meanwhile, the Shanghai Stock Exchange (SSEC) was established in 1990 with its first market index in 1991, has grown to become the third largest market capitalization in the world (Rana, 2015), following New York Stock Exchange (NYSE) – United States, and Nasdaq OMX – United States, even has surpassed Hong Kong Stock Exchanges and Japan Exchange Group (Arora, 2021).

The growth of China's stock market is closely related to the growth of China's economy when it becomes the second largest economy in the world, after the United States. Although it will take many years for China's per capita income to catch up with the United States', China's economy has been growing and has had a lot of influence on the world's economy, especially in Asia (Lee, 2021). For Vietnam, the two countries currently have large trade and investment relations, but the advantages always belong to China. In the 1990s, the economic relations between the two countries were relatively balanced, but now the

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advantage in investment and trade from China is always more than that of Vietnam. Specifically, among trading partners, Vietnam has the largest trade deficit from China. In 2020, Vietnam's exports to China reached $48.9 billion but imports were $84.1 billion, therefore trade in favor of China was about $35.2 billion. In the first 8 months of 2021, Vietnam continued to have a large deficit of 38.7 billion USD from China and slightly higher than 2020. It reflects that Vietnam's economy has a great dependence on China.

Assessing the impact of dependence on the stock markets of countries has been carried out through a number of studies in recent times by using the copula method (Guo and Wang, 2016; Yang et al., 2019 and Cardoso et al., 2020). Simultaneously, the world has to face the situation of the Covid - 19 epidemic in the past 2 years, which has had many impacts on the economy, investment, supply chain, and stock markets including Vietnam and China. Currently, Vietnam and China are among the few countries with socialist-oriented economic development, similar political institutions and geographical borders. However, the research on the dependency impact between these two countries has not been evaluated by any author, especially the assessment of the dependency impact of Vietnam on China in the context of the Covid - 19 pandemic. In fact, China's economy is large and its per capita income is high, it indicates a better ability to limit its vulnerability to economic shocks than Vietnam, whose economic size is smaller and average income is also lower and less than 40% compared to China. The Covid-19 pandemic is a big shock and the impact on the Vietnamese and Chinese stock markets is completely different and it leads to different effects of the Chinese stock market on Vietnam during dissimilar periods. Therefore, it is extremely urgent to conduct research to evaluate this dependence effect. In addition, the study can bring findings for Vietnam as well as small-sized economies in agreement with large-sized economies, typically China. Concretely, handling data on the Ho Chi Minh City Stock Exchange (VNI) and the Shanghai Stock Exchange (SSEC) representing, respectively, for Vietnamese and Chinese stock markets, the tail dependence across three periods including: pre-pandemic, during the chaos of the pandemic, and the period of adaptation to the pandemic was discovered. Using the copula method including Normal, Clayton, Plackett, Frank, Student, Symmetrised Joe-Clayton copulas, which is one of the most appropriate method in modelling dependence structure between random variables. Modelling of multivariate density functions thanks to copula approaches has several advantages compared to traditional approaches such as mentioned in Dowd (2008):

Firstly, copulas are much more flexible, since they help us to fit the dependence structure separately from the marginal distributions. It is superior as a modelling strategy. With traditional F(x, y) representations, we could not obtain the dependence structure without also having to give assumptions about marginal distributions, and there is the related problem that dependence parameters are sometimes present in the marginals.

Secondly, it is the fact that copulas help us to separate the modelling of dependence from the modelling of the marginals. It means that copulas allow us to fit different marginal distributions to different random variables. Thanks to literature review, if traditional approaches are employed, marginal for every random variable is typically required to be the same. The greater flexibility raised by copula approaches is often of enormous value, as empirical marginal distributions can often be very different from each other.

Thirdly, copula approaches also create for much greater flexibility since they allow us to make plenty of choice over the type of dependence structure that we can fit to our data. With copulas, one can fit any type of dependence structure that is achievable using traditional F(x, y) representations of the multivariate density function.

Slightly conclusion, with copulas we can do anything we have already done with traditional approaches, however, we can also do a great deal more. By conducting the tail dependence between Chinese stock market and Vietnamese stock market in the context of the Covid-19 pandemic and using the data on the Ho Chi Minh City Stock Exchange (VNI) and the Shanghai Stock Exchange (SSEC) representing for Vietnam and China stock markets, the empirical results show that there does not exist dependent relationship between the stock market between the two countries in the pre-pandemic. However, during the pandemic, the Vietnamese stock market is heavily dependent on Chinese stock market, especially the upper tail dependence. During the period of adaptation to the pandemic, this dependence relationship still exists, but less than that in the pandemic.

In addition to the introduction presented, the rest of this paper includes 4 parts as follows: Part 2 discusses previous studies, part 3 presents data collection and research methods. Section 4 shows the results and finally, the study offers the conclusions and some policy implications.

2. Literature review

The stock market is a long-term capital mobilization channel of the economy and businesses can mobilize long-term capital sources to cover capital needs in production and business, investment in fixed assets, investment in production and business and create driving force for economic development (Nawrocki, 1995; Guo and Wang, 2016; Yakubu et al., 2021; Abaidoo and Agyapong, 2022). Countries with large economies mean large capital needs and therefore stock markets have many motivations to develop. Moreover, countries with large economies often have certain advantages over countries with small economies of scale and stock markets.

Research on the dependence relation between stock markets has been studied by a rich variety of authors in recent times, typically the study of Nawrocki (1995), Guo and Wang (2016), Fry-McKibbin et al. (2018), Yang et al. (2019), Batten et al. (2019), Cardoso et al. (2020). Among them, there might exist dependent relationship between markets within the same country, as studied by Guo and Wang (2016) in the relationship between Shanghai and Shenzhen stock markets, or Sukcharoen and Leatham (2016) affirmed the relationship in economic sectors in the United States. In addition, countries in the same region often showed some economic, investment, trade or logistics relationship, as studied by Cardoso et al. (2020) in Latin American stock markets and its dependence. However, the evidence normally confirmed the dependencies between the stock markets could be found and at the same time the dependencies were likely to increase with business cycle, as discussed in the study by Nawrocki (1995).

Research by Guo and Wang (2016) in assessing the dependency relationship between Shanghai and Shenzhen stock markets in China argued that there existed a dependency relationship within a country. The author used the copula method to evaluate this relationship, and only Gumpel copula was the best choice in the analysis. The results indicated that it had a very high relationship in the upper tail, showing that when a market rallied, the other market would increase as well as the positive dependence was stronger than the negative dependence. Research on the relationship within the same country, typically also the study of Sukcharoen and Leatham (2016) evaluated the dependent relationship between economic sectors in the United States, and assessed through 3 periods, respectively 1995 - 2000, 2001 - 2006 and 2007 - 2012, the study found some important evidences: the degree of dependence and the correlation within the same industry was high while the relationship between different industries was low. The study also confirmed that the benefits of industry diversification were diminishing while the potential of diversification might not exist. Sukcharoen and Leatham (2016) suggested that investors should consider normal and extreme fluctuations among industry indices to maximize the benefits of diversification. Further discussed on the Warsaw Stock Exchange between 2007 and 2018, Echaust (2021) studied the dependence relationship thanks to the copula method and concluded that fluctuations in implied volatility were asymptotically reliant on positive extreme returns and significant reliant on negative extreme returns.

