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Does COVID-19 Crisis Affects the Spillover of Oil Market's Return and Risk on Thailand's Sectoral Stock Return?: Evidence from Bivariate DCC GARCH-in-Mean Model

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Abstract – *This paper utilizes a bivariate DCC GARCH-in-Mean model to capture the spillover of Singapore's oil market risk and return on Thailand's stock market return by using daily data of 11 stock indices include 1 market level, 8 industry levels and 2 sector levels. For the period before COVID-19 appearance from October 5, 2016 to October 31, 2019, we found that Singapore's oil market return had a significant positive effect on the return of Resources, Industrials, Petrochemicals and Chemicals, Energy and Utilities and Stock Exchange of Thailand while Singapore's oil market risk had a significant negative effect on Consumer Products, Industrials and Petrochemicals and Chemicals. For the period during COVID-19 crisis from November 1, 2019 to June 8, 2020, we found that Singapore's oil market return had a significant positive effect on every category of Thailand's stock return while Singapore's oil market risk had a significant negative effect on Financials, Consumer Products, Agro and Food Industry, Property and Construction, Services and Stock Exchange of Thailand. We found that the spillover of Singapore's oil price return on Thailand's sectoral stock return became aggressively higher during COVID-19 crisis. According to our results, we can conclude that the investors consider Singapore's Oil market and Thailand's stock market as a complimentary investment product in their portfolio. Moreover, the investors consider Singapore's oil market volatility as a signal of incoming recession or crisis to withdraw their investment from Thailand's stock market. In addition, our study found the evidence that the daily changing of COVID-19 anxiousness had a significant negative effect on every category of Thailand's stock return. The DCC estimation results showed that the correlation between Singapore's oil market return and Thailand's sectoral stock return was varying over time and became more fluctuated during COVID-19 crisis.*

Keywords – *bivariate GARCH in mean model, COVID-19, dynamic conditional correlation, Singapore's oil market, Thailand's stock market.*

1. INTRODUCTION

The impact of oil market return and risk on stock market return has attracted considerable attention from researchers and investors since the spillover effect of both oil market return and risk on stock market return has important implications for portfolio management.

For the market level, it is very interesting to study on the investor's point of view on oil and stock market. The investors may consider oil and stock as a complimentary investment product which means they will invest in oil and stock together, then the relationship between oil market return and stock market return will be positive. On the other hand, the investors may consider oil and stock as a substituted investment product which means if they want to invest in stock market they will take the money out of oil market, then the relationship between oil market return and stock market return will be negative.

For the industry level, the changing in oil price may have a positive or negative effect on some industries differently. The industry that involve with the high volume of oil inventory will get a benefit when oil price goes up, then the stock return of this industry will move in the same direction with oil's return. For the industry that their production cost and transportation cost rely heavily on oil price will get a benefit when oil price goes down, then the stock return of this industry will move in the opposite direction with oil's return. Therefore, instead of study only on market level like many previous studies, we also study on difference industry groups since the effect of oil market return may have a difference effect on each industry [1]-[3]. The result on this study will confirm whether there is an asymmetric relationship between oil market return and stock return on each industry which will help the investor the optimized their investment portfolio [2], [4].

Since oil is one of the most important commodities that being involved in the production process and the transportation of many industries, when there is some uncertainty about the future economy, it will affect the demand and supply of oil which will make the oil price become more volatility. The investor may consider the oil price volatility as a signal of incoming economic recession or crisis, then they will response by withdrawing their investment from stock market. So, if this hypothesis is true, we will see the negative relationship between oil price volatility or oil market risk and stock market return.

A large number of studies have found that there is relationship between oil price change and stock market return all over the globe. For instance, [5] found the impact of oil price volatility on real stock returns in

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South Korea. Diaz and de Gracia [6] found negative response of stock markets return to an increase in oil price volatility in G7 countries. Likewise, [7] found strong evidence of volatility spillover between oil and stock markets in G-7 countries including time-varying correlations between them. Also, the results from [8] indicated that oil price shock significantly affect the volatility of real stock returns in U.S. and 13 European countries. Furthermore, [9] found positive effect of oil price shocks on Chinese stock returns. Ratti and Hasan [10] also found that an increase in oil price return significantly reduces stock market return in Australia. Huynh and Phan [11], by using Autoregressive-Distributed Lag (ARDL) approach, found the positive and negative impact of crude oil price on stock market return in short run and long run, respectively in Vietnam. This result consistent with one from [12] who studied the relationship between oil price and stock returns in Nigeria.

Oil price movement is an essential factor in the economy since the role of oil continues to be the most significant economic driver. Many studies found the shocks of oil prices cause a substantial role in the economic downturn (*e.g.*, [13]-[15]). So, it is very crucial to study the relationship between the oil price change and stock return because the movement of oil price causes the economic sector uncertainty. Several studies paid attention to investigate the oil price instability impact on the stock market. For example, [16] show the oil price shock on the U.S. stock return significantly. The study of [17], [18], who present the significant impact of oil price movement on stock return and found the change of oil price is a risk for portfolio management. Our objectives are concentrating on the influence of oil shock on the stock market return in the ASEAN region. Koh [19] and Robiyanto [20] examined the impact of oil price shocks on real stock prices in ASEAN-5, and they found the positive and negative oil price shocks lead to the fall in the real stock price in all countries. Hersugondo [21] research on the effect of the oil price movement on stock market return in several countries in ASEAN and the results show the oil price change only has a significant impact on Thai and Malaysian stock return. Moreover, [13] investigated the effect of the uncertainty of oil price effect on the Thai stock market and revealed that there exists volatility transmission from oil price to the Thai stock market by the oil price movement and its volatility adversely affect the main stock returns. The research of [22] show that the movement of oil price has a negative impact on the stock market return of Malaysia.

Since the coronavirus (COVID-19) appearance began in China on November 2019, it has caused a dramatic drop in demand for oil products. As a result, investors and traders are more concerned about market situation and has led to the oil price shock and increase in oil market volatility. Moreover, the COVID-19 pandemic has continued to be a source of volatility in financial markets, for example, stock markets, exchange rate markets, and credit markets. Therefore, this crisis might affect the relationship between oil price shock and stock market return. According to the study of [23], who studied co-movements between oil prices and sector stock markets in Saudi Arabia, the result show that the co-movements between oil prices and stock markets intensify in the aftermath of the crisis. In addition, [24] found positive interdependence between oil and stock prices during the global financial crisis period while oil price changes had no effect on stock returns in the pre-crisis period. More importantly, many recent researches have focus on studying the impact of COVID-19 on oil price and stock market volatility, for instance, [25] investigated the impact of COVID-19 numbers on crude oil prices and found that the number of COVID-19 new infections have a marginal negative affect on the crude oil price. Sharif and Yarovaya [26] analysed the connectedness between the spread of COVID-19, oil price volatility, stock market, geopolitical risk and economic policy uncertainty in the US. However, there is still a lack of research in examining the impact of COVID-19 on the volatility spillover between oil market and stock market.

Thailand's stock market has attracted many investors around the world for decades since it is considered as one of the world's best performers. Not only a relatively high stock market return, but also foreign exchange market stability that make Thai stock market more complacent. Nevertheless, it appears only few papers dealing with the impact of oil price shock on stock market return in Thailand, for example, the study of [27], [28] Additionally, many recent studies have applied Dynamic Conditional Correlation (DCC) multivariate GARCH models which allows correlation to change over time. This model utilizes the flexibility of the univariate GARCH models and yet simplifies the parametrization and the empirical estimation. Consequently, Dynamic Conditional Correlation model becomes a reliable tool and widely used for estimating interconnections between several assets in financial markets [29]-[35].

