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Risk Spillover Effect of Crude Oil Prices Against Stock Price Indices: Case Study of Oil-Producing and Consumer Countries for The Period of 2000-2022

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ABSTRACT

Keywords: Risk Spillover Effect; GARCH Copula Quantile Regression

This research investigates the risk spillover effects of crude oil prices on stock price indices in both oil-producing and consumer countries during the period 2000–2022. The research employs the GARCH Copula Quantile Regression (CQR) model, a method capable of capturing nonlinear dependencies and tail risks between crude oil prices and stock indices across different risk levels. The data includes daily crude oil prices (WTI) and stock indices of oil-producing countries (S&P500, TASI, MOEX, TSX) and consumer countries (SSE, BSE SENSEX, Nikkei 225). The findings reveal significant downside and upside risk spillovers from crude oil prices to stock indices, with oil-producing countries experiencing higher spillover risks compared to consumer countries. Notably, the TASI index exhibits the greatest risk spillover among producing countries, while the SSE index is most affected among consumer countries. These results highlight the asymmetrical nature of risk spillovers, with downside risks posing greater challenges than upside risks. This research contributes to the existing literature by providing a more detailed analysis of risk dependencies using the GARCH CQR model and offering practical insights for investors and policymakers to better manage risks in volatile markets. The study underscores the importance of understanding tail dependencies in financial markets affected by crude oil price fluctuations.

Introduction

Crude oil is one of the most important raw materials for industrial production. This crude oil price movement can affect and interfere with other economic activities. One of them is the existence of a significant relationship between crude oil prices and financial markets, where a dynamic and effect correlation is found spillover between crude oil and the stock market (Liu et al., 2020).

Crude oil is an unprocessed petroleum and is widely found on the seabed and rocks. Crude oil is classified in several types based on sulfur content and oil density. Several types of crude oil exist such as Brent Blend, West Texas Intermediate, Russien Export Blend, and Dubai oil.

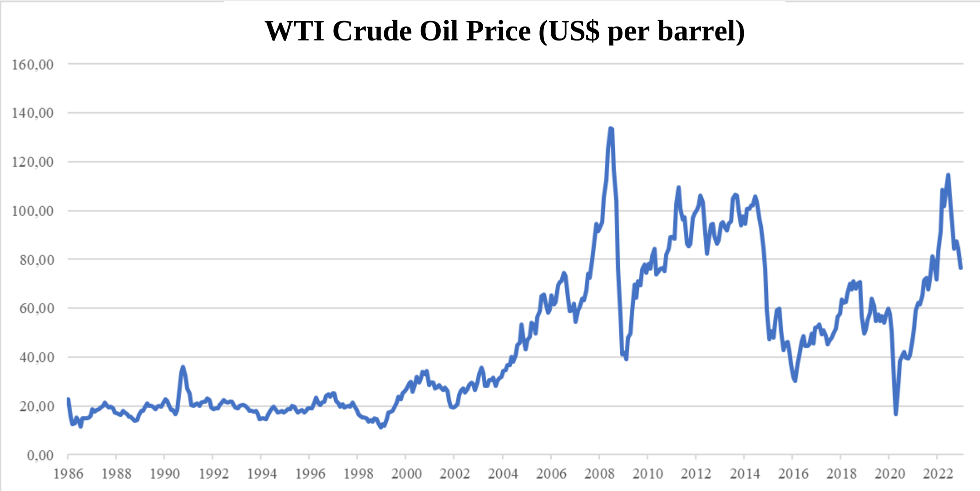


Figure Error! No text of specified style in document.. **WTI crude oil price**
Source: West Texas Intermediate

WTI or West Texas Intermediate is a type of crude oil that is used as a reference in determining world oil prices. WTI itself has the advantage of being a high-quality oil that is easy to reprocess, containing 0.24% sulfur with a low density making the oil light. WTI itself is the benchmark of world oil trade, oil prices are left fluctuating according to market needs and demands. Figure Error! No text of specified style in document. explained the price of WTI crude oil starting from 1980 to 2022. It can be seen that the price has experienced a high increase since 1980 to 2008. The crisis in 2008 caused the price to fall. Furthermore, WTI crude oil prices experienced fluctuations due to several phenomena such as in 2014 there was an increase in production and a decrease in market demand, then in 2020 due to the COVID-19 pandemic, and in 2021 due to the war between Russia and Ukraine.

