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Research Article

The Impacts of Crude Oil Market Structure on Stock Market Growth: Evidence from Asian Countries

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The purpose of this paper is to investigate the impact of crude oil market structure on stock market volatility in Asian countries in the period 2008–2017. We integrate network analysis with the SGMM estimation technique to achieve the research objective. Network analysis was conducted with 43 Asian countries, while analysis of the impact of crude oil market structure on stock markets was performed with a sample of 19 countries. The results show that the stock market has a positive growth in countries with stronger export capacity while it is negatively affected in larger importing countries. In addition, the research results show that the stock market's growth is greater in countries with a central position in the crude oil market. The study results will be useful for countries in reducing the undesirable impact of crude oil market on the stock market.

1. Introduction

Petroleum is one of the most important inputs in economic production. Specifically, 50% of the oil production is used to produce electric power and fuel for vehicles to transport goods to the market, while the remaining 50% is used for petrochemicals to produce plastics, solvents, fertilizers, asphalt, pesticides, and many other products. As a result, fluctuations in oil prices can affect the performance of the economy. An increase in oil price causes a temporary decrease in total output, as investors would defer from business activities due to increased oil prices [1]. Rising oil prices may push the prices of other commodities, which in turn causes inflation.

During the first half of 2020, the COVID-19 pandemic negatively affected all manufacturing and industrial sectors in many major economies. Disturbances in production and demand for goods and raw materials severely impacted value chains. In addition, countries are also looking for opportunities to produce green energy after the COVID-19 pandemic [2]. In such context, OPEC members have reached an agreement to reduce crude oil production. Under the agreement in April 2020, OPEC currently cuts production by 7.7 million BPD and might reach 5.8 million BPD by January 2021. Most of OPEC members agreed with the proposal to cut production despite positive news about the success of a COVID-19 vaccine, which causes the rise of crude oil prices and the temporary fall of total output as investors delay trading due to increased uncertainty about oil prices [1]. The rise of oil prices leads to higher prices of other commodities, which stimulates inflation. As a result, consumers' expenditure and demand for goods and services are limited. Consequentially, both companies' profits and the consumers' income go down, which implies a negative impact on the stock prices.

In previous studies, the volatility of crude oil prices was often considered as a factor to explain the stock price fluctuations. For instance, Kilian and Park [3] examined the impact of oil price shocks on the US stock market. The study results indicate that the response of total real US stock returns may vary upon the cause of the increase in crude oil prices. Apergis and Miller [4] studied the effects of oil market structural shocks on stock markets in eight countries: Australia, Canada, France, Germany, Italy, Japan, the United

Kingdom, and the United States. The results show that different oil market structural shocks have different significant influences on the corrections in stock market returns. Besides, Elyasiani et al. [5] investigated oil price shocks and industry stock returns. The findings show strong evidence that oil price volatility constitutes a systemic risk of asset prices at the industry level and influences stock market volatility. Abhyankar et al. [6]; on the other hand, find that changing oil prices positively and significantly influence the stock market.

Although there are many studies on the impact of oil prices on the stock market, to the best of our knowledge, there is almost no study on the impact of oil market structure on stock market growth. Oil market structure shows oil import and export activity between countries in the region, which can lead to various oil price shocks. In turn, these oil price shocks affect the stock market. Therefore, studying the impact of oil market structure on stock market growth may provide a complete explanation for the relationship between these two markets. To fill this research gap, this study has the following objectives:

(i) To analyze crude oil import and export market structure in Asian countries

(ii) To assess the impact of oil import and export market structure on stock markets of Asian countries

The next parts of the study are structured as follows. Section 2 presents the literature review. The research model, methods and data are presented in Section 3. Results and policy implications are shown in Sections 4 and 5, respectively.

2. Literature Review

Theoretically, oil price contributes to the cost of production of the industry and the constitutive factor of the value of output products. Jones and Kaul [7] found that higher oil prices imply more expensive fuels, which can lead to higher costs of transportation, higher prices of goods and services, and bring up concerns about inflation. As a result, the shrink of consumers' expenditure results in the reduction in demand for goods and services. This, in turn, can cause a decline in company profits and income when production output is cut off. As a consequence, the value of shares of companies will be affected and create changes in the stock market. Thus, the common understanding is that rising oil prices tend to force stakeholders in the economy to spend more money on energy consumption, thereby reducing profit margins and adversely affecting the stock market. However, it can be seen that the above analysis comes from oil supply shocks. Given oil price fluctuations are caused by oil demand shocks, the results of this impact on the stock market may change. Recent studies by Bernanke [8]; Filis et al. [9]; Prabheesh et al. [10] show that there is a positive movement of stock market returns and oil prices. The tendency for stock prices to move in line with world oil prices is quite unexpected, especially in such countries as Bangladesh, India, Pakistan, and Sri Lanka, which are net importers of oil [3, 9]. Bernanke [8] explains that both oil prices and stock prices respond to changes called global aggregate demand. For example, on the one hand, a decrease in aggregate demand will reduce oil demand and reduce pressure on oil prices. On the other hand, a decrease in aggregate demand will also affect corporate profits, causing stock prices to fall. This implies that the reactions of stock traders to a change in the oil price include their reactions to a change in a group of common factors that cause oil prices to change.

Although evidence for the impact of oil price shocks on stock markets has been provided by related studies [3–6, 8–12], there are still some research gaps in this area of research. Specifically, related studies have provided evidence on the impact of oil price shocks on stock markets in many countries around the world. However, one problem that has not been examined by the previous studies is that these countries have different oil import and export activities. Therefore, the effects of oil price shocks on these countries may vary. A rare study that mentioned the issue is that of Park and Ratti, which focuses on analyzing the relationship between oil prices and stock returns in 13 European countries. Research results show that oil price shocks have a positive impact on stock markets in oil-exporting countries, which implies that larger oil exporters will have a growing stock market.