Therefore, this paper aims to investigate the spillover effect of Singapore's oil market return on sectoral stock return in Thailand. More importantly, we study the impact of COVID-19 crisis on Thailand's stock return and the volatility spill over of Singapore's oil market on Thailand's stock return. We employ the bivariate DCC GARCH-in-Mean model which allow the correlation between oil market return on sectoral stock return to be varied over time.

Our paper offers four contributions; the first is to study the spill over of Singapore's oil market return on Thailand's sectoral stock return. The second is to study the spill over of Singapore's oil market risk on Thailand's sectoral stock return. The third is to study the dynamic correlation between Singapore's oil market return and Thailand's sectoral stock return. Lastly, we study the effect of COVID-19 crisis on Thailand's sectoral stock return. The rest of this study is constructed as follows. In Section 2, we describe the dataset. Section 3 presents the methodology. Section 4 provides the empirical results and the section 5 contains conclusions.

2. DATA DESCRIPTION

Our study is about the risk and return of oil market and the return of Thailand's stock market. For the data that we use in this study, we use the "Asian Fuel Oil 3.5% 180 cst FOB Singapore cargo spot" in Singapore Exchange Limited (SGX) market for the oil price data. We use oil price from SGX because Singapore is the hub for Asian Oil market and its location is very close to Thailand. So, the SGX's oil price directly affects Thailand's stock market [36]. The oil price from SGX has a unit in "US dollar per metric tonne" and the oil price data is retrieved from Bloomberg.

Table 1. The list of industry group and sector in stock exchange of Thailand (SET).

Industry	Abbreviation	Sector
Agro and Food Industry	AGRO	Agribusiness, Food and Beverage
Consumer Products	CONSUMP	Fashion, Home and Office Products, Personal Products and Pharmaceuticals
Financials	FINCIAL	Banking, Finance and Securities, Insurance
Industrials	INDUS	Automotive, Industrial Materials and Machinery, Paper and Printing Materials, Petrochemicals and Chemicals, Packaging, Steel
Property and Construction	PROPCON	Construction Materials, Construction Services, Property Fund and REITs, Property Development
Resources	RESOURC	Energy and Utilities, Mining
Services	SERVICE	Commerce, Health Care Services, Media and Publishing, Professional Services, Tourism and Leisure, Transportation and Logistics
Technology	TECH	Electronic Components, Information and Communication Technology

For the data of Thailand's stock return, we focus on 3 levels; market level, industry level and sector level. For the market level, we use Stock Exchange of Thailand (SET) index. The Stock Exchange of Thailand divides the companies in the market into 8 industries and 28 sectors as it's shown in Table 1. For the industry level, we use the data of 8 industry group indices; Agro and Food Industry (AGRO), Consumer Products (CONSUMP), Financials (FINCIAL), Industrials (INDUS), Property and Construction (PROPCORN), Resources (RESOURC), Services (SERVICE) and Technology (TECH) [37].

For the sector level, we focus only the sectors that relate directly to oil price which are Petrochemicals and Chemicals (PETRO) and Energy and Utilities (ENERG).

So, in total, we have 11 stock indices, that come from 1 market level, 8 industry levels and 2 sector levels, to study in this paper. All of the data on Thailand's stock indices are retrieved from Stock Exchange of Thailand.

The price of oil in SGX and the stock index of each categories will be converted to the return by using the conventional formula, $R_t = ln\left(\frac{P_t}{P_{t-1}}\right)$ .The name of variables in this paper are defines as follow. SGX is the return of oil price in Singapore oil market. FINCIAL is the return of financials group index. CONSUMP is the return of consumer products group index. AGRO is the return of agriculture and food industry group index. PROPCON is the return of property and construction group index. RESOURC is the return of resources group index. SERVICE is the return of services group index. TECH is the return of technology group index. INDUS is the return of industrials group index. PETRO is the return of petrochemicals and chemicals sector index. ENERG is the return of energy and utilities sector index. SET is the return of Stock Exchange of Thailand index. The graph of price and return of SGX's oil and each category of stock are shown in Figure 1 and 2. The red line in Figure 1 and 2 indicates the date of NOV 1, 2019 in which we divide the data set into two parts, before COVID-19 appearance and during COVID-19 crisis. The blue line indicates the date of MAR 9, 2020 in which 2020 Oil-Price War begins. As we can see in Figure 1, after 2020 Oil-Price War, the prices of Thailand's sectoral stocks are heavily plummet.

In our paper, we use the daily data in which the range of the data set covers from October 5, 2016 to June 8, 2020. Since we want to capture the effect of COVID-19 crisis on Thailand's stock return, we divide the data into 2 sets, the first data set which covers from October 5, 2016 to October 31, 2019 and the second data set that covers from November 1, 2019 to June 8, 2020. We use November, 2019 as the beginning of the second data set because the first case of COVID-19 infection was found in China on this month [38]. The first data set will be used to study the spill over of oil market risk and return on Thailand's sectoral stock return before the appearance of COVID-19. The second data set will be used to study the spill over of oil market risk and return on Thailand's sectoral stock return during COVID-19 crisis.

For the second data set that cover the COVID-19 pandemic period, we desire to add the variable that represent the COVID-19 crisis. Since people nowadays use "Google" on their computer and mobile phone to search for what they want to know. Therefore, we consider the "Google trend" as a proxy of how people worry about COVID-19 pandemic. Many studies use "Google Trend" as a main variable in their models such

as [39]-[41]. More importantly, the study of [42] found that the increasing of COVID-19 cases in 8 countries: United States, Spain, Italy, France, United Kingdom, China, Iran and India, can be reflected by the growing of "Google" searches. In the end, this study concluded that the fear and concern of people on COVID-19 have been well reflected on the Google searches.

Therefore, we use the "Google Trend" daily data (Gt) that capture how often that people around the globe using "COVID-19" keyword to search on Google's website. Since Singapore's oil market and Thailand's stock market can be invested by any people around the world, the "Google Trend" data that we use come from the searching on keyword COVID-19 of the people around the world. This variable has a scale unit from 0 to 100 in which 0 means people are not worry about COVID-19 while 100 means people are extremely worry about COVID-19. The "Google Trend" data on "Covid-19" is shown in Figure 3.

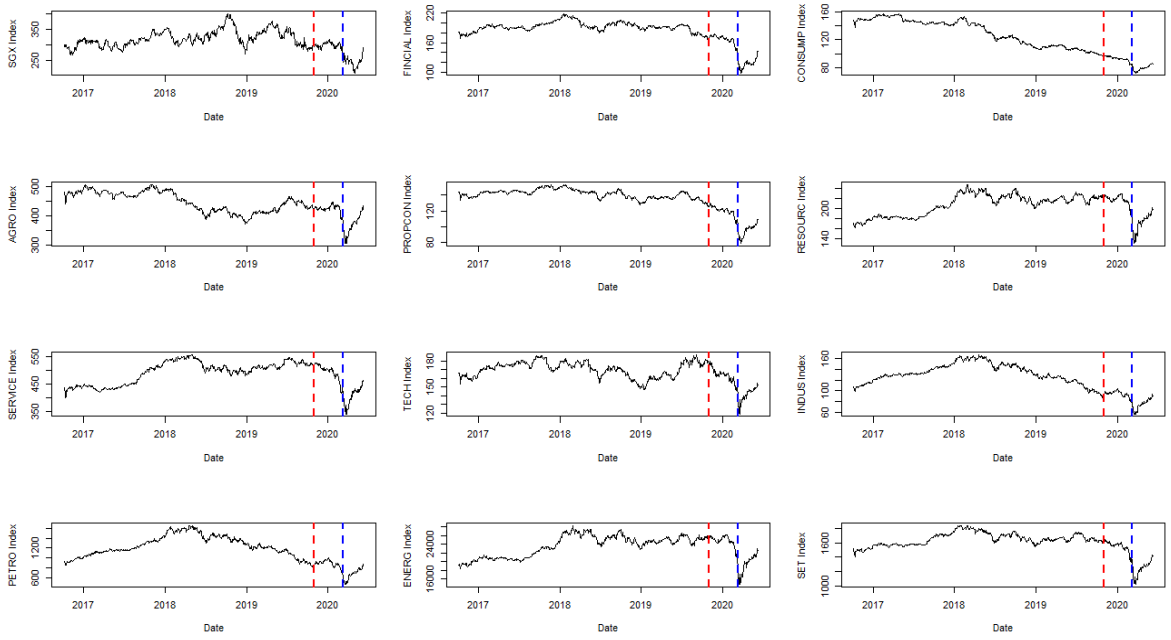

Fig. 1. Daily oil price and Thailand's stock indices on market level, industry level and sector level.