Within the same economic region, some evidence has found interdependent relationships between countries. Typically, the study of Cardoso et al. (2020) performed in the Latin America stock exchange with the best choice copula of the Joe – Clayton copula. The study confirmed that the dependency structure in the upper tail was higher than that in the lower tail, as well as the market could diversify in favor of the downtrend during the global crisis unfolding in Latin America. Earlier, a study of 10 representative stock markets in the European region, Shahzad et al. (2017) investigated the dependence of gold and bonds for 10 typical stock markets, including 5 large-sized stock markets and 5 medium-sized stock markets of the world. Shahzad et al. (2017) assessed that the gold-stock, and bond-stock dependencies were not the same and this outcome varied from country to country. However, when the stock market declined, gold was a strong hedge and diversifier for the stock portfolio. The results of the study were opposite as Cepoi (2020) confirmed that the return of gold was directly proportional to the stock markets and it did not behave as a "safe heaven" asset.

The impact on the stock market may come from internal or external shocks that change economic activity in the affected country and the domestic market. As suggested in the study of Dong et al. (2021) asserting that the stock market could be affected by economic factors during the pandemic. Typical economic factors could be referred to such as cryptocurrencies, monetary policy, international capital flows and market uncertainty. The internal factors could be policy uncertainty in the country, which may have effects on the market as discussed by Guo et al. (2018). The authors argued that policy uncertainty could harm stock returns in most countries and that there existed an uptrend and downtrend effect of policy uncertainty. However, another study Guo et al. (2018) also argued that this effect does not exist in the France and UK market. It confirms the dependent effect is different between countries and depending on the characteristics of each country as well as each country's policy response to impacts from external shocks.

Arouri et al. (2014) analyzed the evolution of stock market integration of ASEAN-5 (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) with China, India, the US, and Japan based on the DCC-MGARCH approach. The authors also examined the structural breaks that affected the correlations between the markets by using the Bai and Perron multiple structural breaks test. The findings confirmed an increase in the financial integration between ASEAN-5 and China but still at a relatively low level. However, ASEAN-5 did not respond to external disturbance simultaneously and the impact of external turbulence on each ASEAN-5 member was not similar.

Stefan and Eduard (2015) investigated the risk-return distances of 18 emerging stock markets including ASEAN-4 (Indonesia, Malaysia, Philippines, and Thailand) in the period during January 2000 and December 2013. Distances were linked to volatility and time-varying correlations estimated in standard and asymmetric DCC models. Empirical results revealed a positive relationship between risk-return distances and volatility, which meant that during more volatile periods, the risk-return characteristics in emerging markets exhibit lower similarity to the characteristics found in developed markets. This result seemed to be in sharp contrast to most empirical studies using correlations. Within the portfolio framework, the results suggested that diversification into emerging stock markets might still provide desirable benefits to international investors.

Jiang et al. (2017) aimed to study the co-movement and the volatility fluctuation between stock markets in the ASEAN countries. The data covered the period from 2009 to 2016, the interdependence level and lag-lead relationship among ASEAN trading link participants were estimated. The degree of interdependence in ASEAN stock markets was found to be stronger in the short term, especially following particular external shocks. A Variational Modes Decomposition (VMD)-based copula estimation showed that the effect of economic shock – in the case when ASEAN trading link establishment – on the stock markets' level of comovement was only temporary and would progressively diminish within approximately two years. Only Indonesia and Malaysia displayed strong fundamental linkages between each other. Both the CWT and Copula methods consistently showed that Vietnam (Indonesia) had the lowest (highest) interdependence with the rest of ASEAN trading link participants.

Jones and Gamini (2017) studied how the banking sectors in the various economies co-move with each other. In concrete, the authors examined the dependence structure between banking sectors in the region using copula functions. Several findings were documented. Firstly, average dependence generally remained at moderate levels, though dependence between the banking sectors of the developed Asian markets were relatively higher than the emerging markets. Secondly, the authors found evidence of asymmetric dependence, suggesting that banking sector returns co-movement varied in bull and bear markets. Thirdly, empirical results showed a mild increase in the bivariate dynamic correlations during crisis periods, indicating very limited risk of contagion.

Renée et al. (2018) focussed on the role of the U.S. in understanding changes in global integration over time, as well as changes in regional integration arising from China. Daily stock returns from 1997 to 2016 was studied, the empirical results showed an overall trend to improvements in financial integration over time with deviations from the trend occurring during periods of financial crises in Asia in 1997–98, the U.S. in 2007–10 and the recent European debt crisis. The influence of the Chinese economy mainly through its trading linkages was found to be an important determinant of financial integration over time both regionally as well as globally.

Lee (2019) used panel unit root test and panel cointegration test to study whether there were common trends among Asian financial markets, and if there were, were they stationary or not. Asian stock market integration was an important issue in the midst of ever increasing goods and service trades. Despite the recent progress, the degree of intra-regional financial integration appeared to lag behind the increase in trades in the region. Asian financial markets generally moved together, and they could be integrated in a statistical point of view. China seemed to be an outlier in this analysis, and Chinese financial market was not in sync with any other Asian financial markets in the study.

Continuing the idea of studying the relationship between other markets such as energy market and emerging stock markets, Jonathan et al. (2019) investigated the integration relation between ten major Asian stock markets and a diversified energy portfolio that comprised oil, coal and gas. Estimation of the relation in a time-varying asset pricing framework, which allowed for regime switching, identifies two major regimes. The first regime represented periods of low energy-stock market integration, where markets tended to be segmented. It accounted for over two-thirds of the sample period from December 1992 to December 2015. The second regime represented periods of high integration, as characterized by limited diversification opportunities and increased levels of volatility. Besides, corporate funding conditions were less favorable in the second regime. The two regimes differed in the way equity markets price energy risk. Empirical results also identified a significant positive energy-related equity risk premium during the high integration regime.

Regarding to relation not only among stock markets but also the volatility spillover effects between precious metals futures (gold, palladium, platinum, and silver), Brent oil futures to stock markets, Mensi et al. (2021) referred to ASEAN stock markets (Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) at multiple time horizons and during both bull and bear market periods. The results showed that precious metals, crude oil, and the Vietnamese stock market were net receivers of spillovers irrespective of time horizons and during bearish market conditions. However, during the bullish market conditions, Brent oil futures and Vietnamese stock markets became net contributors to short-term spillovers. Moreover, the stock markets of Indonesia, Malaysia, and the Philippines were the largest contributors to spillovers under bull and bear market conditions and regardless of the time investment horizons.

Table 1. The relationship between Vietnam and China stock exchanges.

Phase	VNI – SECC	VNI – Covid VN	SECC – Covid CHI
1	Jan 1st 2018 – Jan 22nd 2020		
2	Jan 23rd 2020 – Dec 31st 2020	Jun 30th 2020 – Dec 31st 2020	Jan 22th 2020 - Dec 31st 2020
3	Jan 1st 2021 – Jun 30th 2021	Jan 1st 2021 – Jun 30th 2021	Jan 1st 2021 – Jun 30th 2021

Note: VNI, CHI denote for Vietnam and China.