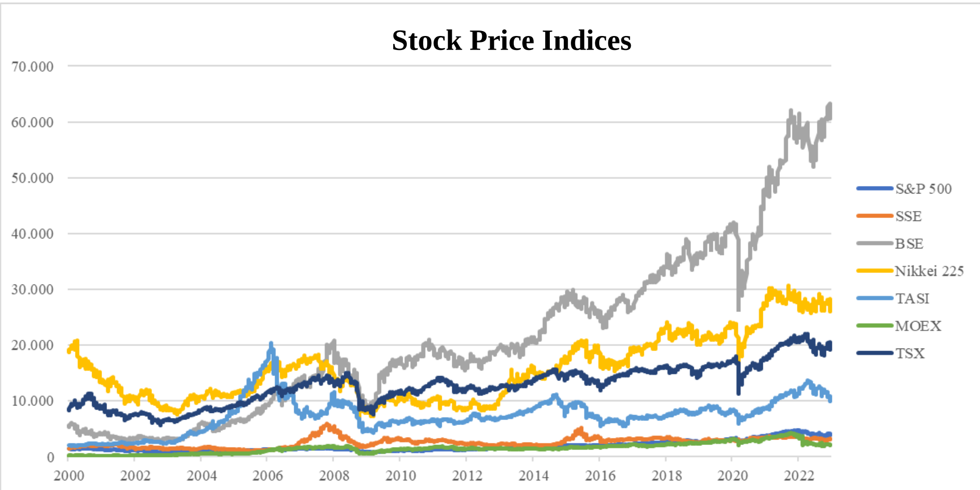


Figure 1. Stock price indices

Changes in oil prices have a significant impact on some countries in the world in a variety of ways. Oil-producing countries such as the United States, Saudi Arabia, Russia, and Canada, tend to rely heavily on revenues generated from oil exports. When oil prices are high, the country can see significant economic growth and increased government revenues. Conversely, when oil prices are low, the country can experience economic difficulties and budget deficits. Oil-consuming countries such as China, India, and Japan tend to be affected by oil changes in different ways. When oil prices are high, it can increase production costs for industries that rely on oil and increase people's living costs. This will cause inflation and slow down economic growth. Meanwhile, when oil prices are low, the country can reduce production costs and can lead to economic growth and job growth.

Changes in the price of crude oil can affect the price of stocks through several factors. Crude oil is one of the basic and main ingredients in the industry, so the increase in the price will directly affect the increase in raw materials and increase production costs. In other words, an increase in crude oil prices can affect inflation, increase unemployment and decrease the level of facility utilization, which triggers a recession which results in a negative outlook on the stock market. In addition, with the increase in production costs, it will reduce the profits received from companies that are highly dependent on crude oil, so that it will affect the decline in the company's share price. The increase in crude oil prices also affects economic activity and stock prices with a system of shifting purchasing power from oil-importing countries to oil-exporting countries, which can be called income shifts and aggregate demand effects (Fried et al., 1975; Rasche & Tatom, 1977).

One of the methods that can be used to analyze the relationship between crude oil and stock price indices is Copula Quantile Regression (CQR). CQR is a statistical method that combines the concept of copula and quantile regression. Copula used to model the relationship between two random variables, and quantile regression used to model Quantile of the dependent variable. This method can not only capture serial correlations and volatility clustering, but accurately describes nonlinearity downside dependence between variables at different levels of risk. Using such methods can capture the inverse dependence between financial returns at different levels of risk and can create a new framework for accounting for Tian et al. (2022) downside CoVaR dan upside CoVaR.

The purpose of this study is to conduct an effect risk analysis spillover between the price of crude oil against the stock price index. This research also aims to provide information and insights for investors and decision-makers in managing their investment risks in the stock market.

Previous research explained the relationship between oil prices and the stock market. The results of the study explain that there is strong evidence of an effect spillover from oil to the stock market (Abuzayed & Al-Fayoumi, 2021; Mensi et al., 2021; Tian et al., 2022). The study explained that changes in oil prices will result in dependencies and transition mechanisms between the Chinese stock market and changes in exchange rates. In addition, the study explains the relationship between the stock price index in producing and consumer countries and changes in oil prices. The results of the study explain that changes in oil prices will have an impact on the stock price index of oil-producing countries while in oil-consuming countries, changes in oil prices have no effect on the stock price index (Atif et al., 2022; Phan et al., 2015; Zeng et al., 2022).