Notes: The red line indicates the date of NOV 1, 2019 in which we divide the data set into two parts, before COVID-19 appearance and during COVID-19 crisis. The blue line indicates the date of MAR 9, 2020 in which 2020 Oil-Price War began.

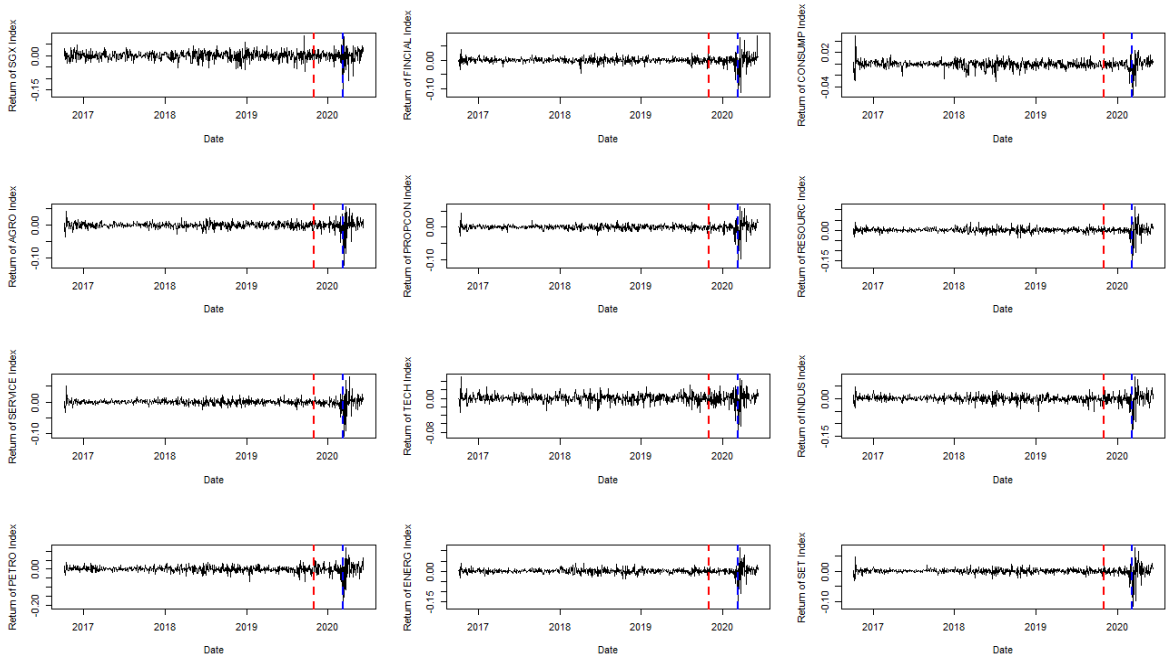

Fig. 2. Daily Oil market return and Thailand's stock return on market level, industry level and sector level.

Notes: See notes of Figure 1.

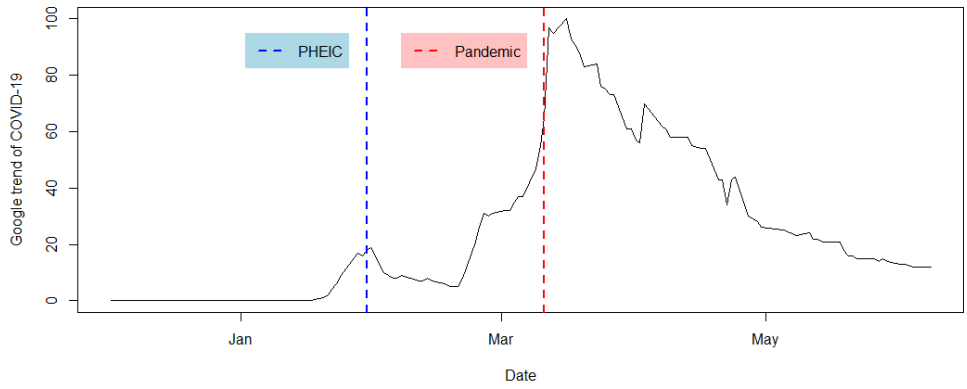

Fig. 3. Google trend on "COVID-19" keyword.
Notes: The blue line indicates the date of JAN 30, 2020 in which WHO announced COVID-19 a Public Health Emergency of International Concern (PHEIC). The red line indicates the date of MAR 11, 2020 in which WHO announced COVID-19 a pandemic.

Table 2. Descriptive statistics of each variable before the appearance of COVID-19.

Variable	Mean	St. Dev.	Skewness	Kurtosis	JB	Q (p)	Q^2 (p)
SGX	-0.0003	0.0175	-0.2166	4.7300	90.5900***	6.2970	52.2700***
					(0.0000)	(0.5056)	(0.0000)
FINCIAL	-0.0002	0.0080	-0.2458	6.1020	279.7600***	23.0820***	26.7700***
					(0.0000)	(0.0017)	(0.0004)
CONSUMP	-0.0006	0.0062	-0.0479	11.0440	1829.5700***	12.6040*	73.8900***
					(0.0000)	(0.0824)	(0.0000)
AGRO	-0.0001	0.0078	-0.1268	5.2660	147.8400***	7.8750	94.5200***
					(0.0000)	(0.3438)	(0.0000)
PROPCON	-0.0001	0.0062	0.0301	7.7960	651.3500***	9.5720	98.4900***
					(0.0000)	(0.2141)	(0.0000)
RESOURC	0.0004	0.0099	0.1052	5.0620	122.2700***	5.0250	24.7800***
					(0.0000)	(0.6570)	(0.0008)
SERVICE	0.0002	0.0071	0.2483	8.7170	931.7700***	4.5090	83.1800***
					(0.0000)	(0.7196)	(0.0000)
TECH	0.0001	0.0088	-0.0412	5.6900	205.6400***	5.8540	17.5700**
					(0.0000)	(0.5569)	(0.0141)
INDUS	-0.0003	0.0111	-0.4104	5.4060	183.5300***	3.4650	24.4500***
					(0.0000)	(0.8389)	(0.0010)
PETRO	-0.0003	0.0138	-0.4522	5.6560	223.3200***	4.7960	23.8300***
					(0.0000)	(0.6849)	(0.0012)
ENERG	0.0004	0.0099	0.1052	5.0530	121.2200***	4.9430	24.6700***
					(0.0000)	(0.6669)	(0.0009)
SET	0.0001	0.0066	0.0075	7.7950	650.9300***	6.7360	71.4500***
					(0.0000)	(0.4568)	(0.0000)

Notes: SGX is the return of Singapore's oil market. FINCIAL is the return of financials group index. CONSUMP is the return of consumer products group index. AGRO is the return of agriculture and food industry group index. PROPCON is the return of property and construction group index. RESOURC is the return of resources group index. SERVICE is the return of services group index. TECH is the return of technology group index. INDUS is the return of industrials group index. PETRO is the return of petrochemicals and chemicals sector index. ENERG is the return of energy and utilities sector index. SET is the return of Stock Exchange of Thailand index. JB is the Jarque – Bera Test with the null hypothesis of normal distribution. Q(p) and Q^2(p) are Ljung-box test for the p^{th} order serial correlation on the return and squared return with the null hypothesis of non-autocorrelation. P-values are reported in parentheses. Asterisks indicate the rejection of null hypothesis statistical at the 10% (*), 5% (**) or 1% (***) level.