Another study carried out for ASEAN, Tsang et al. (2021) employed the VAR-MGARCH model to explore the spillover across the sovereign bond markets between the US and ASEAN-4 economies (Indonesia, Malaysia, Philippines, and Thailand). The empirical results confirmed the unidirectional spillover in bond return from the US to ASEAN-4, while there was a bidirectional influence in volatility. Furthermore, dynamic conditional correlation (DCC) analysis was conducted to describe the changing correlation in volatility. The empirical results also showed that the yields of ASEAN-4 bonds increased with emerging market risks, and the exchange rate could act as a buffer to reduce spillover. Given that ASEAN-4 governments had issued a large number of government bonds to finance their large fiscal spending during the ongoing COVID-19 pandemic, the return and volatility spillovers from the US to ASEAN-4 could be important factors to consider when the US unwinded its unconventional monetary policy and normalized its interest rates in the medium to long term.

Since the implementation of economic reforms in 1977, China has made remarkable changes which have promoted this country to be the world's leading fast-growing country. In 2014, China's economic scale surpassed Japan's and became the second largest economy in the world. Simultaneously, China has also increased investment, trade and investment abroad, meaning that China's economic growth has a lot of impact on other countries. Assessing this effect, the study of Yang et al. (2019) evaluated the relationship between China and London stock exchanges before and after two-stock-connecting programs in China. The results indicated that Shanghai – Hong Kong stock-connecting program could promote the dependence between mainland China and London stock exchanges. Specifically, mainland China stock market was influenced by the London stock market. In addition, the dependence may slightly decrease after Shanghai – Hong Kong stock connect program. Besides, the lower-tail dependence between mainland China and London stock exchanges significantly increased after stock-connecting program while the upper-tail dependence went up in the first stock-connecting program but steadily decreased after the second stock-connecting program. Previously, research by Hussain and Li (2018) on the relationship between the Chinese stock market and other stock markets such as US, Canada, UK, Germany, Japan and Australia showed that the dependence structure between the Chinese stock market and other developed markets were low, and the Chinese stock market had more dependence on Asian ones than on the United States. In particular, the dependence between Chinese and Australian stock market was the largest while the smallest for China and the United States. It confirmed that geographical location had an impact on the dependence between markets, Australian and Asian countries near China had a greater dependency effect than the United States, which was geographically located further away. In addition, the UK and US stock markets had no impact on China in the upper tail dependence. However, dependence did exist between Japan and China stock markets, but then the effect has been fading since 2014.

Meanwhile, China's impact on smaller economies such as Vietnam, has not been studied in scholars. This can be explained that Vietnam's economic scale is still very small and has reached 343 billion USD, equal to 1/43 compared to China's 14720 billion USD, simultaneously Vietnam has lost in trade relations with China about 35.2 billion USD per year. Furthermore, the role of Vietnam in the international market is not much significant, so there have minor scholars interested in studying the dependent effects on the Vietnamese economy. Therefore, evaluating the dependence structure between China and Vietnam's stock market is a high priority, especially evaluating this relationship in the period: before the pandemic, during the pandemic, and in the context of adapting to the pandemic in order to more fully appreciate the dependent relationship of both countries. In addition, the study can bring important policy implications for Vietnam as well as countries with small-sized economies in relations with a large economy such as China. As one can see, empirical studies on dependence structure in emerging countries conducted related to ASEAN have not referred to Vietnam and China at the same time. In spite of the fact that there has been a plenty of studies which have paid attention to the situation of COVID-19, the empirical results are still lack for the issue of dependence structure between Vietnamese and Chinese stock markets. Our study will fill this gap in the empirical literature review. Furthermore, copula has been proved to be useful in capturing dependence structure in empirical review. Therefore, it is continuously employed in our study in studying the dependence between Chinese and Vietnamese stock markets during the COVID-19 pandemic.

3. Data and methodology

3.1. Data

By conducting the tail dependence between Chinese stock market and Vietnamese stock market in the context of the Covid-19 pandemic and using the data on the Ho Chi Minh City Stock Exchange (VNI) and the Shanghai Stock Exchange (SSEC) representing for Vietnam and China stock markets. In this study, we use the data on the stock exchange on the Ho Chi Minh City Stock Exchange (VNI) and the Shanghai Stock Exchange (SECC), and data is collected from January 2nd, 2018 to June 30th, 2021. We use the daily COVID cases instead of daily COVID deaths because the availability and disversification of the data that is taken from WHO, published daily.

To know the yield, the yield (R_t) is calculated by the formula (1) as follows:

$$R_t = ln\frac{x_{t+1}}{x_t}. \quad (1)$$

In which, x_{t+1} and x_t are the stock indexes of the day $t+1$ and the day t.

To assess the dependent impact of the stock market in Vietnam and China, the study is carried out through 3 phases. Phase 1, from January 1st, 2018 to January 22nd, 2020, this can be considered as the pre-Covid-19 pandemic. Phase 2, from January 23rd, 2020 to December 31st, 2020, assessing the dependence structure between Vietnamese and Chinese stock markets in the context of a huge impact of the pandemic on economy, trade, supply chain and stock markets. Phase 3, from January 1st, 2021 to June 30th, 2021, most countries are gradually adapting to live with the pandemic, vaccinate and maintain social distance. At this stage, the study re-evaluates the dependence structure between Vietnamese and Chinese stock markets in the new context, the study also makes comparisons with previous phases to assess the change in the dependent relationship between Vietnamese and Chinese stock markets. Although the COVID-19 epidemic began to appear from November 2019, the first case of covid was recorded in Vietnam on January 22, 2020. So, relatively, the authors chose a timeline as January 22, 2020 to slope the duration of the impact of COVID-19 on the dependence structure between the Chinese and Vietnamese stock markets (Table 1).

Table 2. Copula functions and its characteristics.

Copula	$C(u,v)$	Lowertail coefficient	Uppertail coefficient
Normal	$\Phi_\rho\left(\Phi^{-1}(u),\Phi^{-1}(v)\right)$, where Φ_ρ is the bivariate standardized Gaussian cdf with Pearson's correlation ρ. Φ^{-1} is the inverse of the univariate standardized Gaussian cdf		0
Clayton	$(u^{-\alpha}+v^{-\alpha}-1)^{-1/\alpha}$, $\alpha>0$		$2^{-1/\alpha}$
Plackett	$\begin{cases}\left((1+(\theta-1)(u+v))-\frac{\sqrt{(1+(\theta-1)(u+v))^2-4uv\theta(\theta-1)}}{2(\theta-1)}\right), & \text{for } 0<\theta\neq 1,\\ uv & \text{for } \theta=1\end{cases}$		0
Frank	$\frac{1}{\alpha}ln\left(1+\frac{(e^{\alpha u}-1)(e^{\alpha v}-1)}{(e^{\alpha}-1)}\right)$, where $\alpha\neq 0$		0
Student	$t_{v,r}\left(t_v^{-1}(u),t_v^{-1}(v)\right)$, where $t_{v,r}$ is the bivariate t-Student's cdf with parameter r v is degrees of freedom t_v^{-1} is the inverse of the univariate t-Student's cdf with v degrees of freedom		$2t_{v+1}\left(-\sqrt{\frac{(v+1)(1-r)}{(1+r)}}\right)$
Symmetrized Joe-Clayton	$0.5\left(C_{\tau^U,\tau^L}(u,v)+u+v-1+C_{\tau^L,\tau^U}(1-u,1-v)\right)$, where $C_{\tau^U,\tau^L}(u,v)=1-\left\{\left[(1-(1-u)^\kappa)^{-\gamma}+\left[(1-(1-v)^\kappa)^{-\gamma}-1\right]\right]^{-1/\gamma}\right\}^{1/\kappa}$ for $\kappa=1/log_2(2-\tau^U)$, $\gamma=-1/log_2(\tau^L)$, and $\tau^U,\tau^L\in(0,1)$	τ^L	τ^U

Source: Synthesis by the authors.

