EXPLORING THE RELATIONSHIPS BETWEEN CHINA'S CRUDE OIL FUTURES MARKET AND OTHER RELATED MARKETS: NEW FINDINGS

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
AIC	The Akaike Information Criterion
ARDL	Autoregressive Distributed Lag
BEKK	Baba, Engle, Kraft and Kroner
BK	Barunik & Krehlik
CDME	The Cumulative Dynamic Multiplier Effect
CIED	China's industrial economic development
CNY	Chinese Yuan
CPI	Consumer Price Index
CUSUM	The Cumulative Sum Control Chart
DCC	Dynamic Conditional Corelational
DSI	Directional Connectivity Index
DY	Diebold And Yilmaz
ESI	Energy Storage Industry Index
EXR	The Exchange Rate
FEVD	Forecast Error Variance Decomposition
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GDP	Gross Domestic Product
GVD	Generalized Variance Decompositions
IET	Total Imports And Exports
IPO	Industrial Production Output
INE	Shanghai International Energy Exchange
IRF	Impulse Response Function
IV	Industrial Growth Value
J-B	Jarque-Bera Statistics
KPSS	Kwiatkowski Phillips Schmidt Shin Tests
M2	Broad Money Supply
NARDL	Nonlinear Autoregressive Distributed Lag
NEVI	New Energy Vehicle Industry Index
NSI	Net Total Directional Connectivity Index
PI	Photovoltaic Industry Index

PP	Phillips-Perron Tests
SC	Schwarz Criterion
SCOF	Shanghai Crude Oil Futures
SVAR	Structured Vector Autoregressive Model
TCI	Total Connectivity Index
VAR	Vector Autoregression
VIRF	Volatility Impulse Response Function
WPI	Wind Power Industry Index

MENEROKA HUBUNGAN ANTARA PASARAN KEHADAPAN MINYAK MENTAH CHINA DAN PASARAN LAIN YANG BERKAITAN: PENEMUAN BARU

ABSTRAK

Kajian ini meneliti pasaran Hadapan Minyak Mentah Shanghai (SCOF), dengan menilai interaksinya dengan sektor tenaga baharu di China—seperti industri fotovoltaik, penyimpanan tenaga, dan tenaga angin—serta hubungannya dengan pasaran saham kewangan di seluruh Asia (China, Korea, Jepun, Singapur dan India) dan indikator makroekonomi utama seperti kadar inflasi, bekalan wang, dan kadar pertukaran. Menggunakan data dari tahun 2000 hingga yang terkini, serta menggunakan model ekonometrik seperti indeks kemeruapan, DCC-GARCH, NARDL, dan SVAR, analisis ini mendedahkan hubungan yang ketara antara SCOF dan pasaran kewangan di negara pengimport minyak utama di Asia. Walaupun SCOF masih dipengaruhi oleh niaga hadapan minyak antarabangsa, pelancarannya telah membantu mengurangkan hubungan antara harga minyak global dan pertumbuhan industri China. Walau bagaimanapun, kesan kemeruapan ke pasaran lain adalah terhad, dan impaknya terhadap pembolehubah makroekonomi China adalah kecil. Penyelidikan ini memberikan pandangan mengenai peranan SCOF dalam mengurangkan kejutan harga minyak global dan hubungannya dalam landskap pasaran kewangan dan tenaga yang lebih luas, membantu para pemegang kepentingan dalam mengemudi pasaran SCOF yang sedang berkembang.