Then, we create the variable names "COVID" in which represent the daily changing of COVID-19 anxiousness by using the conventional formula, $COVID_t = ln\left(\frac{G_t}{G_{t-1}}\right)$.

The basic descriptive statistics of the return on each variable is shown in Table 2 and Table 3. Table 2 reports the results of the first data set that cover the period before the appearance of COVID-19 while Table 3 reports the results of second data set that cover the period during COVID-19 crisis. For every variable, skewness numbers are all different from zero while kurtosis number are all greater than 3. Then, every variable exhibit excess kurtosis and skewness. The

Jarque-Bera (JB) test results show the rejection of normality null hypothesis. The Ljung-Box tests, which is used to test the autocorrelation of return and return square with the null hypothesis of non-autocorrelation, are reported on the column of Q (p) and Q2 (p). We follow the suggestion of [43] to choose the lags of Ljung-Box test by this formula, P ≈ ln(T), where T is the time length of the variable. For the period before COVID-19 appearance, we found autocorrelation on the return of FINCIAL and CONSUMP while we found autocorrelation on every return square variable. For the period during COVID-19 crisis, we found autocorrelation on every return variable except the return of AGRO and TECH while we found autocorrelation on every return square variable except SGX.

Table 3. Descriptive statistics of each variable during COVID-19 crisis.

Variable	Mean	St. Dev.	Skewness	Kurtosis	JB	Q (p)	Q^2 (p)
SGX	-0.0008	0.0294	-1.7630	11.8150	541.4000***	15.3817***	7.5290
					(0.0000)	(0.0089)	(0.1842)
FINCIAL	-0.0010	0.0257	-1.3170	10.1330	348.1000***	15.5445***	15.7210***
					(0.0000)	(0.0083)	(0.0077)
CONSUMP	-0.0007	0.0103	-1.7210	9.8060	349.7000***	27.6169***	27.0900***
					(0.0000)	(0.0000)	(0.0001)
AGRO	0.0002	0.0219	-2.0240	11.6810	550.6000***	8.1830	15.2210***
					(0.0000)	(0.1464)	(0.0095)
PROPCON	-0.0010	0.0212	-2.0030	13.3860	743.3000***	13.3611**	14.3420**
					(0.0000)	(0.0202)	(0.0136)
RESOURC	-0.0006	0.0304	-1.6850	14.0610	802.2000***	11.7514**	19.8610***
					(0.0000)	(0.0384)	(0.0013)
SERVICE	-0.0007	0.0217	-1.1510	10.7020	389.0000***	15.8193***	12.9110**
					(0.0000)	(0.0074)	(0.0242)
TECH	-0.0010	0.0185	-1.0320	7.5020	148.4000***	0.1397	47.5020***
					(0.0000)	(0.9996)	(0.0000)
INDUS	0.0001	0.0287	-1.5410	10.0690	357.7000***	14.2069**	23.7510***
					(0.0000)	(0.0144)	(0.0002)
PETRO	0.0002	0.0381	-1.7040	11.0850	462.6000***	15.4468***	19.8590***
					(0.0000)	(0.0086)	(0.0013)
ENERG	-0.0006	0.0304	-1.7060	14.1350	813.8000***	15.5101***	19.1930***
					(0.0000)	(0.0084)	(0.0018)
SET	-0.0007	0.0224	-1.6740	11.5240	503.8000***	17.3407***	20.6520***
					(0.0000)	(0.0039)	(0.0009)
COVID	0.0248	0.1580	3.1820	16.5280	1337.6000***	80.1369***	57.7960***
					(0.0000)	(0.0000)	(0.0000)

Notes: See notes of Table 2.

3. RESULTS AND DISCUSSION

3.1. Model

Our paper has 4 main objectives, the first one is to study the spillover of oil market return on Thailand's sectoral stock return. Secondly, we study the spillover of oil market risk on Thailand's sectoral stock return. Thirdly, we study the dynamic correlation between oil market return and Thailand's sectoral stock return. Lastly, we study the effect of COVID-19 crisis on Thailand's sectoral stock return. In order to answer these 4 objectives, we use the bivariate DCC GARCH-in-Mean model [31] in which the conditional mean equations are specified as follows.

$$r_{o,t} = \mathcal{E}_{o,t} \quad (1)$$

$$r_{s,t} = \mu + \phi_1 r_{o,t} + \phi_2 h_{o,t} + \phi_3 COVID_t + \varepsilon_{s,t} \quad (2)$$

where $r_{o,t}$ is the return of oil market and $r_{s,t}$ is the return of Thailand's stock on each section and each industry. In Equation 1, there is no explanatory variable because we want the variance of this equation, $var(\mathcal{E}_{o,t}) = var(r_{o,t}) = h_{o,t}$, to fully capture the volatility or risk of oil market. In Equation 2, the parameter ϕ_1 will capture the spillover of oil market return on Thailand's sectoral stock return while the parameter ϕ_2 will capture the spillover of oil market risk on Thailand's sectoral stock return [44].

For the first data set that covers the time between OCT 5, 2016 to OCT 31, 2019, we exclude the variable $COVID_t$ out of Equation 2 because during that time there is no COVID-19 pandemic. The variable $COVID_t$ will be used in the Equation 2 for the second data set that cover the time between NOV 1, 2019 to JUN 8, 2020. The parameter ϕ_3 will show how COVID-19 affects

Thailand's sectoral stock return.

$$\mathcal{E}_t|\mathcal{F}_{t-1}\sim N(0,H_t) \quad (3)$$

$$\mathcal{E}_t = H_t^{1/2} z_t \;;\; z_t \sim i.i.d.(0,1) \quad (4)$$

The residual vector, $\mathcal{E}_t$, is assumed to have a normal distribution with the conditional covariance matrix, H_t. Equation 4 shows the standardized residual vector, z_t, that can be break off from the residual vector, $\mathcal{E}_t$.

$$H_t = D_t R_t D_t \quad (5)$$

$$D_t = \begin{bmatrix} \sqrt{h_{o,t}} & 0 \\ 0 & \sqrt{h_{s,t}} \end{bmatrix} \quad (6)$$

$$h_{o,t} = \omega_o + \alpha_o \varepsilon_{o,t-1}^2 + \beta_o h_{o,t-1} \quad (7)$$

$$h_{s,t} = \omega_s + \alpha_s \varepsilon_{s,t-1}^2 + \beta_s h_{s,t-1} \quad (8)$$

The covariance matrix, H_t, can be decomposed into 3 elements as it's shown in Equation 5. The matrix D_t is the diagonal matrix of conditional standard deviations. The DCC model assumes that $h_{o,t}$ and $h_{s,t}$ in matrix D_t can be estimated by univariate GARCH which is shown in Equations 7 and 8. Matrix R_t is the conditional correlation matrix in which each element can be varied over time as it is shown in the following equation [31].

$$R_t = \begin{bmatrix} \rho_{11,t} & \rho_{12,t} \\ \rho_{21,t} & \rho_{22,t} \end{bmatrix} \quad (9)$$

where $\rho_{11} = \rho_{22} = 1$ and $\rho_{12,t} = \rho_{21,t}$. The parameter $\rho_{12,t}$ will capture the dynamic conditional correlation between oil price return and Thailand's sectoral stock return that is varying over time. In order to estimate the conditional correlation matrix, the DCC model assumes that matrix R_t can be decomposed into 3 elements as it is shown in the following equation.