Note: $\boldsymbol{\Phi}_\rho(\boldsymbol{y_1};\boldsymbol{y_2})=\int_{-\infty}^{y_1}\int_{-\infty}^{y_2}\frac{1}{2\pi\sigma_X\sigma_Y\sqrt{1-\rho^2}}\exp\left(-\frac{1}{2(1-\rho^2)}\left[\left(\frac{x-\mu_X}{\sigma_X}\right)^2-2\rho\left(\frac{x-\mu_X}{\sigma_X}\right)\left(\frac{y-\mu_Y}{\sigma_Y}\right)+\left(\frac{y-\mu_Y}{\sigma_Y}\right)^2\right]\right)$; $t_{v,r}=\frac{\Gamma\left(\frac{v+n}{2}\right)|R|^{-\frac{1}{2}}}{\Gamma\left(\frac{v}{2}\right)(v\pi)^{\frac{n}{2}}}\times\left(1+\frac{1}{v}\boldsymbol{x}^T\boldsymbol{R}^{-1}\boldsymbol{x}\right)^{-\frac{v+n}{2}}$.

3.2. Methodology

To carry out this study, the authors use the copula method to assess the dependence effect between the stock markets. One can find that using the copula method is appropriate, as discussed in the study of Lyócsa and Baumöhl (2015), Guo and Wang (2016), Jiang et al. (2017), Hussain and Li (2018), Lee (2019), Yang et al. (2019), Cardoso et al. (2020), Nguyen et al. (2020), Nguyen and Nguyen (2022a), Nguyen and Nguyen (2022b). In this study, 6 copulas are concerned including Normal, Clayton, Plackett, Frank, Student and Symmetrise Joe-Clayton. As we mentioned in the previous section about the advantages of copula method, we can fit any copula functions to the data. In addition, using the copula method, there are two ways to build models of the marginal distributions as the non-parametric method and the parametric method. Further, the copula is ultimately applied on the residuals of corresponding dependence models. That is why we select the copula approach for this analysis.

In this study we choose six copulas as proxy of some copula family (Elliptic copulas include Gauss and Student copulas; and Archimedean copulas include Gumbel, Clayton and Frank copulas). Other copula functions will be employed in the future studies. In this paper, we first employ static copula. In future research, time varying copulas will be employed. The copula functions, and its characteristics, are presented in Table 2, the copula parameters are shown in the following Table 3. Moreover, the procedure to carry out the copula fitting to our data is as follows: First, we calculate the returns of daily stock prices. According to non-parameter method, we estimate the empirical cumulative distribution functions of the two returns. Six copula functions are applied on the residuals of the dependence model between two empirical cumulative distribution functions as in Arouri et al. (2014), Shahzad et al. (2017), Reboredo et al. (2016) and Rehman et al. (2020). For each fitted copula, Log-Likelihood, AIC and BIC criteria are stored so that we can select the best copula. The definition and description of these copula functions can be found in Chapter 8 in Fusai and Roncoroni (2008). For instance, Student copula is defined as follows:

Definition (Student copula): For a symmetric and positive definite matrix R with unit diagonal entries, let $T_{R,v}$ denote the standardized multivariate Student's t distribution with correlation matrix R and $v\geq 1$ degrees of freedom as the equation (2):

$$T_{R,v}(y_1,\dots y_n)=\int_{-\infty}^{y_1}\cdots\int_{-\infty}^{y_n}\frac{\Gamma(\frac{v+n}{2})|R|^{\frac{-1}{2}}}{\Gamma(\frac{v}{2})(v\pi)^{\frac{n}{2}}}.(1+\frac{1}{v}x^TR^{-1}x)^{\frac{(v+n)}{2}}dx_1\dots dx_n \quad (2)$$

The multivariate Student copula is defined as in the equation (3):

$$C(u_1,\dots,u_n;T,v)=T_{R,v}\left(T_v^{-1}(u_1),\dots,T_v^{-1}(u_n)\right) \quad (3)$$

where T_v^{-1} is the inverse of the univariate Student's t cumulative distribution function with v degrees of freedom. $\Gamma(z)$ is the Gamma function, which is defined by:

$$\Gamma(z)=\int_0^{+\infty}x^{z-1}e^{-x}dx$$

The corresponding copula density can be computed as in the equation (4):

$$C(u_1,\dots,u_n;R)=|R|^{\frac{-1}{2}}\frac{\Gamma\left(\frac{v+n}{2}\right)}{\Gamma\left(\frac{v}{2}\right)}\left(\frac{\Gamma\left(\frac{v}{2}\right)}{\Gamma\left(\frac{v+1}{2}\right)}\right)^n\frac{(1+\frac{1}{v}\omega^TR^{-1}\omega)^{\frac{-(v+n)}{2}}}{\prod_{j=1}^n\left(1+(\varrho_j^2)/v\right)^{\frac{-(v+1)}{2}}} \quad (4)$$

where $\omega_j=T_v^{-1}(u_j)$. It can be proved that the Student t copula exhibits identical upper and lower tail dependence coefficients, as in the equation (5):

$$\lambda_U=\lambda_L=2\overline{T}_{v+1}\left(\frac{\sqrt{v+1}}{\sqrt{1+p}}.\sqrt{1-p}\right) \quad (5)$$

where $\overline{T}_{v+1}$ denotes the survival probability for a univariate Student t with v + 1 degrees of freedom. Clearly, this coefficient is increasing with ρ, decreasing with v, and vanishes as the number of degrees of freedom diverges to infinity, provided that $\rho<1$. All information related to copula functions, parameters and its characteristics can be shown in Table 2, and Table 3.

Before presenting the empirical results, let us begin with the procedure of fitting copulas on time series. When using the copula method, there are two ways to build models of the marginal distributions: the non-parametric method (using the empirical distribution of returns as the marginal distribution) and the parametric method (using boundary models built from the same set of independent variables, such as ARMA, ARFIMA, ARIMA, ARMA GARCH, ARFIMA GARCH, ARIMA GARCH, etc.). In this paper, the authors chose empirical distribution of returns as the marginal distribution. Whatever the choice of the two methods, the copula is ultimately applied on the residuals of corresponding dependence models. And the copula approach has greatly contributed on the dependence structure that has been ignored in the parametric method based on ARMA, ARFIMA, ARIMA, ARMA GARCH, ARFIMA GARCH, ARIMA GARCH, etc.

Table 3. Copula parameters.