EXPLORING THE RELATIONSHIPS BETWEEN CHINA'S CRUDE OIL FUTURES MARKET AND OTHER RELATED MARKETS: NEW FINDINGS

ABSTRACT

This study examines the Shanghai Crude Oil Futures (SCOF) market, assessing its interactions with China's new energy sectors—such as photovoltaic, energy storage, and wind power industries—and its connections with financial stock markets across Asia (China, Korea, Japan, Singapore, and India), as well as key macroeconomic indicators like inflation, money supply, and exchange rates. Using data spanning from 2000 to the most recent available, and employing econometric models including the spillover index, DCC-GARCH, NARDL, and SVAR models, the analysis reveals substantial links between SCOF and financial markets in major oil-importing Asian countries. Although SCOF is still influenced by international oil futures, its launch has helped moderate the relationship between global oil prices and China's industrial growth. However, spillover effects to other markets are limited, and the impact on China's macroeconomic variables remains minor. This research provides insights into SCOF's role in mitigating global oil price shocks and its connections within the broader financial and energy market landscape, aiding stakeholders in navigating the evolving SCOF market.

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter introduce the thesis by presenting its conceptual framework. It includes the study's background, identifies research gaps, outlines the study's objectives and research questions, and describes its scope and methodology. Additionally, this chapter highlights the study's contributions and provides an overview of the thesis structure.

1.2 Background of the study

Nowadays, financial markets are all integrated into a global system. While international financial integration has enhanced risk sharing and lowered capital costs, it has also increased local financial markets' susceptibility to shocks from the outside world (Lee, 2023). Events in one market have an immediate impact on other markets. The continuing process of globalization has led to the creation and further development of the analysis of spillover effects. The COVID-19 pandemic has a significant impact on worldwide financial system contagion routes and global economic activity (Guo et al., 2021). It has been shown that during the COVID-19 pandemic, there is a considerable increase in the correlations across different financial markets (Akhtaruzzaman et al., 2021, Bouri et al., 2021).

Crude oil, one of the most basic and important factors of production in a modern industrial economy, is an important strategic resource for all countries and

has a significant impact on a country's economic performance and social development. Global economic and financial markets, as well as nations that import and export crude oil, are all impacted by changes in the price of the commodity (Escribano et al., 2023, Demirer et al., 2020, Dagher and Hasanov, 2023, Gong et al., 2021). Ever since the USA introduced crude oil futures in 1978, the crude oil futures market has had a significant impact on oil prices and the prices of the crude oil futures have gradually become an important basis for pricing in the spot market.