Meanwhile, these shocks have a negative impact on stock markets in oil-importing countries, which means that the stock markets in larger oil importers will be negatively affected.

Based on the previous studies, two hypotheses are formulated in this paper as follows:

Hypothesis 1 (H1). A country exports more crude oil to other countries, its stock market will grow positively

Hypothesis 2 (H2). A country imports more crude oil from other countries, this country's stock market will be negatively affected

As analyzed above, the study by Park and Ratti has shown how the stock market is affected in oil-exporting and oil-importing countries. However, these results are only based on a single country-by-country assessment and do not consider the overall oil import and export activities between these countries. On the other hand, a country can both export and import oil from other countries. Therefore, it is necessary to have a more suitable method to assess the different oil import and export activities of countries. Finally, in previous studies, the independent variable representing the oil trading activities was also not included in the research model.

Therefore, the first contribution of this study is to evaluate the structure of the oil import and export market through social network analysis. We will evaluate the oil trading activities and identify the largest oil importers and exporters with this method. As a result, the study will give an overview (linked networks) of the oil import and export market structure in Asian countries. The next contribution of this study is to include in the model the independent variables that represent the position of the oil-importing or oil-exporting country. Specifically, we include in-degree and out-degree variables that represent the import and export position of each country in the network. These variables are calculated from social network analysis, which is presented in the next section.

3. Data and Methods

3.1. Data. Although the construction of the crude oil import and export market structure in Asian countries was conducted with 43 countries, the impact of the oil import and export market structure on the stock market growth was only considered in 19 Asian countries. The reason is that among these 43 Asian countries, the stock market has only just formed and has complete data in 19 countries in the period from 2008 to 2017.

Research data to examine the impact of oil price fluctuations on stock markets in Asian countries are collected from reliable sources, which are as follows:

(i) Crude oil prices are collected from the US Energy Information Administration.

(ii) Private investment as a percentage of GDP, human capital, and trade openness are collected from the World Economic Outlook (WEO) dataset of the International Monetary Fund (IMF) and the set of World Development Indicators (WDI) for 43 Asian countries in the period from 2008 to 2017.

(iii) Stock index data for Asian countries is collected from Investing.com. All data in the study were collected for the year from 2008 to 2017. The starting point is set by the availability of country stock market data.

3.2. Methods

3.2.1. Method for Assessing the Oil Market Structure. To assess the oil market structure in Asian countries, the study employs the social network analysis in terms of distribution, centrality and reciprocity. In particular, the indicators are as follows:

(1) Distribution. Distribution is a property of the network that measures the extent to which all nodes in the network are connected. Distribution describes the degree of cohesion of all nodes in the network and can be calculated as the ratio of the actual number of connections that a node has to the total number of possible connections if each of these nodes is tied to all the other nodes (maximum number of connections). A complete system is the one in which all possible connections exist [13] and the density of the network is equal to 1 [14]. The complex network theory suggests that the distribution of a network provides an idea of the proximity of connections and its importance to the nodes participating in the network. As a result of the dense network structure, values, norms, and information sharing will become more prevalent. As networks get denser (closer to 1), communication (information exchange) throughout the network becomes more seamless and efficient. Additionally, as network density rises, the possibility of connections/edges forming increases, ensuring that shared expectations for resource exchange for node activities are satisfied.

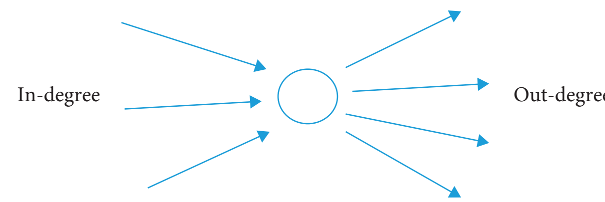

Figure 1: Degree centrality of a vertex. Source: composed by the authors.

The formula is as follows:

$$D = \frac{q}{N(N-1)/2}, \quad (1)$$

where q is the number of connections or edges, N is the number of nodes in the network.

(2) Centrality. Network centrality refers to the position of one node in the network relative to other nodes. Centrality enables an agent to have the advantage of attracting resources in conjunction with other nodes [15], which measures the level of communication of an agent in the network. Centrality indicates resources obtained through the structure of the network [13]. The centrality is identified by the following main parameters:

(3) Degree Centrality. Degree centrality is the total number of actual links of a vertex to other vertices in the network (see Figure 1). In a directed graph, the number of links is often defined of a vertex in terms of central order, namely in-degree and out-degree. Accordingly, in-degree is the total number of connections leading from other vertices to the vertex in the network (the sum of links entering a vertex), while out-degree is the total number of direct linkages leading from the vertex to other vertices in the network (sum of links coming out of a vertex). If a vertex has more incoming linkages than outgoing links, that vertex might be considered the network's terminus. Otherwise, the vertex is considered as the starting point of the network. In addition, when the numbers of two links at a vertex are equivalent, this point is the transit point of the network.

(4) Between Centrality. Between centrality measures the degree of centrality to which a vertex lies among other vertices in a set of vertices of the network [16]. It quantifies the number of times a vertex (i) performs as a bridge along the shortest path connecting two other vertices in the network. In other words, Between centrality determines the relative importance of a vertex by measuring the traffic of links flowing through that vertex to other vertices in the network.

The central position of a vertex is high when there is a high probability of randomly choosing the shortest path between any two vertices, so this peak provides control over the source of inter-core communication and other elements in the network. In practice, actors outside the network can communicate or exchange resources with other parts of the system simply by passing through focal organizations or central vertices in which the leading organizations are located, and the environment can control the flow of all resources.

The formula is as follows.

$$\text{Between centrality}(i) = \frac{\sigma_{st}(i)}{\sigma_{st}}, \quad (2)$$

where: $\sigma_{st}(i)$ the number of shortest paths between each vertex t passing through vertex i. σ_{st} is the number of shortest paths passing through vertex t.