Copula	Parameters	Copula function
Normal	ρ	$C(\mu_x, \mu_y, \rho) = \varphi_\rho(\varphi^{-1}(\mu_x), \varphi^{-1}(\mu_y))$
Clayton	$\theta > 0$	$C(\mu, \upsilon, \theta) = (\mu^{-\theta} + \upsilon^{-\theta} - 1)^{\frac{-1}{\theta}}$
Plackett	$\theta > 0$	$C(\mu, \upsilon) = \frac{1+(\theta-1)(\mu+\upsilon) - \{[1+(\theta-1)(\mu+\upsilon)]^2 - 4\theta(\theta-1)\mu\upsilon\}^{\frac{1}{2}}}{2(\theta-1)}$
Frank	$\theta \neq 0$	$C(\mu, \upsilon, \theta) = \frac{-1}{\theta} Ln\left[1 + \frac{\left(exp(-\theta_\mu)^{-1}\right)\left(exp(-\theta_\upsilon)^{-1}\right)}{exp(-\theta)-1}\right]$
Student	ρ, k	$C(\mu_x, \mu_y, \rho, k) = T_{\rho,k}(T_k^{-1}(\mu_x), T_k^{-1}(\mu_y))$
Symmetrized-Joe-Clayton	u, v	$C(u, \upsilon \mid \tau^U, \tau^L) = 1 - \left(\left[1-(1-u)^k\right]^{-\gamma} + \left[1-\upsilon^k\right]^{-\gamma} - 1^{-1/\gamma}\right)^{1/k}$

Source: Synthesis by the authors.

Note: $\varphi(x; y) = \frac{1}{2\pi\sigma_X\sigma_Y\sqrt{1-\rho^2}} \exp\left(-\frac{1}{2(1-\rho^2)}\left[\left(\frac{x-\mu_X}{\sigma_X}\right)^2 - 2\rho\left(\frac{x-\mu_X}{\sigma_X}\right)\left(\frac{y-\mu_Y}{\sigma_Y}\right) + \left(\frac{y-\mu_Y}{\sigma_Y}\right)^2\right]\right)$.

Table 4. Returns of daily stocks.

Returns	R_VNI			R_SSEC		
Period	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
Mean	−8.73E-06	0.0004	0.0019	−0.0001	0.0005	0.0002
Median	0.0004	0.0021	0.0030	3.11E-05	0.0011	0.0004
Maximum	0.0370	0.0486	0.0379	0.0544	0.0555	0.0237
Minimum	−0.0549	−0.0659	−0.0690	−0.0574	−0.1082	−0.0232
Std. Dev.	0.0112	0.0156	0.0154	0.0119	0.0142	0.0094
Skewness	−0.8869	−1.4410	−1.3373	−0.3669	−1.9876	−0.0785
Kurtosis	6.7415	7.8839	7.5423	6.2732	18.4291	3.2280
Jarque-Bera	355.0511	302.8347	135.4630	233.0260	2390.540	0.3737
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.8295
Sum	−0.0043	0.1073	0.2288	−0.0898	0.1263	0.0248
Sum Sq. Dev.	0.0629	0.0553	0.0277	0.0702	0.0456	0.0103
Obs.	497	226	117	497	226	117

Note: R_VNI, R_SSEC denote for returns of Vietnam Index and China Index.
Source: Analyzed by the authors.

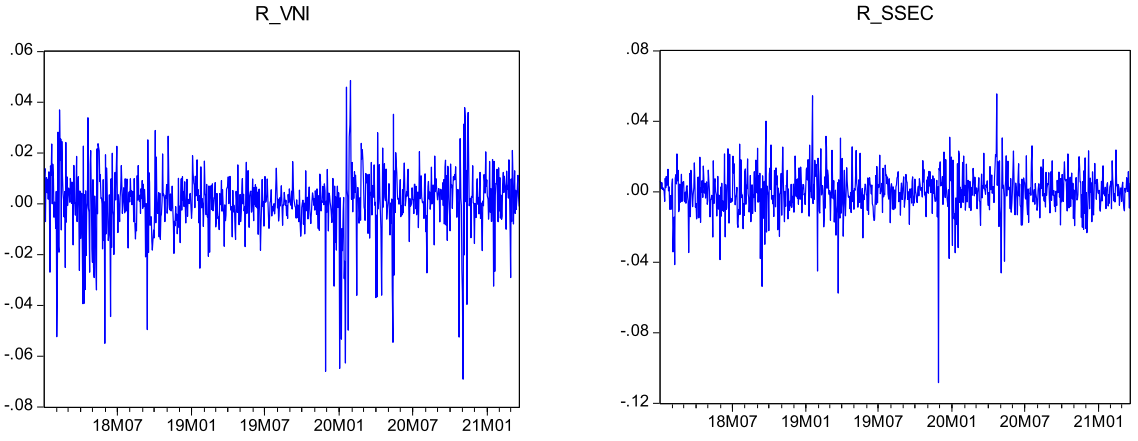


Fig. 1. VNI and SSEC returns' plots.

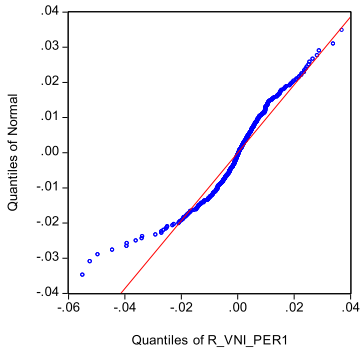
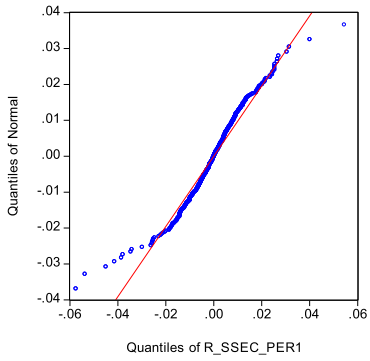
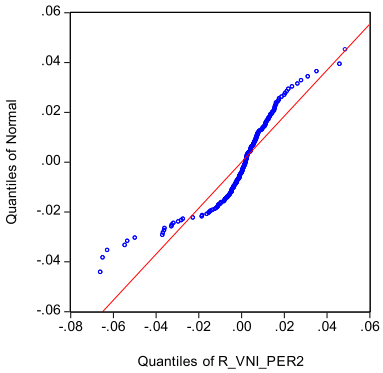
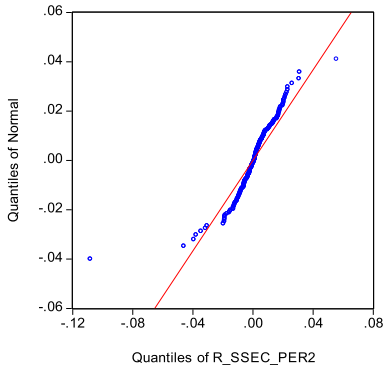
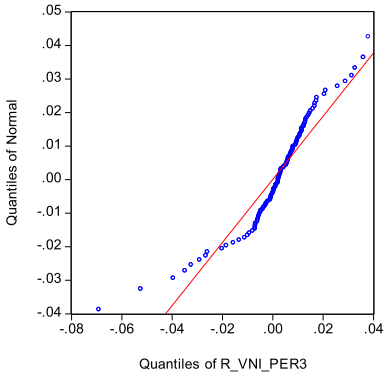
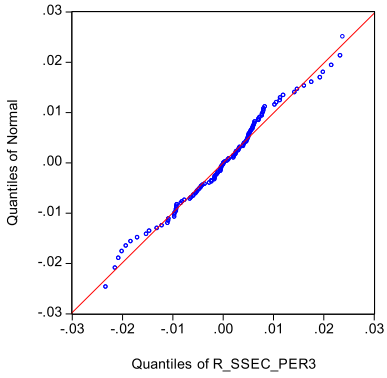
4. Results

4.1. Descriptive statistics

Table 4 presents descriptive statistics of the stock markets of Vietnam and China in the three studied periods. In the pre-pandemic (before Covid pandemic), the stock market of Vietnam and China had negative on average returns, and the Chinese market had a lower rate of return than Vietnamese one. Indeed, the US has waged the Sino-American war by raising tariffs on exports from China since 2018, and increased protectionism in some countries, which has had an impact on the Chinese economy while Vietnam's economy has been considered to have many benefits. Moreover, the stock markets of both countries fell during this period, but the impact on China was more than Vietnam.