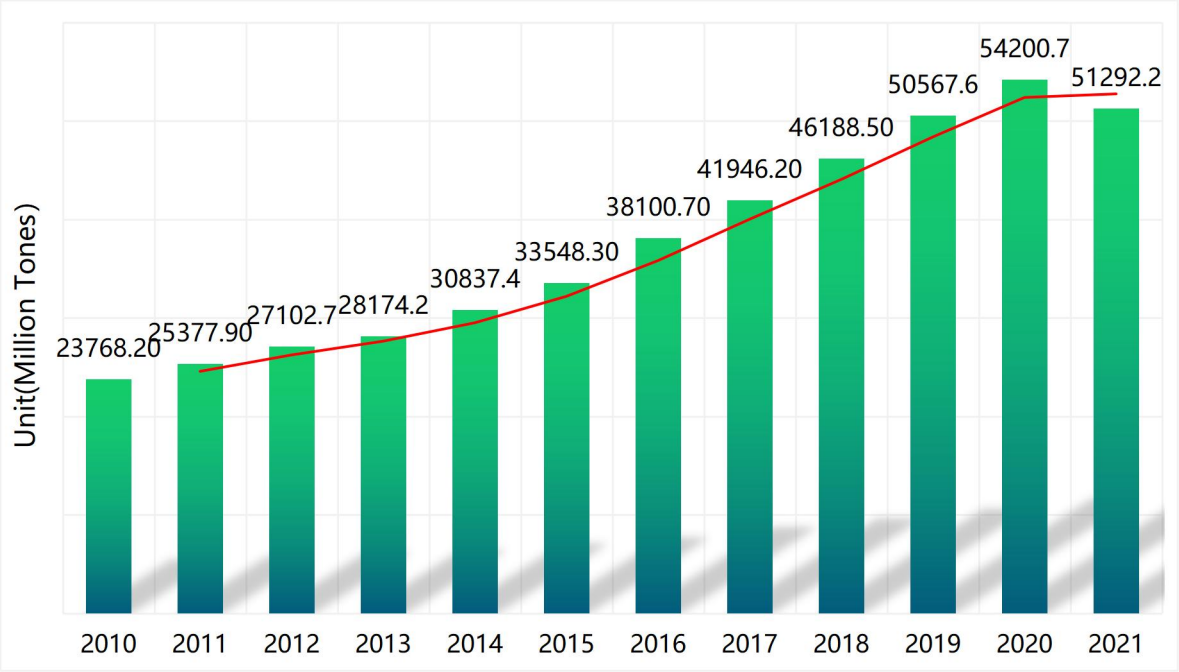

Figure 1.1 Import of crude oil in China, 2010-2021

Figure 1.1 illustrates the rising trend of China's crude oil imports from 2010 to 2021. Since 2017, China has emerged as the global leader in crude oil imports, but has long lacked a voice in crude oil pricing (Sun et al., 2023). Due to China's growing reliance on crude oil, the country is attempting to strengthen its position and mitigate risks in the crude oil market. Shanghai Crude Oil Futures (SCOF) were

launched at the Shanghai International Energy Exchange (INE) in March 2018 and are traded in Chinese Yuan (CNY), making them the first derivatives market in China to be open to international investors.

The main differences between SCOF and the already existing crude oil futures (West Texas Intermediate (WTI), Brent Crude and Oman Crude Oil futures) are their underlying assets, trading cycles, locations and transaction costs. In terms of underlying assets, WTI and Brent Crude have light, low-sulphur crudes as their underlying assets, while SCOF has medium and low-sulphur crudes. In addition to better meeting the demands of the global incremental market to enhance the pricing mechanism for medium quality crude oil, the SCOF market may also reflect changes in the supply and demand of crude oil in China and the Asia-Pacific region. In terms of trading duration, the intraday trading session of the SCOF in the Eastern time zone is complemented by the WTI and Brent trading sessions in the Western time zone. In terms of geography, the SCOF market reacts faster to the demands of the Asia-Pacific area.

Considering a daily average turnover of 221,400 lots in 2022, after WTI and Brent crude oil, SCOF is now the third-largest crude oil futures market. Since the launch of Chinese crude oil futures, the global crude oil market is increasingly connected to the Chinese energy futures market (Li et al., 2022, Yang and Zhou, 2020). Traders in the local Chinese market are also familiar with China's crude oil futures pricing (Palao et al., 2020, Wang et al., 2022, Zhang et al., 2021).

In addition to helping to reflect shifts in the supply and demand structure of China's crude oil market, the steady functioning of the SCOF market fosters the growth of the country's futures market. Being the first global futures product introduced in China, it is necessary and meaningful to study what kind of radiating effect SCOF have on the relevant markets, and what kind of influence SCOF have in various fields for the stable and sustainable development of SCOF.

1.3 Problem statement

It remains a concern for academics to understand the linkages between financial markets, which are important for managing financial risk and stabilising market development (Ngene et al., 2018). With the further acceleration of the financialisation of commodities, more financial investors are becoming widely involved in trading in commodity markets, and the connections between the financial and commodities markets are growing stronger. Considering the futures market for crude oil as the most significant commodities market, its endogenous volatility can spread to the stock market, commodity market and macro economy through the open financial market system, generating risk spillover effects.

With the listing of the SCOF market, it has not only improved the financial market in China, but also enhanced the Asian crude oil futures market's impact (Yang et al., 2020), laying an insistent foundation for China's bid for crude oil pricing discourse. The smooth functioning of China's crude oil futures market is crucial to the global crude oil pricing structure as well as the growth of China's

futures market. The difference between WTI and Brent crude oil futures and Chinese crude oil futures remains significant (Shao and Hua, 2022). Therefore, It is especially crucial to comprehend the connection between the associated financial markets and China's crude oil futures, as it will support the steady growth of China's crude oil futures market and aid in determining the country's crude oil futures market's current standing internationally.