This study examines the impact of changes in oil prices adapted to stock price indexes. Unlike the previous study, this study uses the copula quantile regression method which can provide more detailed information about the relationship between crude oil prices and stock price indices. The stock price index to be used is based on the producer and consumer countries at the top. In addition, this study uses a different data period from previous studies.

This study examines the impact of oil price fluctuations on the stock market, using WTI crude oil data, the United States stock price index, the Saudi Arabia stock price index, the Russian stock price index, the Canadian stock price index, the Chinese stock price index, and the Japanese stock price index from 2000 to 2022 using the GARCH CQR model developed by Tian and Ji (2022).

Method

The data used in this study are crude oil price data, stock price indices of crude oil-producing countries, namely the United States, Saudi Arabia, Russia, and Canada, and stock price indices of crude oil-consuming countries, namely China, India, and Japan. The data period used was from January 13, 2000 to December 29, 2022 (3,259 data). Data is obtained from the Refinitiv Eikon database.

This study uses several stages in calculating risk spillover. The main approach used is the GARCH CQR (Copula Quantile Regression) method. The GARCH CQR model is a more sensible approach than the traditional GARCH copula model (Tian & Ji, 2022). The risk spillover calculation is carried out using R software. In R software, the packages to be used are rugarch, copula, fGarch, and quantreg using the source code in the research (Tian & Ji, 2022). The stages in the method are to test the return data, perform the CoVaR model, perform the CQR model, and perform the GARCH CQR model. Then by using the Kolmogorov-Smirnov (KS) Test to conduct significance and asymmetry tests.

Results and Discussio

Descriptive Statistics

Figure 3 shows the crude oil return graph and Figure 4 to Figure 10 shows the stock price index return chart. In general, the return data of the stock price index is higher than the return data of crude oil.

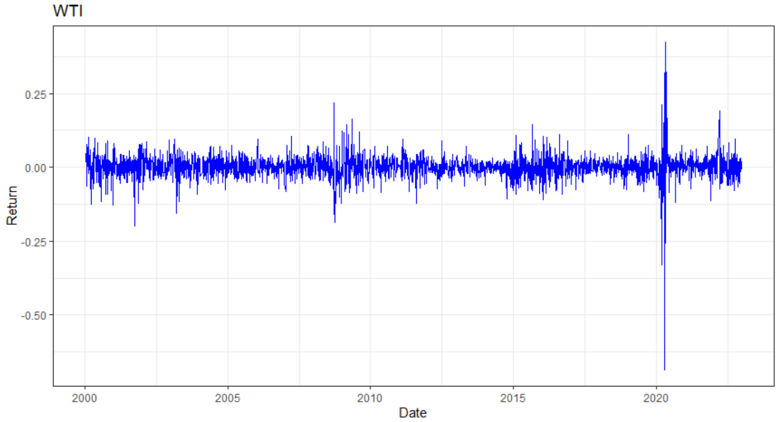
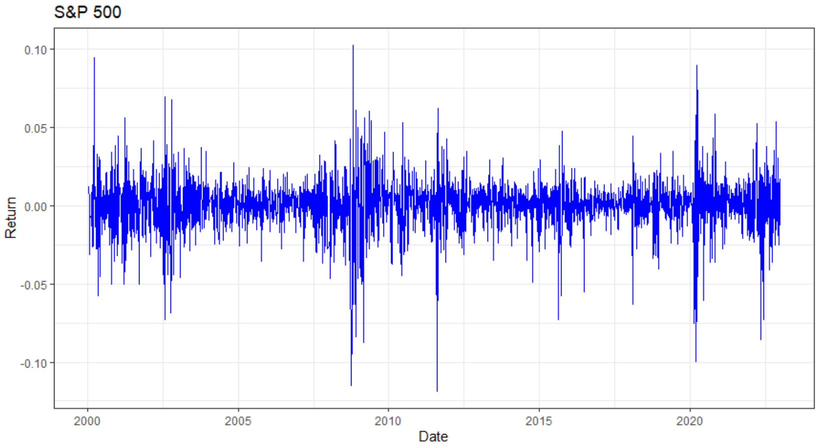


Figure 3. WTI crude oil return chart

Figure 3 shows the WTI crude oil return chart. The chart shows less significant crude oil volatility. This shows that crude oil prices tend to be stable. However, in 2008 and 2020, there was a volatility clustering behavior which was shown with a fairly high volatility value compared to other periods due to the global financial crisis in 2008 and the Covid-19 pandemic in 2020.