This coefficient determines the importance of a vertex in the network. The larger coefficient indicates that the country is more important in the oil trading network.

(5) Reciprocity. The reciprocity coefficient of a network represents the correlation between two entries of the adjacency matrix of a directed network. This coefficient is measured as follows.

$$\text{Reciprocity} = \frac{\sum_{i\neq j}\left(a_{ij}-\overline{a}\right)\left(a_{ji}-\overline{a}\right)}{\sum_{i\neq j}\left(a_{ij}-\overline{a}\right)^{2}}, \quad (3)$$

where: $\overline{a} = \sum_{i\neq j} a_{ij}/n(n-1)$, $a_{ij} = 1$ if there is a link from vertex i to vertex j, otherwise $a_{ij} = 0$.

This coefficient is greater than 0, indicating a statistically significant correlation between the two entries. The larger the coefficient, the higher the bidirectional relationship between the vertices in the network.

3.2.2. Method for Assessing the Impact of Oil Market Structure on Stock Market Growth. To assess the impact of oil market structure on stock market growth of Asian countries, this study employs the model from Kilian and Park [3] and Kang et al. [12]; which are modified with additional variables measuring crude oil import and export market structure. The specification of the model is as follows:

$$\text{Stock}_{it} = \beta_0 + \beta_1 S_{it} + \beta_i X_{it} + \varepsilon_{it}, \quad (4)$$

where Stock_{it} is the stock market growth of country i in year t. S_{it} is the oil market structure measured by the degree centrality and between centrality of country i in year t. X_{it} are the characteristics of country i in year t, including private investment as a percentage of GDP, human capital, trade openness.

To control endogeneity which often occurs in macroeconomic models, the study estimates the models by the system generalized method of moment (SGMM) approach [17]. This method is commonly applied to estimate linear dynamic panel data or panel data in which variable variance and autocorrelation exist.

The SGMM method is appropriate for this study for several reasons. First, the panel data of the study has a small T sample (10 years) and a large N sample (19 countries), which means few time points but many observations. Second, this method is suitable for estimating dynamic research models with the system of the equation containing the lagged variables. Third, this method can be used when the independent variables are not strictly exogenous, implying that these variables are correlated with the residuals or an endogenous variable in the model. Finally, when the model has separate fixed effects and variable variance or autocorrelation of errors, this method is appropriate due to its characteristics to cancel out the fixed effects individually and overcome the errors model defects.

4. Results and Discussion

4.1. Oil Market Structure of Asian Countries. As presented in Section 3, the distribution of the crude oil market in Asian countries is presented in the figure

Figure 2 shows that the network structure of the Asian crude oil market has a downward trend in distribution over the years in the period 2008–2017. Throughout this time, the average network distribution was 0.1224, with a maximum of 0.1429 in 2009 and a minimum of 0.1123 in 2017. Network distribution gradually decreased over the years, showing that the degree of connectivity among Asian countries is going down. In other words, the volume of crude oil import and export of Asian countries is shrinking over time. A possible explanation for this result is the geopolitical conflicts recently. Despite the short-term increase in crude oil demand, the market sentiment is turning pessimistic. The International Energy Agency reduced its forecast for annual oil demand growth from 1.6 million to 1.2 million barrels per day. OPEC's forecast for oil demand growth has been revised downward to 1.12 million barrels per day and is expected to decline further. Oil supply instability can be traced back to the history of the ongoing conflict between the United States and Iran. As the tension between the two countries has continued to escalate, the leading oil importers in Asia have carefully observed. Asian nations, which are the driving force behind the world's rise in oil demand, have been cautious as the United States gradually tightened its grip on Iran's oil exports. With the growing possibility of military confrontation, the Asia-Pacific economies dependent on imported oil need to think about alternative energy sources to cope with the increasingly volatile supply risks in the Strait of Hormuz. In addition, the impact of trade wars between countries and the change of trading environment have reduced fuel consumption and threatened to push key exporting countries into recession.

The results of degree centrality will be analyzed by two indicators of in-degree and out-degree of countries participating in the Asian crude oil market. In-degree is the total number of links originating from other vertices to the vertex under consideration (sum of paths entering a vertex). In other words, in-degree is the total number of countries that are importing crude oil. In contrast, out-degree is the number of links that direct from that vertex to other vertices in the network (sum of paths going out from a vertex), which can be calculated by the total number of countries that are exporting crude oil.

The results of degree centrality analysis by the in-degree indicator are presented in the figure below:

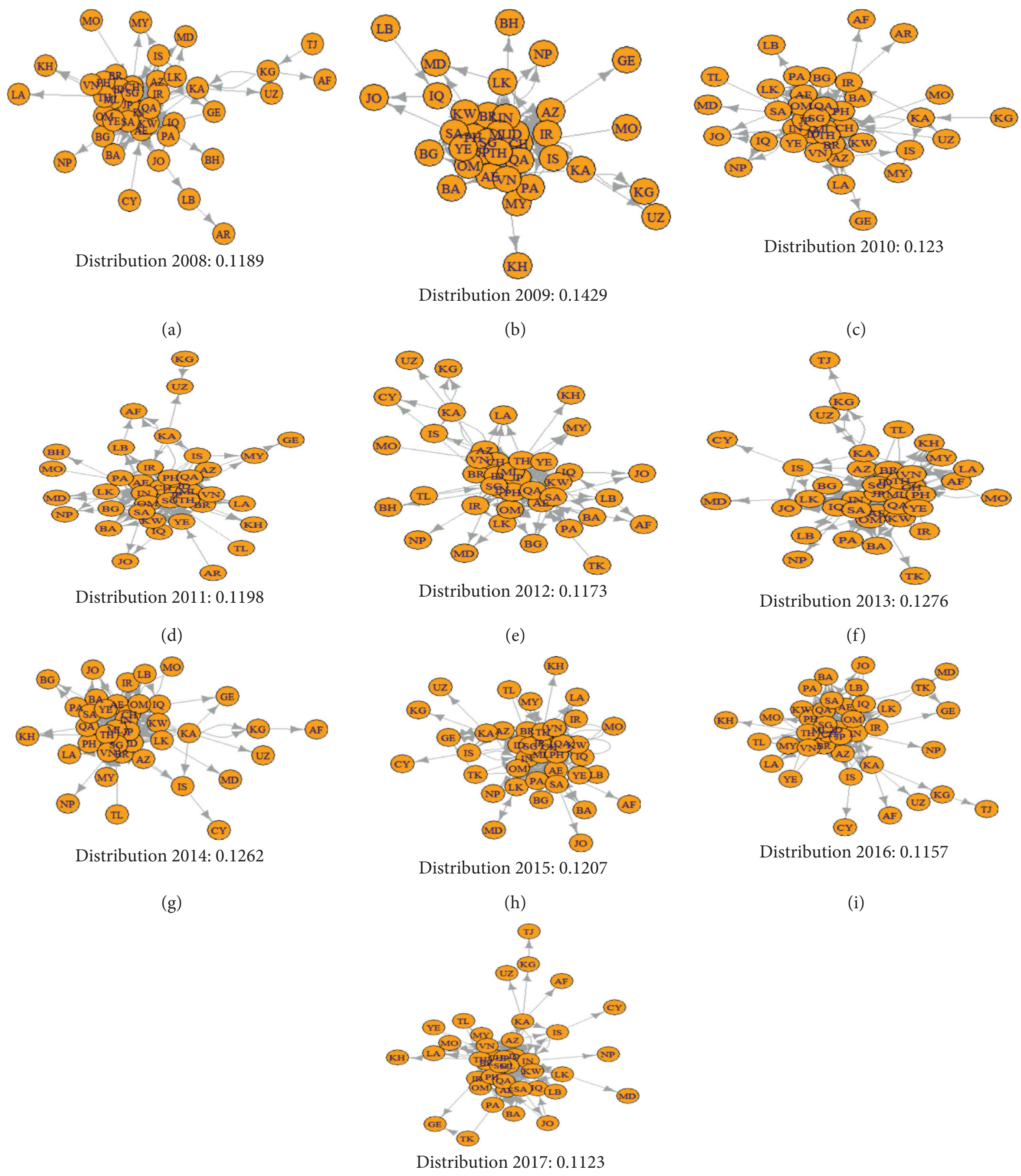

FIGURE 2: Network structure of Asian oil import and export market. Source: results calculated from the software STATA 16.0. (a) Distribution 2008: 0.1189 (b) Distribution 2009: 0.1429 (c) Distribution 2010: 0.123 (d) Distribution 2011: 0.1198 (e) Distribution 2012: 0.1173 (f) Distribution 2013: 0.1276 (g) Distribution 2014: 0.1262 (h) Distribution 2015: 0.1207 (i) Distribution 2016: 0.1157 (j) Distribution 2017: 0.1123.

The in-degree distribution, as seen in Figure 3, follows a power-law distribution. As a result, the crude oil import market network is a huge distinction. To be precise, the largest oil importers account for only a small amount in the market. The majority of nations in the market have a low level of imports from the remainder. In particular, oil import activities are concentrated mainly in China, India, and Japan. These countries are also among the world's largest crude oil importers. Thus, over the past two decades, the Asia region has driven an increase in global oil demand, and any fluctuations in oil demand from such top markets as China and India have a huge impact on oil demand forecasts.

The results of degree centrality analysis by the out-degree indicator are presented in the figure below:

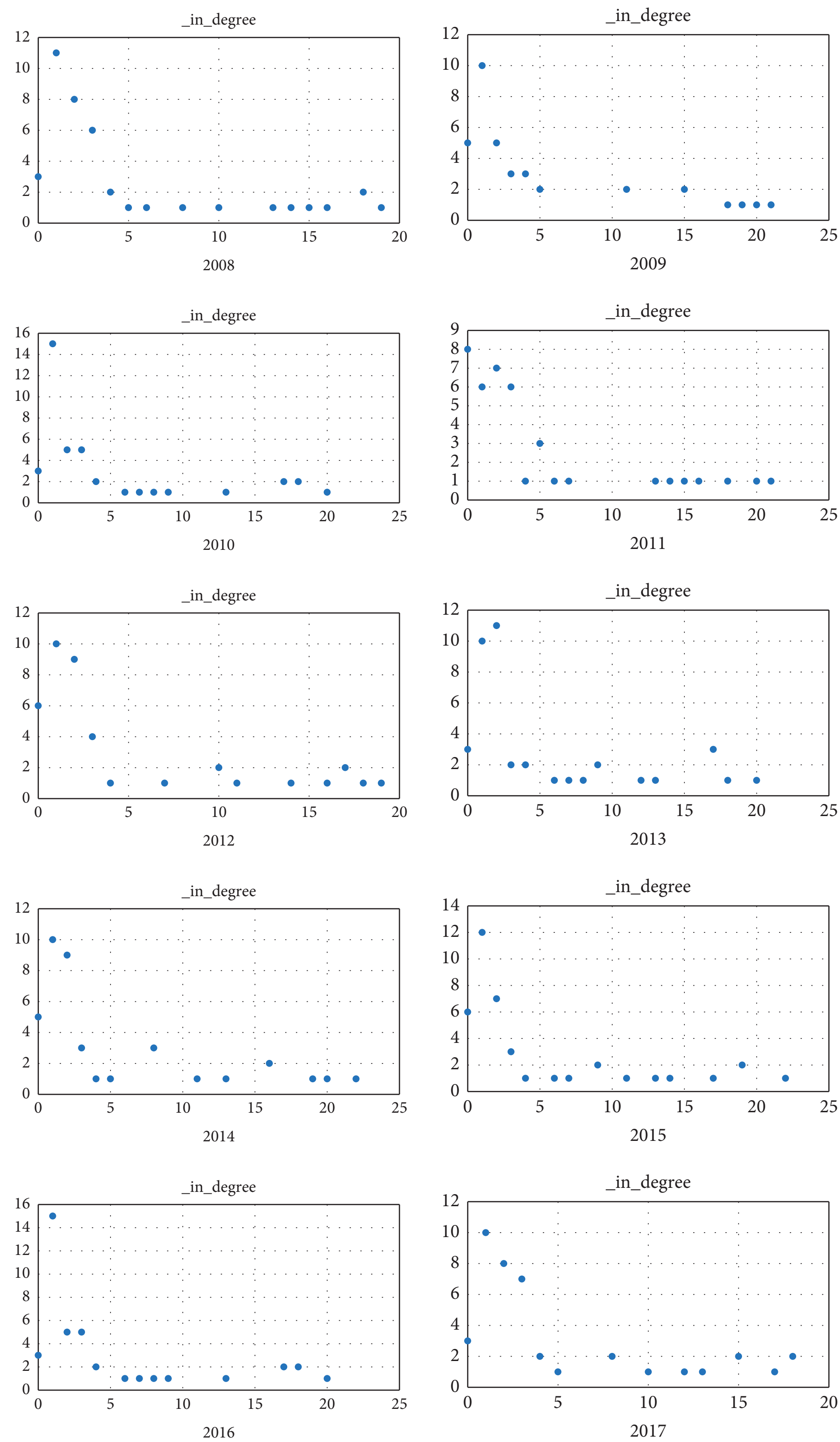

Figure 3: In-degree indicator of the Asian crude oil market network. Source: results calculated from the software STATA 16.0.

Figure 4 shows that the out-degree distribution also follows the power-law distribution. As a result, the crude oil export market network presents a huge distinction. In line with previous analysis for in-degree distribution, the largest oil exporters account for only a very small amount of the market, and the majority of

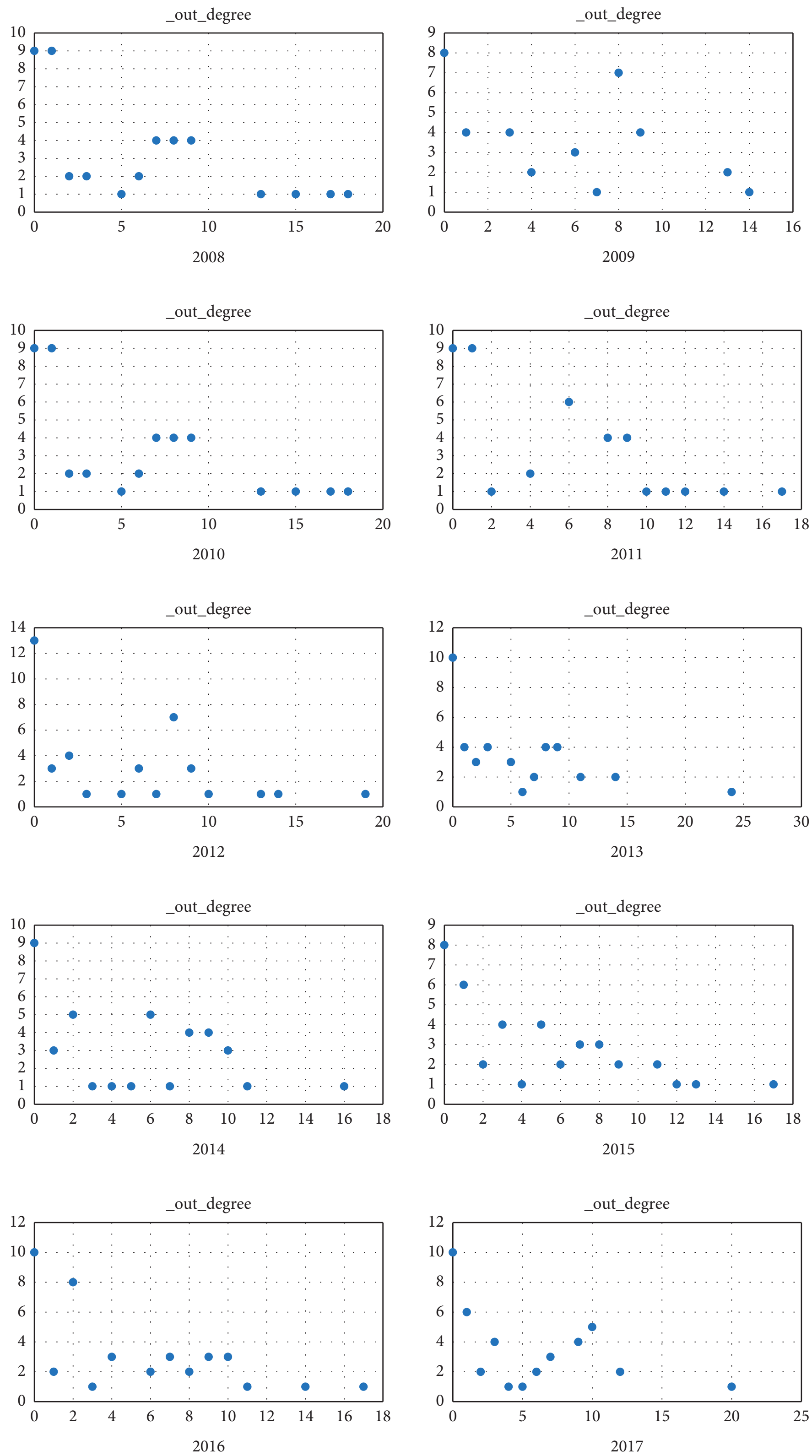

Figure 4: Out-degree indicator of the Asian crude oil market network. Source: results calculated from the software STATA 16.0.

countries in the market do not perform relatively high export activities with the others. In particular, Saudi Arabia, Iraq, and Iran are the three major crude oil suppliers to Asia. According to Mackenzie [18]; Asia accounts for 72% of Saudi Arabia's crude oil exports or 5 million barrels per day.