Numerous research works have examined the relationship between the price of crude oil and other financial markets, and the SCOF market is gradually receiving attention from scholars (Sun et al., 2023, Huang et al., 2023, Shao and Hua, 2022), but research gaps still exist, as follows:

Firstly, WTI and Brent crude oil futures are the primary indicators of global crude oil prices in the current research on the link between the crude oil market and the Asian financial markets, while there are few studies on the SCOF market. Among the existing studies, between the SCOF market and the Asian financial market, no correlation research has been conducted from the level of crude oil importing countries.

Secondly, the link between crude oil futures and new energy stock markets is more complicated due to the inter-substitution between conventional and alternative energy sources. While analysing the interaction between crude oil prices and new energy stocks, there is less research on the constant interplay between the crude oil futures market and the new energy market, and studying the relationship between

China's new energy market and crude oil prices, the new energy industries are mostly viewed as a whole, without further refining the new energy industry segments.

In addition, some scholars have pointed out that the SCOF market is anticipated to assist China in establishing a new benchmark for crude oil pricing in Asia and to lessen the likelihood that fluctuations in global crude oil prices would have an adverse effect on China's economic expansion (Wang et al., 2022). Scholars have explored the role played by the SCOF market from different perspectives, but no empirical studies have been conducted on whether it has contributed in some way in stabilizing China's macroeconomic development.

1.4 Research question

In response to the above research gaps, this study will focus on the following research questions.

(a) What effect do the fluctuations in SCOF pricing have on the growth of China's new energy market, and what are the time-varying risk spillovers between them?

(b) How does the development of the SCOF market affect Asian financial markets? What is the dynamic correlation between the SCOF and Asia's main oil-importing nations' financial markets?

(c) Has the correlation between the macroeconomic development of China and the fluctuations in crude oil prices changed in structure as a result of the listing of SCOF?

(d) Has the first CNY-delivered internationalised futures contributed to China's stable macroeconomic development?

1.5 Research objectives

This study embarks on the following objectives:

(i) To examine the effects of time-varying spillovers between China's new energy market and the SCOF market. Research question (a) addresses this objective.

(ii) To investigate the spillover effects of SCOF prices on Asia's financial markets. Research question (b) evaluates this objective

(iii) To explore the role of the SCOF market in managing China's economic response to global oil price shocks. Research question (c) assesses this objective.

(iv) To analyze the dynamic correlation between the SCOF market and China's macroeconomic variables. Research question (d) evaluates this objective.

1.6 Scope and methodology

SCOF is the first internationally listed futures variety launched in China. Its stable operation supports the growth of China's futures market in China, and provides a more accurate depiction of shifts in the supply and demand dynamics of the country's crude oil market. However, due to its relatively recent launch, there is limited research on this topic, and comprehensive quantitative studies are scarce. To address this gap, this study examines the role of SCOF market in the international market, specifically, we investigate the correlation between SCOF market and the

financial markets of major crude oil importing countries in Asia, China's new energy stock market and China's industrial economic development (CIED). To achieve this, we employ the spillover effect index model, the DCC-GARCH model and the NARDL model, respectively, exploring the influence of the SCOF market from different perspectives.

In order to achieve objective (i), we employ the dynamic connectedness approach of the DCC-GARCH model to examine the dynamic spillover effects between crude oil prices, represented by SCOF market, and the stock prices of four industries in the new energy market: photovoltaic, energy storage, new energy vehicles, and wind power.

For objective (ii), we examine the spillover effects between the financial markets of major Asian oil-importing nations and SCOF and Brent futures is examined using a connectedness spillover index model in both time and frequency domains.

To address objective (iii), we apply the Nonlinear Autoregressive Distributed Lag (NARDL) model to explore the transmission effects of China's economic development on international crude oil price changes. Through the introduction of dummy variables, we explore whether the launch of the SCOF market changes the asymmetric transmission effect between the Chinese economy and crude oil prices.