Picture Error! No text of specified style in document.**. Graphs return S&P 500 stock price index**

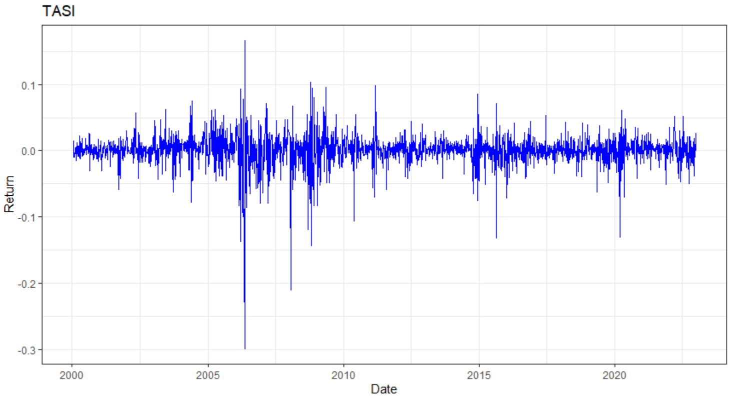


Figure 5. TASI stock price index return chart

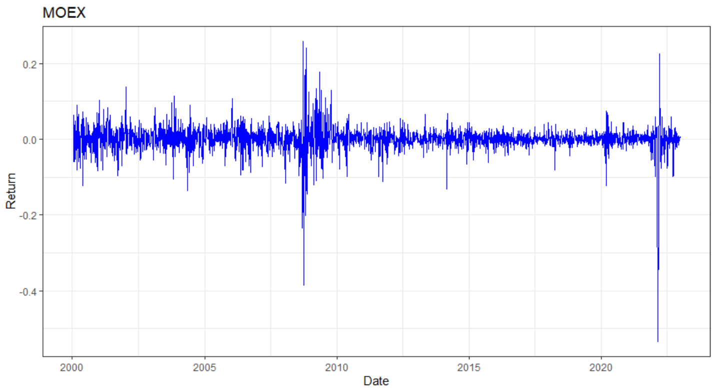


Figure 6. MOEX stock price index return chart

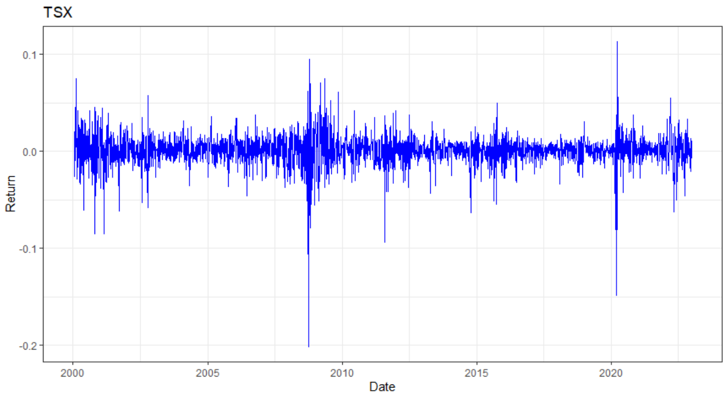


Figure 7. TSX stock price index return chart

Figures 4 to 7 show the return charts of the S&P 500, TASI, MOEX, and TSX stock price indices that are included as stock price indices of crude oil producing countries. The volatility of the S&P 500 stock price index is higher than that of other producing countries, because the United States is also a crude oil consumer. The return graph of the stock price index of crude oil producing countries also shows volatility clustering in 2008 and 2020.