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (10)$$

$$Q_t^* = \begin{bmatrix} \sqrt{q_{11,t}} & 0 \\ 0 & \sqrt{q_{22,t}} \end{bmatrix} \quad (11)$$

$$Q_t = \begin{bmatrix} q_{11,t} & q_{12,t} \\ q_{21,t} & q_{22,t} \end{bmatrix} \quad (12)$$

The Equation 10 can be ensure that the value of conditional correlation, $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}}$, will be in between -1 and 1, and ensure that matrix R_t will be positive definite. The DCC model assumes that the correlation matrix Q_t is specified as it is shown in the following equation [31], [45].

$$Q_t = (1 - a^{DCC} - b^{DCC})\bar{Q} + a^{DCC} z_{t-1} z_{t-1}^T + b^{DCC} Q_{t-1} \quad (13)$$

where $a^{DCC} \geq 0, b^{DCC} \geq 0$ and $a^{DCC} + b^{DCC} < 1$, while $\bar{Q}$ can be estimated by $\bar{Q} = \frac{1}{T}\sum_{t=1}^{T} z_t z_t^T$.

3.2 Estimation Procedure

Step 1: Use the residual of oil price return, $\varepsilon_{o,t}$, in Equation 1 to estimate the conditional volatility, $h_{o,t}$, by using univariate GARCH(1,1) in Equation 7.

Step 2: Take the estimated conditional volatility of oil return, $\hat{h}_{o,t}$, from step 1 and put it in Equation 2 and then estimates equation (2). Use the estimated residual of stock return, $\hat{\varepsilon}_{s,t}$ from Equation 2 to estimate the conditional volatility, $h_{s,t}$, by using univariate GARCH(1,1) in Equation 8.

Step 3: Use the estimated residuals, $\hat{\varepsilon}_{o,t}$ and $\hat{\varepsilon}_{s,t}$, and estimated volatility, $\hat{h}_{o,t}$ and $\hat{h}_{s,t}$, to get the standardized residuals and use them to estimate dynamic conditional correlation in Equation 13 by using maximum of log likelihood function [31].

For the univariate GARCH estimation in step 1 and 2, we use "rugarch" package on "R" program and we use the generalized error distribution (GED) option in which allows for the thick tail. For the bivariate DCC GARCH estimation in step 3, we use "rmgarch" package on "R" program and we use the multivariate normal distribution option.

4. EMPIRICAL RESULTS

The estimated parameters of the bivariate DCC GARCH-in-Mean model are shown in Tables 4 and 5. Table 4 presents the results from the first data set that covers the period before the COVID-19 appearance while the results of the period during COVID-19 crisis are shown in Table 5. The column SGX shows the results of Equations 1 and 7 while the rest show the results of Equations 2 and 8. The estimated parameter ,which captures the spillover of SGX's oil market return on Thailand's sectoral stock return, show that, before COVID-19 appearance, SGX' oil market return had a significant positive effect on RESOURC, INDUS, PETRO, ENERG and SET. So, we can conclude that, in the normal situation, the resources and industrials industry gain a benefit when oil price increases. The Petrochemicals and Chemicals and Energy and Utilities sector also gain a benefit when oil price increases. These sectors involve with a high volume of oil inventory, then their profit will be increase when oil price goes up. Moreover, for the Petrochemicals and Chemicals sector, oil is the main output and the demand for oil is strongly inelastic, then when oil price goes up, the profit of this sector goes up as same as the return on their stock [46].

For the period during COVID-19 crisis, SGX' oil Singapore's oil market and Thailand's stock market in all industries.

In conclusion, we have the evidence that there was a positive spillover of SGX's oil market return on Thailand's stock return on both before COVID-19 market return had a significant positive effect on every category of Thailand's stock return. The estimated parameter ϕ_1 of the period during COVID-19 crisis was higher than the period before COVID-19 appearance which means the spillover of SGX's oil price return on Thailand's sectoral stock return was

higher during COVID-19 crisis compare to the period before COVID-19 appearance. It can be explained that during the COVID-19 crisis, investors withdraw their investment from Singapore's oil market and Thailand's stock market in all industries.

In conclusion, we have the evidence that there was a positive spillover of SGX's oil market return on Thailand's stock return on both before COVID-19 appearance and during COVID-19 crisis. It can be explained that when the investors invest more on Singapore's oil market and make the return of oil to be higher, then they will also invest more in Thailand's stock market, so, the return in stock market will be higher in the same way as it's happened in oil market. On opposite way, when investors withdraw their investment, they will withdraw from both Singapore's oil market and Thailand's stock market, which make the return in oil market and the return in stock market become lower together. So, this is the evidence to support that investors may consider Singapore's oil market and Thailand's stock market as a complimentary investment in their portfolio.

The parameter ϕ_2 ,which captures the spillover of Singapore's oil market risk on Thailand's sectoral stock return, show that, before COVID-19 appearance, SGX' oil market risk had a significant negative effect on CONSUMP, INDUS and PETRO while, during COVID-19 crisis, SGX' oil price risk had a significant negative effect on FINCIAL, CONSUMP, AGRO, PROPCON, SERVICE and SET. So, these results mean that the higher of oil market risk, the lower of return on Thailand's stocks. In conclusion, we have the evidence that there was a negative spillover of SGX's oil market risk on Thailand's stock return on both before COVID-19 appearance and during COVID-19 crisis. It can be explained that when there is a shock or any factors that make the Singapore's oil market to become more fluctuated, it will affect the return in Thailand's stock market to be lower. So, the risk in Singapore's oil market may be the sign of uncertainty for the investors that make them decide to withdraw their investment from Thailand's stock market and hold cash instead.

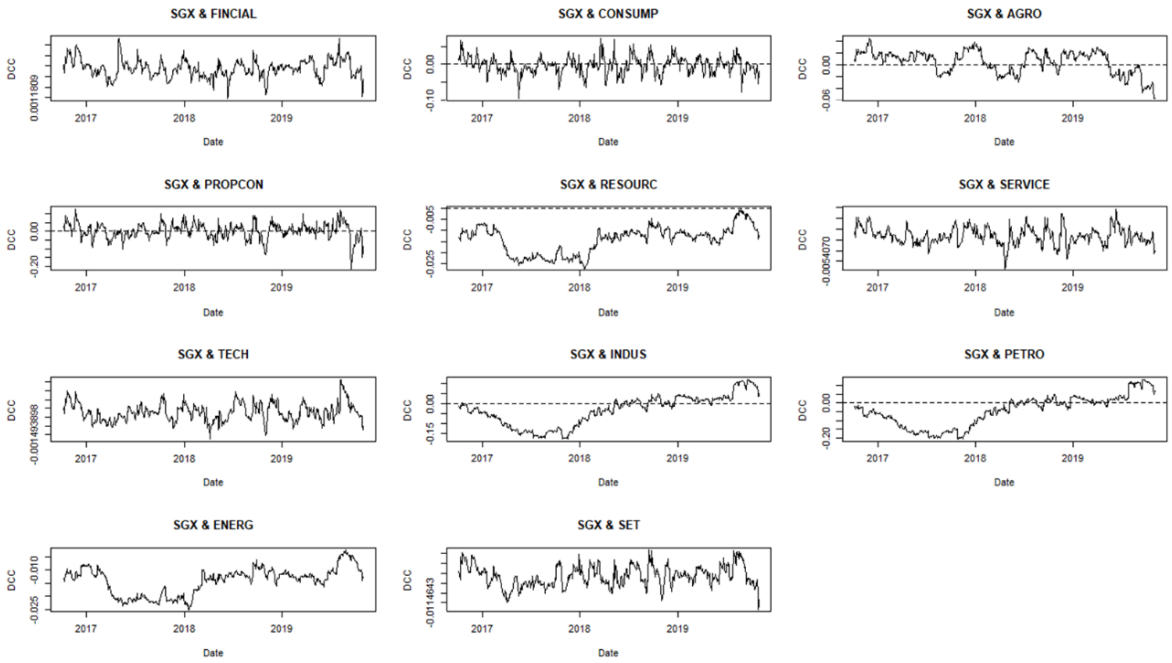

Fig. 4. The estimated dynamic conditional correlation of SGX's oil market return and Thailand's stock return on each category before COVID-19 appearance (October 5, 2016 to October 31, 2019).