Finally, to achieve objective (iv), we use a structural vector autoregressive (SVAR) model to analyze the relationship between SCOF market and China's macroeconomic variables.

This study employs various econometric models to thoroughly analyze the spillover effects of the SCOF market on Asian financial markets and the China's energy market. It also examines the interaction between China's macroeconomic development and the SCOF market, expanding the research perspectives and enhancing the empirical studies on the SCOF market. The findings will support the SCOF market's further growth and development. The software used for model analysis in this study is R and Eviews. The research process is outlined in the flow chart shown in Figure 1.2.

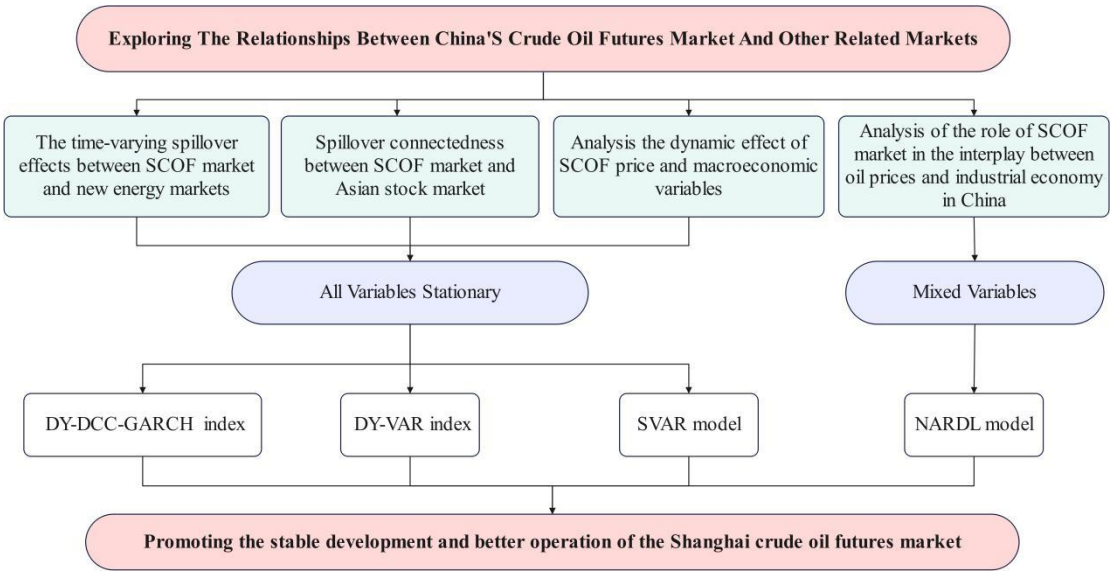

Figure 1.2 Flowchart of this study

1.7 Contribution of the thesis

For the first time, this study examines the perspective of Asian crude oil-importing countries by selecting Shanghai and Brent crude oil futures prices as representatives of the crude oil market. Also, a spillover index is constructed to analyze the return and volatility spillover effects between SCOF and the stock markets of major crude oil-importing countries in Asia, considering both time and

frequency domains.

From the industry perspective, the new energy market is divided into different segment indices, with China’s crude oil futures market price representing crude oil prices. This study examines the spillover effects within different new energy industries and between these industries and crude oil prices. Compared to the existing literature, this approach provides a stronger basis for understanding the interactions between China’s crude oil market and its new energy industry. It also addresses the gap in studying the time-varying spillover effects between the crude oil futures market and the new energy market, specifically in the context of the Chinese market.

The NARDL model is chosen to analyze the asymmetric impact of fluctuations in global crude oil prices on China's industrial and economic growth. For the first time, NARDL model incorporating dummy variables is constructed to examine whether the Chinese crude oil futures market has a moderating effect. The findings offer empirical evidence for the role of the SCOF market in stabilizing China's macroeconomic development.