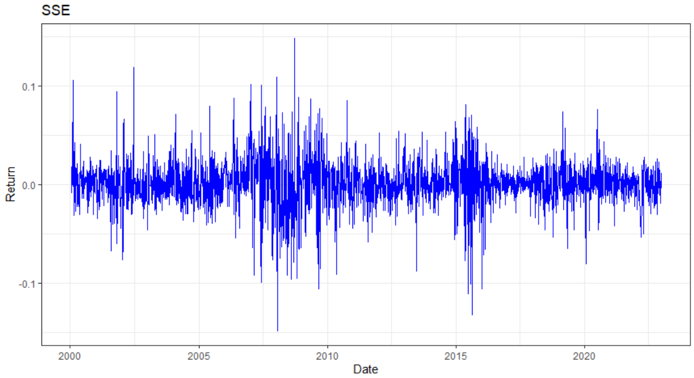


Figure 8. SSE stock price index return chart

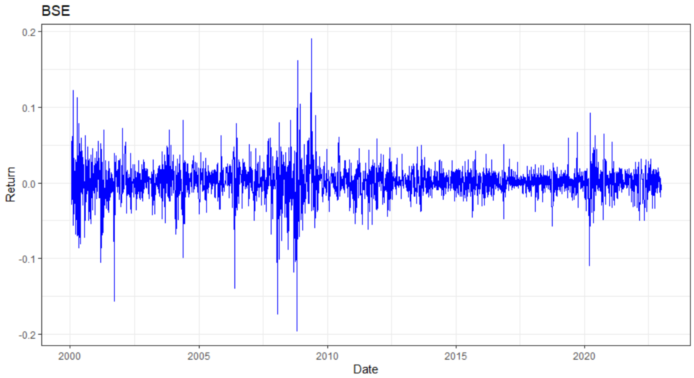


Figure 9. BSE stock price index return chart

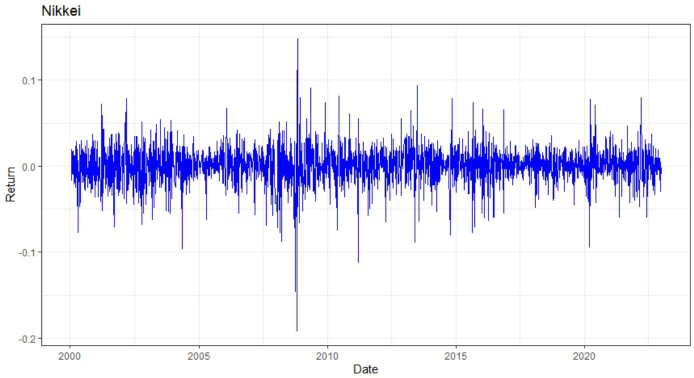


Figure 10. Nikkei 225 stock price index return chart

Figures 8 to 10 show the return charts of SSE, BSE, and Nikkei 225 stock price indices which are included as stock price indices of crude oil consumer countries. In general, the volatility of the stock price index has high fluctuations. This shows that the stock price index of crude oil consuming countries tends to change rapidly. In addition, there was volatility clustering in 2008 and 2020 caused by the global crisis and the Covid-19 pandemic.

Table 1. Descriptive statistics return Crude oil and stock price indices

	WTI	**S&P 500**	**TASI**	**MOEX**	**TSX**	**SSE**	**BSE**	**Nikkei**
Average	0.0003	0.0003	0.0005	0.0007	0.0003	0.0002	0.0007	0.0001
Maximum Value	0.4231	0.1025	0.1659	0.2584	0.1129	0.1478	0.1902	0.1479
Minimum Values	-0.0658	-0.1185	-0.2982	-0.5341	-0.2014	-0.1487	-0.1954	-0.1915
Median Value	0.0015	0.0009	0.0014	0.0013	0.0009	0.0004	0.0014	0.0005
Std Deviation	0.0362	0.0154	0.0194	0.0287	0.0143	0.0206	0.0205	0.019
Skewness	-1.7226	-0.6219	-2.0895	-2.5891	-1.6118	-0.1872	-0.536	-0.63
Kurtosis	53.5106	8,1886	29,2981	56,5831	23,7429	6,8312	12,7781	8,5876
ADF	-14,295	-14,69	-13,906	-13,25	-14,616	-13,425	-13,929	-15,082
	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	390443 <2,2E-16	9315,3 <2,2E-16	118932 <2,2E-16	438399 <2,2E-16	77958 <2,2E-16	6355,7 <2,2E-16	22328 <2,2E-16	10230 <2,2E-16
Ljung- Box	96,842 2,123E-10	85,071 1,829E-08	64,1756 2,242E-05	111,93 5,25E-13	71,998 1,935E-02	67,066 1,040E-02	45,392 7,543E-03	35,845 7,398E-02
ARCH	777,91 <2,2E-16	572,33 <2,2E-16	308,93 <2,2E-16	194,38 <2,2E-16	309,1 <2,2E-16	31649 <2,2E-16	352,45 <2,2E-16	401,38 <2,2E-16

Note: the ADF value is the stationary test value, the Jarque-Bera value is the normality test value, the Ljung-Box value is the autocorrelation test value, and the ARCH value is the ARCH test value.