The reciprocity coefficient of a network represents the correlation between two vertices in the network. In this

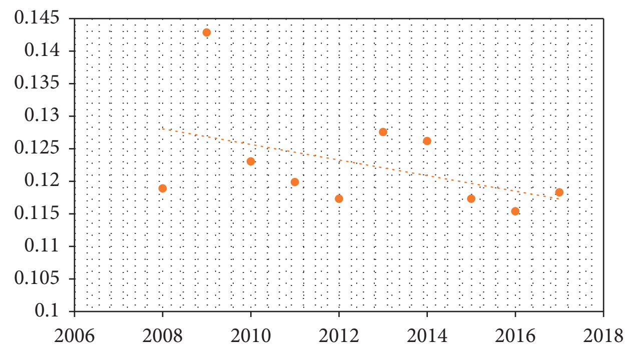

Figure 5: Reciprocity coefficient of the Asian crude oil market network. Source: results calculated from the software STATA 16.0.

Table 1: Descriptive statistics of the variables in the model.

Variables	Observations	Mean	Standard deviation	Min	Max	10th	25th	50th	75th	90th
Stock market										
Stock	190	0.017	0.291	−0.984	0.812	−0.321	−0.085	0.017	0.174	0.386
Oil market structure										
Between	190	47.096	73.880	0.000	325.601	0.000	0.143	12.958	62.626	153.567
In_degree	190	8.247	6.844	0	22	1	2	6	15	18
Out_degree	190	6.968	4.720	0	24	1	3	7	10	13
Control variables										
Inv	190	0.253	0.103	0.000	0.480	0.127	0.213	0.264	0.305	0.365
l	190	0.486	0.104	0.249	0.755	0.380	0.412	0.485	0.553	0.589
Open	190	0.972	0.769	0.000	4.416	0.363	0.503	0.764	1.266	1.636

Source: results calculated from the software STATA 16.0.

study, the reciprocal coefficient represents the bilateral crude oil import and export relationship among Asian countries. If this coefficient excesses 0, there is a statistically significant interaction between the two countries, or in other words, there is a bilateral trade in the Asian crude oil export markets. The higher this coefficient, the higher the bilateral relations between countries.

The analysis of reciprocity between countries are presented in the figure below:

Figure 5 shows that the coefficient of reciprocity of the Asian crude oil market network in the studying period has a positive value. Thus, there exists a bilateral relationship between countries in the Asian crude oil market. However, this coefficient tends to decrease over the years, showing that this bilateral relationship is weakening. This result contributes to strengthening the results of network distribution and centrality analysis presented above.

Generally, the analysis of the network structure of the crude oil market in Asian countries shows the following main results:

The network's distribution has been gradually decreasing over time, indicating that the network's connection across Asian nations is decreasing. In other words, Asian nations' crude oil import and export volumes tend to decline gradually.

Both the in-degree and out-degree distributions are power-law distributions. Thus, the network of crude oil import and export markets demonstrates a significant divergence. Specifically, import and export operations are concentrated in a few nations, with the remainder of the market having limited engagement.

The reciprocal coefficient tends to decline with time, indicating that the bilateral connection between nations participating in the Asian crude oil market is weakening.

4.2. Impact of Oil Market Structure on Stock Markets of Asian Countries. The descriptive statistics are shown in Table 1.

The descriptive statistics show that the average growth rate of stock indexes in Asian countries in the period 2008–2017 is 1.7%/year. During this period, low-growth stock index countries in the 10th percentile observed a fall of more than 32.1% per year. Meanwhile, countries with high-growth stock indexes in the 90th percentile perform stock increased by more than 38.6% per year.

In the period 2008–2017, the between centrality of an Asian country in the crude oil market network has an average value of 47. The process of importing and exporting crude oil between any other two countries in the network must cross this country 47 times on average. During this period, countries in the 10th percentile only reached the value 0, which is not in the intermediate between any two countries in the network. Meanwhile, countries in the 90th percentile are worth nearly 154 times.

During this period, an Asian country imported crude oil from about 9 other countries on average. Crude oil-importing countries in the 10th percentile only imported crude oil from one other country. Meanwhile, the major

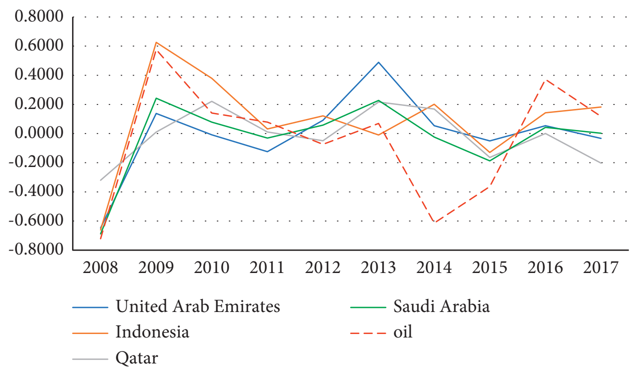

Figure 6: Volatility in oil prices and stock indicator in major crude oil-exporting markets in Asia.

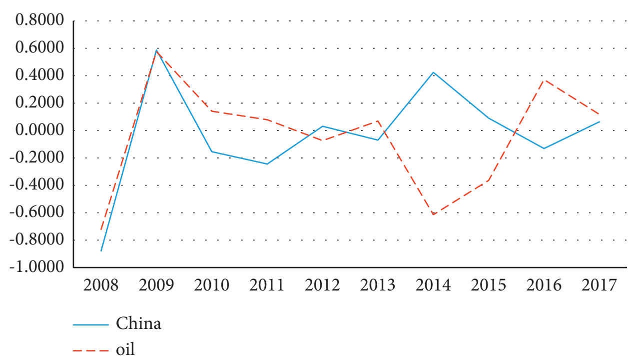

Figure 7: Oil price volatility and China's Shanghai composite index.

importers of crude oil in the 90th percentile, imported from more than 13 other countries.