Phase 2, WHO announced a worldwide epidemic on January 23rd, 2020. Vietnam and China have begun to be affected by the pandemic while many countries around the world implement social distancing and the number of Covid cases is increasing in the first half of 2020. Moreover, many countries' health systems have to operate at full capacity, and economic growth has slowed down in most countries. In that context, the stock market in the first and second quarters of 2020 of Vietnam and China had a decline, but in the third and fourth quarters, the stock market started to grow again, therefore the economy started to recovered slowly. The economic growth of Vietnam and China in 2020 were both positive at 2.92% and 3%, and as the few countries in the world that could still maintain growth.

Phase 3, Vietnam and China started vaccination to maintain their economic status in response to the pandemic, during this time economic growth and stock market in Q1 and Q2 started to recover, which was a signal for economic recovery in the coming quarters. Conclusion, Fig. 1 indicates that the variance of VNI returns was quite high at some days

Period	R_VNI	R_SSEC
Jan 1st 2018 – Jan 22nd 2020		
Jan 23rd 2020 – Dec 31st 2020		
Jan 1st 2021 – Jun 30th 2021		

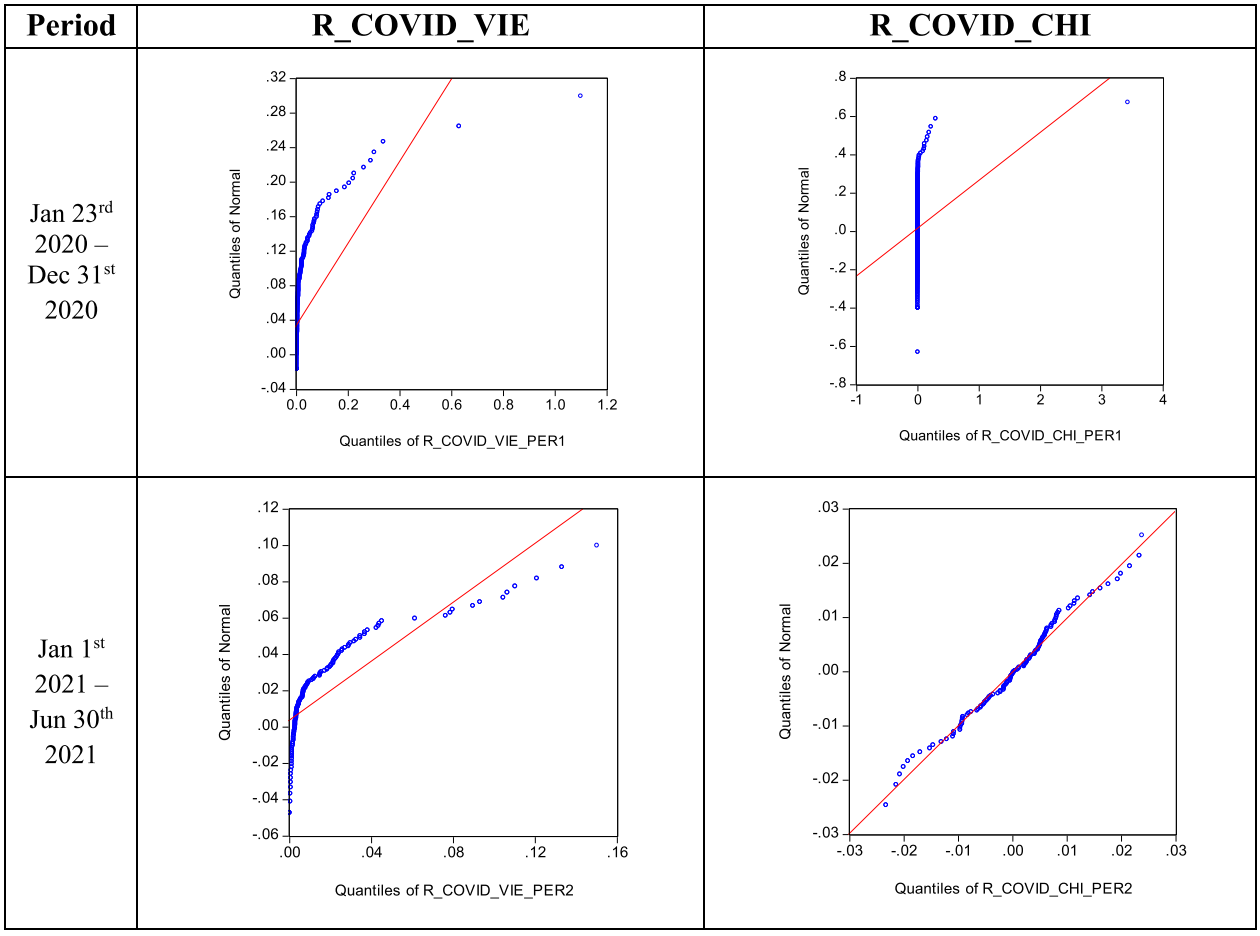
Note: R_VNI, R_SSEC denote for returns of Vietnam Index and China Index.
Source: Drew by the authors.

Fig. 2. Normal q-q plots of returns of stock indices.

in Q1/2020, Q3/2020 and Q1/2021 while the variance of SECC was unusually high in Q3/2020 and more stable in the remaining periods. In addition, this trend will continue to stabilize until 2021, which reflects the lower risk level of the China stock market during the covid pandemic than that of Vietnam.

Table 5 presents the pandemic occurring in Vietnam and China. In 2020, the average daily increase of Covid cases in Vietnam and China is 2.79% and 2.22%, respectively. In 2021, China has basically controlled the pandemic, the number of new cases in this country is very low while Vietnam is still not completely controlled, the increase in the number of cases still reaches an average rate of 2.22%. Also, looking at Figs. 2 and 3, the data series are mostly non-normally distributed, showing volatility in stock indices and infections over time. According to research by Guo and Wang (2016), Shahzad et al. (2017), Yang et al. (2019) and Cardoso et al. (2020), using copula analysis is appropriate in case the data series are not normally distributed. In addition, for the data series that are normally distributed, Normal copula should be preferred. According to Rodriguez (2006), the weakness of correlation-based analysis was if correlation coefficients got zero, it does not indicate the independence among random variables or increasing in the correlation between two variables could increase the variance of one variable. Therefore, the copula is more appropriate to describe the picture of the dependence structure. In addition to Blanca et al. (2013), non-normal distributions will be commonly appeared in analyzing problems of social sciences, concluding that it has not much influenced on the coming results, especially in the copula approach.

Table 6 presents the stationarity test results for the data series, with two cases as (1) intercept, (2) Intercept and trend that are common in the time-series data. According to the Augmented Dickey–Fuller test



Note: R_COVID_VIE, R_COVID_CHI denote for Returns of Daily Total New Cases of Vietnam and China.
Source: Drew by the authors.

Fig. 3. Normal q-q plots of returns of daily total new cases.

Table 5. Returns of daily total new cases.