Table 1 shows descriptive statistics from return crude oil and stock price indices. Average grade return Crude oil and stock price indices tend to be close to zero, this is because the data used is daily data. Return crude oil has the highest maximum and minimum value compared to return Stock price index, this occurred during the period due to the Covid-19 pandemic. Instead return The S&P 500 stock price index has a maximum value and a minimum value of the lowest. All data return has a value skewness negative and high curtosis values, it shows that the data has sharp apex traits and a fat tail.

Stationary testing at a significance level of 5% rejected the null hypothesis so the data used was stationary data. The normality test using the Jarque-Bera test at a significance level of 1% rejects the null hypothesis so that the data used are not normally distributed. The autocorrelation test using the Ljung-Box test at a significance level of 1% rejects the null hypothesis so that the data used is distributed independently. Testing the ARCH effect using the LM test at a significance level of 1% rejected the null hypothesis so that the data used did not contain the ARCH effect.

Marginal Distribution Model

Table 2 shows the AIC (Akaike Information Criteria), SIC (Schwarz Information Criterion), HQC (Hannan-Quinn Information Criterion), and LLF (Loglikelihood) criteria for the selection of marginal distribution models.

Table 2. Election marginal distribution model

	Distribusi	ARMA(1,1)-GARCH(1,1)				ARMA(1,1)-EGARCH(1,1)			
		AIC	SIC	HQC	LLF	AIC	SIC	HQC	LLF
WTI	Normal	-4,167	-4,167	-4,163	6796,719	-4,205	-4,205	-4,200	6859,179
	STD	-4,319	-4,319	-4,314	7044,404	-4,337	-4,337	-4,332	7075,454
	SSTD	-4,321	-4,321	-4,315	7048,385	-4,341	-4,341	-4,335	7082,184
S&P500	Normal	-5,892	-5,892	-5,888	9607,153	-5,943	-5,943	-5,938	9690,456
	STD	-6,034	-6,034	-6,029	9838,568	-6,075	-6,075	-6,069	9906,764
	SSTD	-6,046	-6,046	-6,040	9859,085	-6,087	-6,087	-6,081	9927,380
TASI	Normal	-5,550	-5,550	-5,546	9050,054	-5,569	-5,569	-5,565	9082,314
	STD	-5,852	-5,852	-5,847	9542,047	-5,871	-5,871	-5,865	9574,192
	SSTD	-5,853	-5,853	-5,848	9545,987	-5,873	-5,873	-5,867	9579,516
MOEX	Normal	-4,794	-4,794	-4,790	7817,655	-4,821	-4,821	-4,817	7863,485
	STD	-5,043	-5,043	-5,038	8224,328	-5,051	-5,051	-5,046	8238,350
	SSTD	-5,045	-5,045	-5,039	8228,109	-5,053	-5,053	-5,047	8243,272
TSX	Normal	-6,095	-6,095	-6,091	9937,900	-6,139	-6,139	-6,135	10010,790
	STD	-6,269	-6,269	-6,264	10221,760	-6,292	-6,292	-6,287	10261,120
	SSTD	-6,277	-6,277	-6,272	10236,850	-6,300	-6,300	-6,294	10275,280
SSE	Normal	-5,225	-5,225	-5,221	8520,597	-5,233	-5,233	-5,228	8533,619
	STD	-5,404	-5,404	-5,399	8812,949	-5,415	-5,415	-5,410	8831,970
	SSTD	-5,404	-5,404	-5,398	8813,257	-5,410	-5,410	-5,404	8824,630
BSE	Normal	-5,302	-5,302	-5,298	8645,781	-5,334	-5,334	-5,329	8698,244
	STD	-5,479	-5,479	-5,474	8934,824	-5,492	-5,492	-5,487	8956,930
	SSTD	-5,480	-5,480	-5,475	8937,546	-5,493	-5,493	-5,487	8960,487
Nikkei	Normal	-5,245	-5,245	-5,241	8552,056	-5,271	-5,271	-5,226	8595,697
	STD	-5,403	-5,403	-5,398	8810,687	-5,417	-5,417	-5,412	8834,745
	SSTD	-5,403	-5,403	-5,398	8812,363	-5,417	-5,417	-5,411	8836,213

Note: The selection of marginal distribution models is done by looking at the models with the lowest AIC, SIC, HQC values and the highest LLF

Based on the values of the AIC, SIC, HQC, and LLF criteria, the ARMA(1,1)-EGARCH (1,1) model with SSST distribution is the best model for calculation.