This study focuses on the newly launched SCOF market as the research subject, conducting a detailed and in-depth analysis of this relatively novel topic. Various econometric models, including the spillover index model, DCC-GARCH model, NARDL model, and SVAR model, are employed to enhance the systematic understanding of the SCOF market. These models also contribute to advancing research on financial time series correlations, providing a fresh perspective for

exploring relationships across different financial markets.

1.8 Organization of thesis

The structure of this thesis is as follows: Chapter 2 provides a review of the literature, discussing the research progress on financial time series spillover effects and the current state of studies on the relationship between the crude oil futures market and related markets. Chapter 3 outlines the primary methodologies and modeling processes employed in this thesis, including the assessment of financial time series stationarity and the application of the generalized spillover index model, DCC-GARCH model, NARDL model, and SVAR model. Chapters 4 and 5 present the key findings of the study. Chapter 4 examines the spillover effects of price changes between the SCOF market and Asian financial markets, as well as the dynamic spillover effects between the SCOF market and China's new energy stock market. Chapter 5 investigates whether the SCOF market moderates the asymmetric relationship between global oil prices and China's economic growth, while also analyzing the relationship between SCOF prices and China's macroeconomic variables. Finally, Chapter 6 summarizes the key findings, highlights the limitations of the study, and provides recommendations for future research.

CHAPTER 2

LITERATURE REVIEWS

2.1 Overview

This chapter reviews the literature relevant to this thesis and is organized into six sections. Section 2.2 outlines the conceptual framework, focusing on spillovers as the main research theme and introducing Chinese crude oil futures as the object of study. Section 2.3 provides a theoretical review, highlighting key concepts and frameworks that underpin this research. Section 2.4 reviews empirical evidence, examining studies related to crude oil prices, the crude oil futures market, and research specifically related to the SCOF market. Section 2.5 presents a critical review of the literature, identifying gaps and areas for further investigation. Finally, Section 2.6 summarizes the chapter.

2.2 The Conceptual framework

2.2.1 Spillover effect

In economic and financial context, spillover effects usually refer to the break down of barriers between different markets and the transfer of information and other elements between them resulting in mutual influence. For example, when a variable (e.g., price, risk, etc.) changes in one market, it not only impacts that market, but may also be transmitted to affect other markets, inducing fluctuations there as well. In this thesis, the focus is on first-order moment spillovers of prices, also known as mean

spillovers.

Economic connectedness is a concept that describes the interaction between different economic systems. Diebold and Yilmaz (2009 , 2012, 2014) proposed the spillover index based on Forecast Error Variance Decompositions (FEVDs) derived from vector autoregressions (VARs) so as to measure the direction and intensity of spillovers and quantify connectedness. The index provides insights into the extent and direction of interactions between variables or markets. Their approach has been recognised and widely used by researchers in various studies.

2.2.2 China crude oil futures

China was the first Asian country to launch an oil futures market, with the former Nanjing Petroleum Exchange launching oil futures trading as early as 1992, followed by the relisting of fuel oil futures on the Shanghai Futures Exchange in August 2004. In March 2008, crude oil futures were officially launched on the Shanghai International Energy Exchange (INE), with the underlying contract based on medium quality sulphur crude oil, denominated in Chinese Yuan (CNY). Shanghai crude oil futures became China's first international listed futures. The listing addressed the missing of benchmark futures prices in Asia, enhanced the global crude oil pricing system, and provided a platform for global investors to engage in price discovery during the Asian trading session.

2.3 Theoretical review

This section reviews the literature on the theoretical approaches used in this study, illustrating the feasibility of the selected methodologies.

2.3.1 Connectedness approach

Economic connectedness is a concept in economics that describes the interaction between different economic systems. Many studies have considered this concept in their analyses of spillover effects, including Diebold and Yilmaz (Diebold and Yilmaz, 2012, Diebold and Yılmaz, 2014). They introduced a volatility spillover measure known as the DY index based on FEVDs from vector autoregressions (VARs). This measure helps to understand the direction and intensity of spillover and describe connectedness, making the analysis of the spillover effects more intuitive, accurate, and convincing. As recommended by Diebold and Yilmaz (2012), Baruník and Křehlík (Baruník and Křehlík, 2018) used the Fourier transformation, but they expanded it to a frequency dynamics-based model.