Returns	R_COVID_VIE		R_COVID_CHI	
Period	Phase 2	Phase 3	Phase 2	Phase 3
Mean	0.0279	0.0204	0.0222	0.0002
Median	0.0029	0.0069	0.0002	0.0006
Maximum	1.0986	0.1501	3.4253	0.0237
Minimum	0.0000	0.0000	−1.20E-05	−0.0232
Std. Dev.	0.0949	0.0301	0.2287	0.0094
Skewness	7.7153	2.3541	14.5507	−0.0947
Kurtosis	77.2312	8.2912	216.7698	3.2203
Jarque-Bera	56525.74	250.8232	442171.9	0.4153
Probability	0.0000	0.0000	0.0000	0.8124
Sum	6.5964	2.4544	5.0687	0.0334
Sum Sq. Dev.	2.1204	0.1081	11.8781	0.0104
Observations	236	120	228	118

Note: R_COVID_VIE, R_COVID_CHI denote for Returns of Daily Total New Cases of Vietnam and China.
Source: Analyzed by the authors.

Table 6. Unit root tests.

Intercept/trend	Variables	Period	Augmented Dickey–Fuller test	Phillips–Perron test
Intercept	R_VNI	Phase 1	−14.099*	−22.949*
		Phase 2	−13.713*	−13.739*
		Phase 3	−10.462*	−11.437*
	R_SSEC	Phase 1	−22.841*	−22.838*
		Phase 2	−17.308*	−17.133*
		Phase 3	−7.128*	−11.193*
	R_COVID_VIE	Phase 2	−4.533*	−16.576*
		Phase 3	−1.577	−9.849*
	R_COVID_CHI	Phase 2	−6.128*	−13.584*
		Phase 3	−7.082*	−11.184*
Intercept and trend	R_VNI	Phase 1	−14.087*	−22.929*
		Phase 2	−13.912*	−13.945*
		Phase 3	−10.452*	−12.764*
	R_SSEC	Phase 1	−22.888*	−22.880*
		Phase 2	−17.250*	−17.080*
		Phase 3	−7.146*	−11.159*
	R_COVID_VIE	Phase 2	−4.747*	−17.336*
		Phase 3	−2.065	−10.878*
	R_COVID_CHI	Phase 2	−6.049*	−13.887*
		Phase 3	−7.080*	−11.142*

Notes: * indicates significant at 1% level.
Note: R_VNI, R_SSEC denote for returns of Vietnam Index and China Index; R_COVID_VIE, R_COVID_CHI denote for Returns of Daily Total New Cases of Vietnam and China.
Source: Authors' computation.

and the Phillips–Perron test, the data series are stationary, which is suitable for performing copula analysis.

Performing analysis across 6 copulas, Normal, Clayton, Plackett, Frank, Student, Symmetrised Joe-Clayton, Tables 7 and 8 analyze the relationship between the Covid-19 pandemic on the Vietnamese stock market and the Chinese stock market in phase 2 and phase 3, concluding that there exists a dependence structure between the impact of the pandemic and the stock market. Among the matched copulas, Log-Likelihood, AIC and BIC criteria are calculated and used to select the best copula. For example, in the upper part of Table 7, among 6 copulas fitted, Student copula is the one whose LL, AIC and BIC values

Table 7. Copula parameters for R_VNI and R_COVID_VNI and best copula.

Copula	Para 1	Para 2	LL	AIC	BIC	R
Phase 2						
Normal	−0.0621		−0.455	−0.903	−0.888	2
Clayton	0.0001		0.0012	0.0108	0.0255	5
Plackett	0.8723		−0.189	−0.371	−0.356	3
Frank	0.0001		0.0001	0.0088	0.0234	4
Student	−0.0444	3.5206	−5.890	−11.76	−11.73	1
Symmetrized Joe-Clayton	1.9e-06	1.9e-06	0.4765	0.969	0.999	6
Phase 3						
Normal	0.1030		−0.640	−1.264	−1.241	4
Clayton	0.1581		−0.945	−1.874	−1.851	3
Plackett	1.3206		−0.467	−0.919	−0.895	5
Frank	0.5346		−0.443	−0.870	−0.847	6
Student	0.0990	7.197	−1.172	−2.311	−2.265	1
Symmetrized Joe-Clayton	3.5e-07	0.067	−1.068	−2.104	−2.057	2

Note: Para and R denote for parameter and ranking.
Source: Analyzed by the authors.

Table 8. Copula parameters for R_SSEC and R_COVID_CHI and best copula.

Copula	Para 1	Para 2	LL	AIC	BIC	R
Phase 2						
Normal	0.0414		−0.195	−0.382	−0.367	5
Clayton	0.0001		6.3e-04	0.010	0.0251	6
Plackett	1.2475		−0.542	−1.076	−1.061	3
Frank	0.4119		−0.502	−0.996	−0.981	4
Student	0.0644	6.3477	−1.916	−3.816	−3.786	1
Symmetrized Joe-Clayton	0.0435	5.2e-08	−1.0956	−2.173	−2.143	2
Phase 3						
Normal	0.0119		−0.008	0.0001	0.0236	3
Clayton	0.0001		0.0008	0.0187	0.0422	5
Plackett	1.1245		−0.095	−0.173	−0.150	2
Frank	0.2475		−0.099	−0.182	−0.158	1
Student	0.0107	100	0.0662	0.1662	0.2132	6
Symmetrized Joe-Clayton	0.0035	1.8e-09	−0.024	−0.015	0.0312	4

Note: Para and R denote for parameter and ranking.
Source: Analyzed by the authors.

Table 9. Copula parameters for R_SSEC and R_VNI and best copula in.

Copula	Para 1	Para 2	LL	AIC	BIC	R
Phase 1						
Normal	0.2734		−19.30	−38.60	−38.59	4
Clayton	0.3970		−22.92	−45.84	−45.83	2
Plackett	2.1180		−15.35	−30.71	−30.70	5
Frank	1.5125		−15.02	−30.05	−30.04	6
Student	0.2725	15.6323	−20.02	−40.04	−40.02	3
Symmetrized Joe-Clayton	0.0084	0.2203	−24.07	−48.13	−48.11	1
Phase 2						
Normal	0.2967		−10.41	−20.82	−20.80	4
Clayton	0.5032		−15.11	−30.21	−30.19	2
Plackett	2.3094		−8.01	−16.01	−15.99	5
Frank	1.6076		−7.355	−14.70	−14.68	6
Student	0.2754	4.8764	−12.87	−25.73	−25.70	3
Symmetrized Joe-Clayton	0.0019	0.2943	−15.68	−31.35	−31.32	1
Phase 3						
Normal	0.2764		−4.650	−9.283	−9.259	4
Clayton	0.4338		−5.667	−11.31	−11.29	1
Plackett	2.2781		−3.982	−7.947	−7.924	5
Frank	1.5964		−3.724	−7.431	−7.408	6
Student	0.2936	76.7887	−4.673	−9.312	−9.265	3
Symmetrized Joe-Clayton	0.0019	0.2578	−5.620	−11.20	−11.15	2

Note: Para and R denote for parameter and ranking.
Source: Analyzed by the authors.

are all the lowest. Therefore, it is indeed the best copulas of all. And it ranks the first order. In order to analyze the dependent effects between Vietnam and China stock markets, Table 9 analyzes the dependence structure between Vietnam and China stock markets through 3 phases, and both confirm the existence of a relationship between Vietnam and China.