Regarding exporting activity, an Asian country exported crude oil to about 7 other countries on average. Crude oil-exporting countries in the 10th percentile only exported crude oil to one other country. Meanwhile, the major exporters of crude oil in the 90th percentile, exported to more than 18 other countries.

In the same period, the ratio of private investment capital to GDP averaged 25.25%/year. The average labor force to total population ratio and the average trade openness in Asian countries are 48.61% and 97.20%, respectively.

Figure 6 shows that oil price trends tended to vary in the same direction as stock index movements in the UAE (United Arab Emirates), Indonesia, Qatar, and Saudi Arabia in 2008–2017. These are all major crude oil-exporting countries in Asia and are also members of the Organization of Petroleum Exporting Countries (OECD). More specifically, the oil price movement seems to fluctuate closely with that of the FTSE Nasdaq Dubai UAE 20 index (this index includes 20 stocks that are allowed to trade on Nasdaq Dubai, the Dubai Financial Market and the Dubai Stock Exchange). Visually, it can be seen that there is a positive relationship between oil price fluctuations and the stock markets of large oil exporters. Stronger and more convincing evidence for this relationship will be presented in the following section.

Figure 7 shows the opposite trend between oil price volatility and stock market volatility in Asian oil-hungry countries. Specifically, the crude oil price movement diverges from that of the Shanghai Composite Index of the Chinese market from 2011. According to statistics from the US Energy Intelligence Agency (EIA), China's actual crude oil use in 2010 was 439 million tons, increasing 13.1%. This was the first time that the actual amount of crude oil used in China exceeded over 400 million tons, which set a new record since 2005.55% of this crude oil, equivalent to 260 million tons, was imported. At the same time, in 2011, China's oil consumption accounted for a third of world fuel demand growth. According to the EIA, despite China's best efforts to diversify its crude oil sources, most of the crude oil imports for China's economic growth come from the UAE. The Middle East supplies about 2.9 million barrels per day to China, accounting for more than half of China's total oil imports, of which the UAE supplies approximately 1.1 million barrels per day. Consequently, there is a negative relationship between oil price fluctuations and the stock markets of some countries that import a lot of oil. Stronger and more convincing evidence for this relationship will be presented in the following section.

Before estimating the models, we check the correlation between the variables. The results are presented in Table 2.

The correlation coefficient measures the degree of linear relationship between two variables. According to Table 2, the correlation coefficient matrix shows that the correlation coefficients of the pairs of independent variables in the model are all less than 80%. This means the independent variables in the model have a low correlation with each other.

To ensure that there is no multicollinearity in the model, we test this phenomenon through the VIF coefficient. Multicollinearity is a phenomenon where the independent variables in the model are linearly dependent on each other. According to Kleinbaum et al. [19]; as an empirical rule, when the VIF index is greater than 5, there is high multicollinearity between the variables. Table 3 shows that the VIF coefficients are all less than 5. This means that there is no multicollinearity between the independent variables in the model. So we use these variables for regression analysis.

Next, we test the stationarity of the time series in the model. Since the data used in the study are panel data of 19 Asian countries in the period from 2008 to 2017, we use the unit-root test proposed by Harris and Tzavalis [20]. The results are presented in Table 4.

Table 4 shows that the p values of the time series in the model are all less than 1% significance level. Therefore, the time series are stationary at the level.

Using STATA software with balanced panel data of 19 Asian countries in the period from 2008 to 2017, the estimated results are presented in Table 5:

The estimated results in Table 5 show that the models have the p value of the AR (1) test less than the 5% significance level, and the p value of the AR (2) test is larger than the significance level of 5%. Therefore, the model has first-order autocorrelation but no second-order autocorrelation of residuals. Meanwhile, the Hansen test of the model has a p value greater than the significance level of 5%, that is,

Table 2: Correlation matrix.

	Stock	Between	Out-degree	In-degree	Inv	l	Open
Stock	1						
Between	−0.0193	1					
Out-degree	−0.0236	0.6729	1				
In-degree	0.0727	0.5886	0.2987	1			
Inv	−0.0366	0.2663	0.2639	0.4043	1		
L	0.0214	−0.0743	−0.1063	−0.2177	−0.0995	1	
Open	−0.0455	−0.2167	−0.0236	−0.3229	−0.5463	0.3576	1

Source: results calculated from the software STATA 16.0.

Table 3: Test for multicollinearity between independent variables.

Variables	VIF	1/VIF
Between	2.87	0.348407
Out_degree	2.19	0.455799
In_degree	1.88	0.532143
Open	1.86	0.538603
Inv	1.78	0.560459
L	1.27	0.788149
Oil	1.01	0.988195
Mean VIF	**1.84**	

Source: results calculated from the software STATA 16.0.

Table 4: Harris-Tzavalis unit-root test.

Variables	Statistic	p value
Stock	−0.2369	0
Between	0.2912	0
Out_degree	0.1696	0
In_degree	0.1248	0
Inv	0.5499	0.0025
L	0.1347	0
Open	0.5515	0.0027

Source: results calculated from the software STATA 16.0.

Table 5: Results of the impact of oil market structure on stock markets in Asian countries.