Copula Quantile Regression Model

Table 3 indicates the estimated coefficient used in the Rotated Gumbel Copula Quantile Regression Model and Gumbel Copula Quantile Regression Model at Quantile 5% and 95%.

Table 3. Coefficient estimation of copula quantile regression model

Quantiles	Estimates	S&P 500	TASI	MOEX	TSX	SSE	BSE	Nikkei
τ = 5%	$\hat{\delta}_\tau$	1.108	1.380	1.096	1.290	1.378	1.237	1.198
	Std. error	0.121	0.473	0.365	0.295	0.427	0.691	0.463
	$\hat{\theta}_\tau$	-0.423	-0.418	-0.459	-0.131	-0.320	-0.463	-0.391
	Std. error	0.891	0.854	2.429	0.588	0.486	1.741	1.223
	$\hat{\eta}_\tau$	0.890	0.797	0.609	0.757	0.619	0.713	0.549
	Std. error	0.540	0.458	1.484	0.321	0.228	0.943	0.704
1-τ = 95%	$\hat{\delta}_{1-\tau}$	2.415	3.224	1.598	1.607	2.327	2.085	2.956
	Std. error	3.334	2.837	1.710	1.365	2.409	2.199	3.616
	$\hat{\theta}_{1-\tau}$	1.074	1.093	1.108	1.099	1.112	1.124	1.022
	Std. error	0.301	0.243	0.409	0.270	0.296	0.234	0.211
	$\hat{\eta}_{1-\tau}$	0.255	0.417	0.223	0.231	0.283	0.217	0.214
	Std. error	0.114	0.103	0.205	0.118	0.142	0.085	0.108

Note: δ_τ is a copula parameter, is a $\theta_\tau$panning parameter, and $\eta_\tau$is a zooming parameter.

Value-based D at Table 3 shows that the TASI stock price index has downside and upside tail dependence high oil prices. Parameter Panning θ is estimated to have a negative value on Quantile 5% and positive on Quantile 95%. While the parameter Zooming ɳ is the smallest parameter value.

Crude Oil Spillover Risk on Stock Price Index

Downside CoVaR dan Upside CoVaR stock price index can be calculated based on the equation **Error! Reference source not found.**) and **Error! Reference source not found.**), where the election model marginal distribution Based on sub-chapters 0 and the coefficient estimation at Copula Quantile Regression model Based on sub-chapters 0 To determine whether crude oil has a contribution to a stock price index, it can be done by using a significance test to compare the CoVaR of a stock price index.

Table 4. Significance test and asymmetry test

	Downside ΔCoVaR	Upside ΔCoVaR	Asymetric ΔCoVaR
S&P500	0.505	0.502	0.140
	0.000	0.000	0.000
TASI	0.512	0.504	0.081
	0.000	0.000	0.000
MOEX	0.502	0.503	0.303
	0.000	0.000	0.000
TSX	0.505	0.502	0.152
	0.000	0.000	0.000
SSE	0.504	0.503	0.180
	0.000	0.000	0.000
BSE	0.504	0.502	0.221
	0.000	0.000	0.000
Nikkei	0.504	0.502	0.142
	0.000	0.000	0.000

Table 4 showed that the results of the significance test rejected H_0, it is indicated by the value and or $\Delta CoVaR^{S|i}_{\tau|\beta,t}\Delta CoVaR^{S|i}_{1-\tau|1-\beta,t}$downside and Upside Risk Spillover not equal to zero. Positive results on grades downside and Upside Risk Spillover shows the direction Risk spillover which is in the same direction, i.e. Risk spillover crude oil against stock price indices. In addition, the positive value shows that $\Delta CoVaR^{S|i}_{1-\tau|1-\beta,t} \geq |\Delta CoVaR^{S|i}_{\tau|\beta,t}$Upside Risk Spillover greater than or equal to Downside Risk spillover.