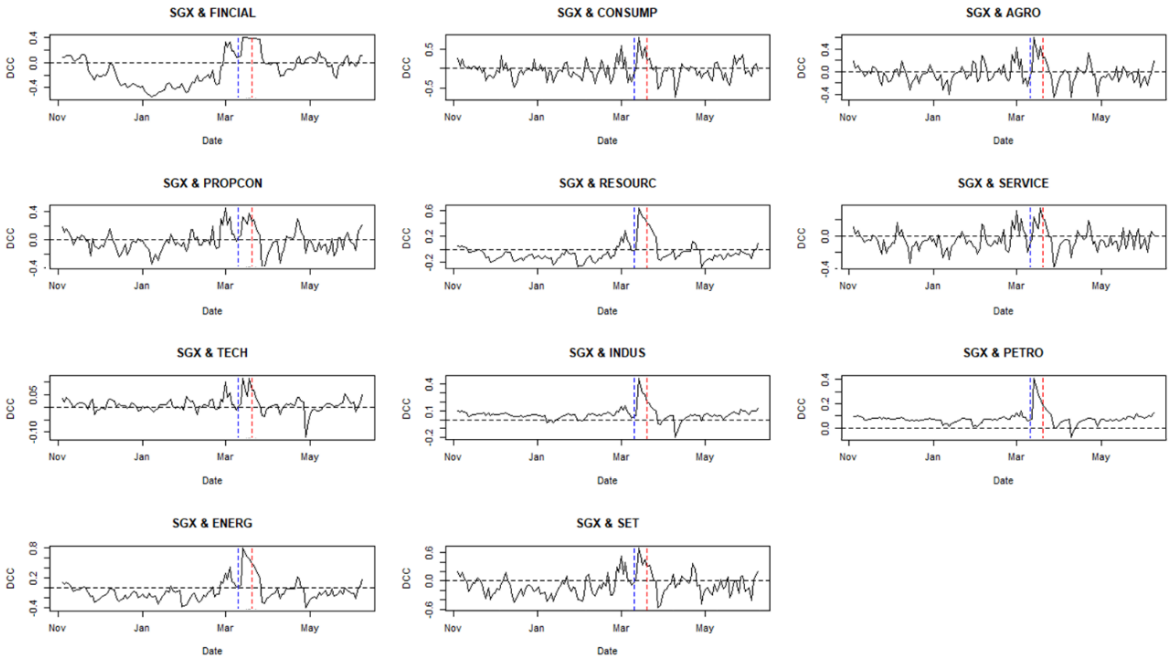

Fig. 5. The estimated dynamic conditional correlation of SGX's oil market return and Thailand's stock return on each category during COVID-19 crisis (November 1, 2019 to June 8, 2020).

Notes: The blue line indicates the date of MAR 9, 2020 in which 2020 Oil-Price War began while the red line indicates the date of MAR 11, 2020 in which WHO announced COVID-19 a pandemic.

Table 4. The bivariate DCC GARCH-in-Mean model results before COVID-19 appearance (October 5, 2016 to October 31, 2019).

Coefficient	SGX	FINCIAL	CONSUMP	AGRO	PROPCON	RESOURC	SERVICE	TECH	INDUS	PETRO	ENERG	SET
μ	-	0.0006	0.0007	-0.0003	0.0007	0.0011	0.0006	0.0008	0.0021*	0.0027*	0.0011	0.0008
	[-]	[0.0009]	[0.0007]	[0.0009]	[0.0007]	[0.0010]	[0.0008]	[0.0010]	[0.0012]	[0.0015]	[0.0010]	[0.0007]
ϕ_1	-	0.0066	0.0024	0.0191	0.01zzz79	0.1564***	0.0203	0.0146	0.1226***	0.1575***	0.1568***	0.0523***
	[-]	[0.0176]	[0.0136]	[0.0173]	[0.0136]	[0.0210]	[0.0156]	[0.0195]	[0.0239]	[0.0298]	[0.0210]	[0.0144]
ϕ_2	-	-2.5723	-4.3137**	0.6325	-2.7944	-2.1323	-1.2172	-2.1947	-7.8883**	-9.9162**	-2.1187	-2.2111
	[-]	[2.6954]	[2.0874]	[2.6454]	[2.0773]	[3.2189]	[2.3886]	[2.9864]	[3.6668]	[4.5660]	[3.2214]	[2.1996]
ω	0.0000***	0.0000	0.0000***	0.0000	0.0000	0.0000	0.0000	0.0000***	0.0000***	0.0000	0.0000	0.0000
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0002]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
α	0.0535***	0.0537	0.1678***	0.0599	0.0822	0.0470	0.0576	0.0296***	0.0672***	0.0467	0.0469	0.0591
	[0.0053]	[0.6449]	[0.0287]	[0.0772]	[0.0967]	[0.0874]	[2.1413]	[0.0025]	[0.0083]	[0.0530]	[0.0876]	[0.1438]
β	0.9142***	0.9233	0.7177***	0.9086***	0.8566***	0.9403***	0.9169	0.9186***	0.8835***	0.9359***	0.9404***	0.9283***
	[0.0101]	[0.7880]	[0.0466]	[0.1314]	[0.0250]	[0.0951]	[2.5874]	[0.0053]	[0.0153]	[0.1326]	[0.0954]	[0.1403]
γ	-	0.0000	0.0151	0.0047	0.0250	0.0010	0.0000	0.0000	0.0084	0.0091*	0.0009	0.0000
	[-]	[0.0000]	[0.0234]	[0.0086]	[0.0226]	[0.0071]	[0.0000]	[0.0000]	[0.0056]	[0.0049]	[0.0071]	[0.0002]
b^{DCC}	-	0.9192***	0.7864***	0.9730***	0.8111***	0.9840***	0.8869***	0.9194***	0.9880***	0.9876***	0.9841***	0.9264***
	[-]	[0.1016]	[0.0757]	[0.0355]	[0.0829]	[0.0158]	[0.1011]	[0.0987]	[0.0043]	[0.0041]	[0.0163]	[0.1672]
Q (p)	3.0829	14.2579**	7.9958	9.3477	10.7134	4.8995	2.8499	5.2904	2.6995	3.4530	4.6004	9.1911
	[0.8772]	[0.0468]	[0.3330]	[0.2287]	[0.1516]	[0.6722]	[0.8985]	[0.6246]	[0.9113]	[0.8402]	[0.7086]	[0.2392]
Q^2 (p)	10.6692	8.3501	5.5249	15.7286**	12.0823*	1.8815	19.6057***	5.3154	6.0214	6.6611	1.9476	8.4053
	[0.1537]	[0.3027]	[0.5962]	[0.0277]	[0.0979]	[0.9661]	[0.0065]	[0.6215]	[0.5373]	[0.4650]	[0.9627]	[0.2982]