It can be concluded that there exists dependence structure between impact of pandemic and stock market based on Table 7 and Table 8.

Table 10. Best copula for pairs of returns of stock indices, total new covid cases, and tail dependence coefficients.

Items	Period	Best copula	Upper tail dependence coefficient	Lower tail dependence coefficient
Returns of stock indices and total new covid cases				
R_VNI and R_COVID_VNI	Phase 2	Student	0.0826	0.0826
	Phase 3	Student	0.0314	0.0314
R_ SSEC and R_COVID_CHI	Phase 2	Student	0.0371	0.0371
	Phase 3	Frank	0.0000	0.0000
Returns of stock indices				
R_VNI and R_SSEC	Phase 1	Symmetrized Joe-Clayton	0.2203	0.0084
	Phase 2	Symmetrized Joe-Clayton	0.2943	0.0019
	Phase 3	Clayton	0.2031	0.0000

Note: UTDC: upper tail dependence coefficient, LTDC: lower tail dependence coefficient.
Source: Analyzed by the authors.

Because we use the time break on January 22, 2020 when the first case of covid was recorded in Vietnam to separate the daily stock returns. And for each period before and after the appearance of COVID-19, we estimate the dependence structure between the two stock markets. The change of best copula function for the pair of returns in the two period reveals the impact of COVID-19 on the dependence structure between the two stock markets. The change of correlation for the pair of returns in the two period shows the impact of COVID-19 on the dependence degree between the two stock markets.

The results of Table 9 and Table 10 present the dependence relationship between Vietnam and China stock markets through 3 periods, and the impact of the Covid pandemic on each country's stock market in the period of 2020 – 2021. Research results show that there does not exist a dependent relationship of Chinese stocks on Vietnam before the pandemic because the results of the dependent effect test are positive, but not significant. In the first year of the pandemic, the pandemic has a higher impact on the Vietnamese stock market than China in both upper and lower tail dependence. It can be seen that the impact of the pandemic makes the Vietnamese market more volatile than the Chinese market. In fact, the Vietnam's economy is much dependent on trade openness while China's economy has a huge market for its products that are made in the country (Lam and Nguyen, 2019). In addition, Vietnam is doing well to further diversify its markets for exporting in order to reduce its dependence on China. Empirical evidence also shows that, the relationship between the Vietnamese and Chinese markets during the pandemic become more interdependent than before the pandemic, especially the upper tail dependence of the market. This evidence is consistent with the case of China and US or London stock markets based on the study of Yang et al. (2019). Similar to Hussain and Li (2018), the dependence between Chinese and United States is smallest while per capita GDP in United States is much higher than China, particularly China has about $15 trillion and roughly a quarter smaller than the US GDP. As suggested in Zhu and Orlik (2021), Chinese productivity will significantly catch up to 70% of the US level by 2050, therefore, China may need more time to catch up with the United States while the birth rate in China is decreasing with disproportionate between regions in development. Another possibility, Hussain and Li (2018) also confirmed that dependence did exist between Japan and China stock markets, but then the effect has been fading since 2014 because Japan's economy fell into recession for more than two decades while China's economic size surpassed Japan in 2014, that's why the impact of Japan's economy on China is gradually decreasing and not much anymore.

During the third phase (i.e. the second year of the pandemic), China mostly controls the pandemic thanks to its vaccination policy and radical social distancing. Therefore, the impact of the pandemic on the stock market in China has disappeared. Indeed, China's economy in 2021 has grown strongly, nearly 12.7% in Q1/2021 and 7.9% in Q2/2021 (PWC, 2021), and is classified as one of the fastest growing countries in the world. Meanwhile, empirical evidence still concludes that the pandemic still has an impact on Vietnam's stock market. Specifically, there will be a strong impact of the Chinese stock market on Vietnam in 2021, especially in the upper tail dependence, which means that when the Chinese stock market rises, the Vietnamese stock market will increase accordingly. In the lower tail dependence, no evidence of impact is found. As shown the results on the economic performance, Vietnam real GDP growth significantly slows to 2.58% in response of the rising of the pandemic in 2021 (Nikkei Asia, 2022). In 2021, the pandemic continued to expand, Vietnam was forced to maintain stricter social distancing and quarantine than its neighbors as China. At the same time, China real GDP growth totally beat expectations with 8.1%, and beyond the target of 6% (Tianyu, 2022). It meant that a stronger rebound for China's economic performance than Vietnam in 2021 or Vietnam's economy is less resilient than their counterpart while China has pledge to safeguard macroeconomic instability, continue to maintain high growth and better adapt to the pandemic.

5. Conclusions

Studying the dependent impact of the Chinese stock market on Vietnam in the context of the Covid-19 pandemic by using data on the Ho Chi Minh Stock Exchange (VNI) as a representative of Vietnam and the Shanghai Stock Exchange (SSEC) representing for China. This impact analysis is carried out across 3 phases, including, pre-pandemic, the pandemic, and pandemic-adaptation phase. Using the analytical method through 6 copulas including Normal, Clayton, Plackett, Frank, Student and Symmetrised Joe-Clayton, the research results confirm that there is no dependent relationship between the stock market between the two countries in the pre-pandemic. However, the pandemic has had an impact on the stock market between the two countries, the Vietnamese stock market has become dependent on the Chinese stock market, especially depending on the upper tail dependence of the Chinese stock market. Finally, in the adaptation period to the pandemic, this dependence relationship between Vietnam and China stock markets still exists but less than, and the pandemic has no impact on the Chinese stock market while the pandemic is still affecting strongly affect the Vietnamese stock market.

The study has several policy implications. First, small economies (such as Vietnam in this study) need extensive economic integration and diversification of relationships with many economies in order to reduce dependence on a particular economy. To do this, the economic structure is diversified, with high added value and the ability to compete in the international market. Second, in the wave of external shocks, the small economy has a larger impact than the large economy, so governments need to have scenarios to deal with external shocks to minimize risks. Thirdly, the financial market improves governance skills, the legal system and supervision mechanism in order to ensure the ability to adapt to risks and minimize the risks. Fourth, the research has implications for investors, in the first year of the pandemic, the pandemic has a higher impact on the Vietnamese stock market than China in both upper and lower tail dependence. It can be seen that the impact of the pandemic makes the Vietnamese market more volatile than the Chinese market. Therefore, investors can get more profit as well as more risks on

the Vietnam's stock market than China. In addition, China mostly controls the pandemic in the second year of the pandemic, and the impact of the pandemic on the stock market in China has disappeared. Therefore, China's stock market was likely to become safer for investors than Vietnam.

The study has some limitations and may be suggestive for future researches. Firstly, the study assesses the impact of the stock market in Vietnam and China in the context of the COVID-19 pandemic, and the study selects the number of new infections as a proxy for the COVID-19 pandemic. However, the number of COVID-19 infections may be affected by vaccination policies and the way in which infection counts as well as information disclosure on infection status are not timely or untimely in each country. Secondly, the dependence structure in the stock markets is also affected by the relationship between the two countries on trade, investment and many other factors, and these factors have not been evaluated in this study. Thirdly, the study selects the Shanghai Stock Exchange to represent for the Chinese stock market and the Ho Chi Minh City Stock Exchange to represent for the Vietnamese stock market, and this selection does not fully reflect the stock exchange in each country.

Declarations

Author contribution statement

Van Chien Nguyen; Thu Thuy Nguyen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

N/A.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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