Model	Out-degree	In-degree	Between centrality
Stock L1.	−0.311*** (0.038)	−0.133** (0.060)	−0.173*** (0.030)
out_degree	0.0566*** (0.014)		
in_degree		−0.005* (0.003)	
Between			0.003*** (0.000)
Inv	0.140 (0.425)	0.556 (0.340)	0.251 (2.237)
L	−1.027 (2.070)	−0.431* (0.233)	−12.627 (8.779)
Open	0.191* (0.109)	−0.0224 (0.233)	−0.0358 (0.340)
_Cons	0.019 (1.072)	0.208 (0.121)	5.957 (4.264)
AR (1) p value	0.003	0.004	0.005
AR (2) p value	0.832	0.157	0.761
Hansen p value	0.092	0.874	0.312
Number of groups	19	19	19
Number of instruments	12	12	12
Second stage F-test p value	0.000	0.000	0.000

Estimation results of the impact model of the degree of centrality (out-degree, in-degree), and between centrality (between centrality) on the stock market in Asian countries made with the SGMM method. AR (1), AR (2) p value are the p value of the first and second-order correlation test of the residuals. Hansen p value is the p value of Hansen's test of the appropriateness of the instrumental variables in the model. Second stage F-test p value is the p value of the F-test for model fit. Standard errors are presented in parentheses (). *** significance level at 1% ** significance level at 5% * significance level at 10%. Source: results calculated from the software STATA 16.0.

the instrumental variables used in the model are appropriate. On the other hand, the p value of the F-test is smaller than the 5% significance level, indicating that the model is appropriate. In addition, Table 5 shows appropriateness when using the SGMM method is satisfied that the number of instrumental variables should not exceed the number of observation groups. Thus, the reliability of the SGMM estimation is guaranteed.

The estimated results show that the regression coefficient of the out-degree variable is 0.0566, which is positively and statistically significant at 1%. This implies that when a country exports more crude oil to other countries, its stock market will grow positively. This result supports hypothesis H1. Thus, this result is quite similar to what was found by Park and Ratti. However, by employing the social network analysis, this study may show a clearer result than has been found previously. Specifically, the out-degree variable can better measure the crude oil export position of the countries in the sample.

Meanwhile, the regression coefficient of the in-degree variable is −0.005 at the statistical significance level of 10%. This is intuitive that when a country imports more crude oil from other countries, this country's stock market will be negatively affected due to the dependence on input costs (oil materials) of the economy into other economies. This result also supports hypothesis H2 and is again similar to the study of Park and Ratti.

Finally, a more interesting result than previous studies was found by adding the between variable model, which represents the central position of a country in the network. The coefficient of between variable is 0.003 and statistically significant at 1%. This is interpreted that when a country has a central position in the crude oil import and export market network, the country's stock market will have positive growth. In fact, this result is clearly true in the case of Singapore, India, and Thailand, which are at the crude oil import and export market network.

5. Conclusions and Policy Implications

Regarding the first research objective, the social network analysis method is used to analyze the structure of crude oil import and export market in Asian countries. To our best knowledge, this is also the first attempt to fill a research gap that has not been addressed by previous studies. Our findings show a gradual decrease in network density over the years from 2008 to 2017. This implies that crude oil import and export activity between Asian countries is gradually decreasing. Besides, the in-degree and out-degree distributions all obey the power-law distribution. This is a skewed distribution with an elongated tail. Therefore, the crude oil import and export market network shows a huge difference. In particular, import and export activities are mainly concentrated in certain countries, manifesting in the tail end of the elongated distribution. Finally, the reciprocal coefficient tends to decrease over the years, showing that the bilateral relationship between countries in the Asian crude oil import and export market is in a stable decreasing trend during this period.

Regarding the second research objective, the model is estimated with the SGMM method to evaluate the impact of oil market structure on stock market growth. Our findings are in line with Park and Ratti. Specifically, the stock market has a positive growth in case of large exporters. However, for larger importers, the stock market is negatively affected. The research results additionally show that countries with a central position in the crude oil import and export market will have a more positive growth stock market than others.

Based on the above research results, the policy implications are proposed as follows:

(i) First, the importers' and exporters' business strategies must be improved to ensure the security of oil supply and demand across the market. For instance, oil importers might minimize their reliance on certain exporters and importers in order to diversify their energy supplies and weaken heterogeneity. Gas producers should restructure their energy mix to address supply shortages by promoting economic and administrative reforms in the energy sector. Another reform to be recommended is to strategy to increase the domestic energy supply and develop the oil and gas processing industry.

(ii) Second, it is necessary to encourage the construction of more crude oil transshipment hubs to promote the oil trading network.

(iii) Third, the plan to reserve crude oil and petroleum products needs to be taken into consideration. Specifically, a purchasing plan should be made for crude oil reserves to take advantage of the bottom oil price and prepare for growth when the economy recovers from the crisis.

(iv) Fourth, due to the influence of the industrial revolution 4.0, climate change and potential high environmental risks are highly related to the oil and gas industry. In the future, oil exporters and importers need to diversify energy sources and exploit new energy sources more efficiently and cleaner to meet consumers' satisfaction of minimizing CO2 emissions. Therefore, a master planning research program with step-by-step development towards non-conventional, renewable, environmental-friendly energy to limit CO2 emissions must be drawn.

Although the research objectives have been achieved, this study is still limited and needs to be supplemented and improved in the future. Firstly, the study collected data from a sample of 43 Asian countries over a relatively long period of 2008–2017 to build the crude oil import and export market structure. However, the assessment of the impact of the oil market structure on the stock market was only done with 19 Asian countries. The reason is that among these 43 Asian countries, the stock market has only just formed and has complete data in 19 countries in the period from 2008 to 2017. This limits the conclusions of the study. Therefore, further studies need to improve the data collection process, thereby increasing the sample size. In addition, theoretically, the stock market is also affected by other variables, so further studies should also be based on specific research objectives to add other variables.

Data Availability

The data used to support the findings of this study have been deposited in the GitHub repository (https://github.com/anhle32/OIL-MARKET-STRUCTURE.git).

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Dr. Hoang Anh Le conceived the idea, wrote Introduction, Literature Review, and Results section. Dr. Doan Trang Do wrote Methodology and Conclusion and Policy Implications sections.

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