Table 5. Descriptive statistics Downside Risk Spillover

Type	Countries	Rank	Mean	S.D.	Max	Min	Median
Producer	S&P500	4	-0.009	0.005	-0.002	-0.041	-0.008
	TASI	1	-0.027	0.017	-0.009	-0.201	-0.021
	MOEX	3	-0.010	0.006	-0.004	-0.071	-0.009
	TSX	2	-0.011	0.007	-0.004	-0.065	-0.010
Consumer	SSE	1	-0.017	0.008	-0.005	-0.052	-0.015
	BSE	2	-0.014	0.072	-0.005	-0.064	-0.013
	Nikkei	3	-0.010	0.004	-0.005	-0.043	-0.010

Table 6. Descriptive statistics Upside Risk Spillover

Type	Countries	Rank	Mean	S.D.	Max	Min	Median
Producer	S&P500	3	0.005	0.003	0.022	0.001	0.004
	TASI	1	0.015	0.009	0.109	0.005	0.012
	MOEX	2	0.007	0.004	0.048	0.002	0.006
	TSX	4	0.004	0.002	0.020	0.001	0.003
Consumer	SSE	1	0.008	0.004	0.024	0.002	0.007
	BSE	3	0.005	0.003	0.024	0.002	0.005
	Nikkei	2	0.005	0.002	0.223	0.003	0.005

Table **5** and Table 6 shows statistical descriptive from downside and upside risk spillover. For crude oil-producing countries, the absolute value of Downside Risk Spillover and Upside Risk Spillover of crude oil to the TASI share price index is the largest. This shows Risk spillover crude oil against the TASI stock price index can pose a great risk to the position of long and short. For crude oil-consuming countries, the absolute value of Downside Risk Spillover and Upside Risk Spillover from crude oil has an impact on the SSE stock price index. While the smallest value of Risk spillover indicates that changes in oil prices have the lowest risk in the event of a sharp increase or decrease.

The downside and upside risk spillover from oil-producing countries is greater than that of oil-consuming countries. This is shown by the absolute value of the average downside and upside risk spillover. This shows that investment in oil-producing countries will be riskier during extreme changes in oil prices.

The downside risk spillover is higher compared to the upside risk spillover. This is shown by the absolute value of the average downside and upside risk spillover. This shows that the upside risk spillover has a low impact on the stock price index compared to the downside risk spillover.

The results of the study show that there are Risk spillover crude oil against stock price indices. This is in line with, ,,, and which shows the existence of (Karimalis & Nomikos, 2018; Liu et al., 2020; Mensi et al., 2022; Tian et al., 2022; Tien & Hung, 2022; Zeng et al., 2022) Risk spillover from crude oil to stock price indices.

The results of this study are in contrast to, which states that an increase in crude oil prices will have a positive impact on the stock price index of producing countries but has a negative impact on oil-consuming countries. In this study, it is stated that an increase in crude oil prices will have a positive impact on the stock price indices of producing countries and consumer countries. This can be due to the existence of Phan et al. (2015) Risk spillover between crude oil and stock price indices, but the effect of Risk spillover Crude oil against the stock price index is higher than the stock price index against crude oil (Zeng et al., 2022).

Conclusion

In this study, it shows that there is a risk spillover between crude oil and the stock price index. This study strengthens the hypothesis that there is a crude oil spillover risk to the stock price index in oil-producing and consumer countries. Based on analysis and discussion, it can be concluded that there is a spillover effect of oil prices on the stock market in both oil-producing and consumer countries. This is shown by the downside and upside risk spillover values that are not equal to zero. Practical Implications, policymakers and investors should consider the asymmetry of risk spillovers when designing strategies to mitigate the impact of crude oil price volatility. For oil-producing countries, emphasis should be placed on diversifying economic reliance on oil revenues to reduce exposure to downside risks. In consumer countries, strategies to manage inflationary pressures from rising oil prices are critical. Recommendations for further research, future studies could expand this analysis by incorporating other financial instruments, such as bonds or commodities, to understand broader market dynamics. Additionally, exploring the impact of macroeconomic variables, such as exchange rates and interest rates, on the risk spillover relationship could provide deeper insights. Employing alternative statistical models or incorporating more recent data could also refine the understanding of these spillover effect

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