Notes: the conditional mean equations are $r_{o,t} = \varepsilon_{o,t}$, $r_{s,t} = \mu + \phi_1 r_{o,t} + \phi_2 h_{o,t} + \varepsilon_{s,t}$, where $r_{o,t}$ is SGX' oil market return, $r_{s,t}$ is Thailand's stock return on each category; FINCIAL, CONSUMP, AGRO, PROPCORN, RESOURC, SERVICE, TECH, INDUS, PETRO, ENERG and SET. The conditional variance equations are $h_{o,t} = \omega_o + \alpha_o \varepsilon_{o,t-1}^2 + \beta_o h_{o,t-1}$, $h_{s,t} = \omega_s + \alpha_s \varepsilon_{s,t-1}^2 + \beta_s h_{s,t-1}$ The Dynamic Conditional Correlation is $Q_t = (1 - \alpha^{DCC} - b^{DCC})\bar{Q} + \alpha^{DCC} z_{t-1} z_{t-1}^T + b^{DCC} Q_{t-1}$. The robust standard errors are reported in parenthesis except the cases of Q (p) and Q^2 (p) which report p-value. Q(p) and Q^2(p) are Ljung-box test for the p^{th} order serial correlation on standardized residual and squared standardized residual with the null hypothesis of non-autocorrelation. Asterisks indicate statistical significance at the 10% (*), 5% (**) or 1% (***) level.

Table 5. The bivariate DCC GARCH-in-mean model results during COVID-19 crisis (November 1, 2019 to June 8, 2020).

Coefficient	SGX	FINCIAL	CONSUMP	AGRO	PROPCON	RESOURC	SERVICE	TECH	INDUS	PETRO	ENERG	SET
μ	-	0.0058*	0.0018	0.0051*	0.0044*	0.0019	0.0033	0.0019	0.0044	0.0055	0.0020	0.0036
	[-]	[0.0031]	[0.0013]	[0.0027]	[0.0026]	[0.0036]	[0.0027]	[0.0023]	[0.0034]	[0.0045]	[0.0035]	[0.0027]
ϕ_1	-	0.2289**	0.0772***	0.1993***	0.1388**	0.4150***	0.1752***	0.1038*	0.2876***	0.4567***	0.4261***	0.2685***
	[-]	[0.0705]	[0.0286]	[0.0603]	[0.0588]	[0.0803]	[0.0601]	[0.0525]	[0.0777]	[0.1008]	[0.0797]	[0.0599]
ϕ_2	-	-6.4493**	-2.3648**	-4.4563**	-5.0669**	-1.6008	-3.5518*	-2.5110	-3.3184	-3.8968	-1.5989	-3.7446*
	[-]	[2.5070]	[1.0190]	[2.1464]	[2.0934]	[2.8569]	[2.1379]	[1.8687]	[2.7637]	[3.5873]	[2.8358]	[2.1306]
ϕ_3	-	-0.0254*	-0.0113**	-0.0217*	-0.0252**	-0.0297**	-0.0248**	-0.0199**	-0.0414***	-0.0551***	-0.0300**	-0.0254**
	[-]	[0.0131]	[0.0053]	[0.0112]	[0.0109]	[0.0149]	[0.0112]	[0.0098]	[0.0144]	[0.0187]	[0.0148]	[0.0111]
ω	0.0000	0.0000	0.0000	0.0000*	0.0000	0.0000*	0.0000	0.0000	0.0000*	0.0001**	0.0000	0.0000
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0001]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
α	0.1209	0.2176**	0.1811***	0.1802***	0.1978	0.2692***	0.2110*	0.1966	0.1431***	0.1376***	0.2774***	0.2519*
	[0.0848]	[0.1978]	[0.1810]	[0.1457]	[0.4798]	[0.1994]	[0.1911]	[0.3983]	[0.1789]	[0.2069]	[0.2010]	[0.2273]
β	0.8426***	0.7720***	0.7808***	0.7912***	0.7822***	0.7298***	0.7880***	0.7749***	0.8068***	0.8117***	0.7216***	0.7459***
	[0.0940]	[0.0602]	[0.1038]	[0.0658]	[0.1156]	[0.0498]	[0.0575]	[0.2074]	[0.0473]	[0.0339]	[0.0470]	[0.0472]
a^{DCC}	-	0.1077	0.2942**	0.2096	0.1837**	0.0782	0.1523	0.0251	0.0343	0.0214	0.1245	0.2476
	[-]	[0.0672]	[0.1362]	[0.1418]	[0.0900]	[0.0745]	[0.1049]	[0.1032]	[0.0672]	[0.0302]	[0.1082]	[0.1113]
b^{DCC}	-	0.8714***	0.2253**	0.3275**	0.5050***	0.7308**	0.3581*	0.5303	0.6423	0.6629**	0.6665***	0.4340***
	[-]	[0.1059]	[0.0922]	[0.1356]	[0.1484]	[0.2876]	[0.1906]	[0.3847]	[0.8868]	[0.2736]	[0.2266]	[0.1256]
Q (p)	9.5827*	8.7320	16.4820***	5.7007	7.1169	5.6422	9.8690*	0.8681	6.0483	5.0429	3.8405	6.3913
	[0.0880]	[0.1202]	[0.0056]	[0.3364]	[0.2121]	[0.3426]	[0.0790]	[0.9725]	[0.3015]	[0.4107]	[0.5726]	[0.2700]
Q^2 (p)	0.3476	0.7655	7.5289	1.8951	2.1740	1.7764	2.0936	2.3176	3.6124	1.9504	0.4115	1.7120
	[0.9967]	[0.9792]	[0.1842]	[0.8635]	[0.8246]	[0.8791]	[0.8360]	[0.8037]	[0.6065]	[0.8560]	[0.9950]	[0.8874]

Notes: the conditional mean equations are $r_{o,t} = \varepsilon_{o,t}$, $r_{s,t} = \mu + \phi_1 r_{o,t} + \phi_2 h_{o,t} + \phi_3 COVID_t + \varepsilon_{s,t}$, where $r_{o,t}$ is SGX' oil market return, $r_{s,t}$ is Thailand's stock return on each category; FINCIAL, CONSUMP, AGRO, PROPCORN, RESOURC, SERVICE, TECH, INDUS, PETRO, ENERG and SET. The conditional variance equations are $h_{o,t} = \omega_o + \alpha_o \varepsilon^2_{o,t-1} + \beta_o h_{o,t-1}$, $h_{s,t} = \omega_s + \alpha_s \varepsilon^2_{s,t-1} + \beta_s h_{s,t-1}$. The Dynamic Conditional Correlation is $Q_t = (1 - a^{DCC} - b^{DCC})\bar{Q} + a^{DCC} z_{t-1} z^T_{t-1} + b^{DCC} Q_{t-1}$. The robust standard errors are reported in parenthesis except the cases of Q (p) and Q^2 (p) which report p-value. Q(p) and Q^2(p) are Ljung-box test for the p^{th} order serial correlation on standardized residual and squared standardized residual with the null hypothesis of non-autocorrelation. Asterisks indicate statistical significance at the 10% (*), 5% (**) or 1% (***) level.

The parameter ϕ_3,which captures how COVID-19 affects Thailand's sectoral stock return, show that the daily changing of COVID-19 anxiousness had a significant negative effect on every category of Thailand's stock return. So, we can conclude that the more people worry about COVID-19, the more they want to withdraw their investment from Thailand's stock market in which make the sectoral stock return to become lower.

The estimated results of univariate GARCH (1,1) of each equation are shown in the row of ω, α and β. For the period before COVID-19 appearance, only FINCIAL and SERVICE show no sign of conditional heteroskedasticity, since all parameters in conditional variance equation are insignificant. For the period during COVID-19 crisis, all cases show the conditional heteroskedasticity. The large value of β and the sum of α and β which is close to one are good under the GARCH(1,1)'s condition.

The estimated results of DCC GARCH (1,1) in Equation 13 are shown in the row of a^{DCC} and b^{DCC}. For the period before COVID-19 appearance, the estimated results of a^{DCC} are insignificant in all cases except PETRO while the estimated results of b^{DCC} are strongly significant in all cases. For the period during COVID-19 crisis, the estimated results of a^{DCC} are insignificant in all cases except CONSUMP and PROPCON while the estimated results of b^{DCC} are significant in all cases except TECH and INDUS.

The Ljung-Box tests, Q (p) and Q^2 (p), are used to test the autocorrelation in standardized residual and squared standardized residual for each equation. For the period before COVID-19 appearance, there are no auto correlation in standardized residual in all cases except FINCIAL while there is no auto correlation in squared standardized residual in all cases except AGRO, PROPCON and SERVICE. For the period during COVID-19 crisis, there are no auto correlation in standardized residual in all cases except SGX, CONSUMP and SERVICE while there is no auto correlation in squared standardized residual in all cases. So, we can conclude that our bivariate DCC GARCH-in-Mean structure is appropriate in the most cases of our study.

The estimated dynamic conditional correlation (DCC) results between SGX's oil market return and Thailand's stock return on each category are shown in Figures 4 and 5. Figure 4 shows DCC results for the period before COVID-19 appearance while Figure 5 shows the results for the period during COVID-19 crisis. For all cases, they appear that the correlation between SGX's oil market return and Thailand's sectoral stock return is time-varying which confirm that the DCC GARCH model is appropriated in our study. For the period before COVID-19 appearance the correlation between SGX's oil market return and FINCIAL was moving in positive area with the average DCC value at 0.0012. The DCC of SGX's oil market return and RESOUC, SERVICE, TECH, ENERG and SET were moving in negative area with the average DCC value at -0.0143, -0.0054, -0.0015, -0.0141 and -0.0115, respectively. The DCC of SGX's oil market return and CONSUMP, AGRO, PROPCORN, INDUS and PETRO swung between positive and negative area with the average DCC value at -0.0032, 0.0042, 0.0015, -0.0353 and -0.0445, respectively.

For the period during COVID-19 crisis, the DCC of SGX's oil market return and Thailand's sectoral stock return became more fluctuated and swung between positive and negative area in all cases which we can conclude that COVID-19 crisis had an impact on the correlation between oil market return and Thailand stock market return. The average DCC values are -0.1054 (FINCIAL), -0.0409 (CONSUMP), -0.0331 (AGRO), -0.0155 (PROPCON), -0.0536 (RESOURC), -0.0502 (SERVICE), 0.0107 (TECH), 0.0584 (INDUS), 0.0783 (PETRO), -0.0560 (ENERG) and -0.0858 (SET).

It is important to note that the dynamic correlation between SGX's oil market return and Thailand's sectoral stock return became positive and heavily related during March 2020 in which there were two important events happened. On March 8, 2020, there was a conflict between OPEC and Russia which is considered to be the date that 2020 Oil Price War started. So, when the oil market opened on Monday, March 9, 2020, the prices of oil around the world were heavily plummeted. Additionally, on March 11, 2020, WHO declared COVID-19 a pandemic. As it's shown in Figure 1, during March, 2020, the oil price and sectoral stock indices were plummeted down together which is the reason why DCC results in period of March 2020 are positive and high correlated. These results on DCC are consistent with the positive relationship between the Singapore's oil market return and Thailand's stock market return in which confirm that when there is a crisis, investors will withdraw their investment on both Singapore's oil market together with Thailand's stock market. Our results of DCC during 2020 Oil Price War and COVID-19 pandemic are consistent with the studies of [23], [24].

According to our overall results, we can say that Singapore's oil market and Thailand's stock market have a very close relationship. The investors consider these two markets as a complimentary investment product in their portfolio. Moreover, the investors consider Singapore's oil market volatility as a sign of incoming recession and crisis in which they will withdraw their investment from Thailand's stock market. For the policy suggestion, if Thailand and Singapore can coordinate on their fiscal and monetary policy, it will convince investors to invest their money on both Singapore's oil market and Thailand's stock market.

Since the volatility in Singapore's oil market has a negative effect on Thailand's stock market, the policy maker may consider the oil market intervention to relieve the oil market volatility to convince the investors to still continue their investment on both oil market and stock market. The government impose some policy to give incentive for the producer to rely more in

renewable energy. If Thailand economy relies less on oil, the volatility in oil market may affect less on Thailand's stock market.

In additional, our study provides the results on each sectoral category of Thailand's stock market, the policy maker may design the specific policy on specific sector rather than create a universal policy for the whole market.

More importantly, during COVID-19 crisis, the government should communicate with their people clearly and provide the complete information to their people. The complete and clear information can reduce the concern in people mind which can reflect on more confident in their investment. The less people worry about COVID-19, the less negative effect on stock return.

5. CONCLUSIONS

Our paper investigates the spillover of SGX's oil market risk and return on Thailand stock market return by using daily data of 11 stock indices include 1 market level, 8 industry levels and 2 sector levels. For the evidence of the spillover of SGX's oil market return on Thailand's sectoral stock return, we found that, before COVID-19 appearance, SGX' oil market return had a significant positive effect on RESOURC, INDUS, PETRO, ENERG and SET. Therefore, we can conclude that, in the normal situation, the resources and industrials industry gain a benefit when oil price increases. The Petrochemicals and Chemicals and Energy and Utilities sector also gain a benefit when oil price increases. These sectors involve with a high volume of oil inventory, then their profit will be increase when oil price goes up. Moreover, for the Petrochemicals and Chemicals sector, oil is the main output and the demand for oil is strongly inelastic, then when oil price goes up, the profit of this sector goes up as same as the return on their stock.

For the period during COVID-19 crisis, SGX' oil market return had a significant positive effect on every category of Thailand's stock return. It can be explained that during the COVID-19 crisis, investors withdraw their investment from Singapore's oil market and Thailand's stock market in all industries. Therefore, this is the evidence to support that investors may consider Singapore's oil market and Thailand's stock market as a complimentary investment in their portfolio.

For the evidence of the spillover of SGX's oil market risk on Thailand's sectoral stock return, we found that, before COVID-19 appearance, SGX' oil market risk had a significant negative effect on CONSUMP, INDUS and PETRO while, during COVID-19 crisis, SGX' oil price risk had a significant negative effect on FINCIAL, CONSUMP, AGRO, PROPCON, SERVICE and SET. It can be explained that when there is a shock or any factors that make the Singapore's oil market to become more fluctuated, it will affect the return in Thailand's stock market to be lower. So, the risk in Singapore's oil market may be the sign of uncertainty for the investors that make them decide to withdraw their investment from Thailand's stock market and hold cash instead.

Our study found the evidence that the daily changing of COVID-19 anxiousness had a significant negative effect on every category of Thailand's stock return. The more people are worry about COVID-19, the more they withdraw their investment from Thailand's stock market. DCC estimation results show that the correlation between SGX's oil market return and Thailand's sectoral stock return was varying over time and became more fluctuated, which the correlation swung between positive and negative area, during COVID-19 crisis. The dynamic correlation between Singapore's oil market return and Thailand's sectoral stock return became positive and heavily related during March 2020 which was the month that 2020 Oil-Price War had started and was the month that WHO announced COVID-19 as a pandemic. These results on DCC are consistent with the positive relationship between the Singapore's oil market return and Thailand's stock market return in which confirm that when there is a crisis, investors will withdraw their investment on both Singapore's oil market together with Thailand's stock market.

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