There are various literature showing how the DY index was applied for analyzing the spillover effects between stock markets and crude oil. For example, Tiwari et al. (2018) estimated volatility spillovers among different financial markets and discussed connectedness across four global financial markets. Meanwhile, applying network spillover method in their study, Yoon et al. (2019) analyzed the connectivity of the net pairwise spillover returns among the currency, stock, commodities markets, and bond. Additionally, based on daily range-based volatility

series of 14 publicly listed commercial banks from 2008 to 2016, Wang et al. (2018) explored volatility connectivity in the Chinese banking system and found that it is highly interrelated. Also, Yi et al. (2018) investigated volatility connectivity in both static and dynamic contexts using the spillover index among eight typical cryptocurrencies, and their findings show that the total connectedness fluctuates periodically. Sugimoto and Matsuki (2019) examined the significance of stock return spillovers between Asian and global markets and found that the biggest spillover is from the US to Asia, and the amount of spillover from Asia to Japan is almost the same as from Japan to Asia. In addition, Gomez-Gonzalez et al. (2021) examined the relationship between oil prices and stock market returns for a group of seven major energy-market players by decomposing oil prices into three orthogonal components and computing the spillovers.

Existing studies showed that the connectedness approach is an effective tool for identifying and quantifying volatility, interconnectedness, and spillover effects among diverse financial entities. This prompted our investigation into the volatility connection between the crude oil futures market and related markets utilizing the connectedness approach.

2.3.2 DCC-GARCH model

Engle and Sheppard (2001) proposed the Dynamic Conditional Correlation Multivariate Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model, which can describe different financial time series more

comprehensively over time and can be used to analyze non-linear relationships between different variables.

For instance, Efimova and Serletis (2014) utilized the DCC and BEKK models to examine connections and spillovers across energy markets, revealing that multivariate GARCH is a superior method for analyzing interactions between three commodity prices (oil, natural gas, electricity) and their volatilities. Furthermore, Kumar and Anandarao (2019) analyzed fluctuations and associations among Indian stock, oil prices, and natural gas using the VARMA-DCC-GARCH model, which outperformed the Constant Conditional Correlation (CCC) model with asymmetry in efficiency when calculating time-varying correlations. Chen et al. (2020) recently employed the DCC-GARCH(1,1) model to explore the dynamic linkages among new energy, crude oil, and rare earth markets, finding notable volatility spillovers. Zhang and Mani (2021) assessed relationships between gold and three prominent crypto assets using DCC-GARCH, discovering that the link between gold and bitcoin peaked during the height of the COVID-19 outbreak. Additionally, Ivanovski and Hailemariam (2021) predicted the dynamic relationship between WTI crude oil prices and S&P 500 stock values, finding that the GAS(1,1) model outperformed the DCC-GARCH model.

The DCC-GARCH model can detect changes in conditional correlation over time, which facilitates the analysis of dynamic relationships (Ben-Ahmed et al., 2023). Due to its effectiveness, the DCC-GARCH model has been extensively applied in studies of dynamic correlations and volatility spillover effects. In this

study, it is employed to analyze the dynamic correlation between the new energy stock market and the Shanghai crude oil futures market.

2.3.3 NARDL model

Shin et al. (2014) extended the symmetric Autoregressive Distributed Lag (ARDL) model proposed by Pesaran et al. (2001) to develop to suggest an asymmetric variant, which they called the NARDL model. The NARDL model can simultaneously estimate both the short-run and long-run relationships between the dependent and independent variables. This makes it particularly useful for examining the dynamic interactions between variables over different time horizons. The model can account both the short and long terms asymmetries by modelling asymmetric cointegration (Demir et al., 2021). NARDL models have gained increasing popularity in empirical studies exploring the relationship between macroeconomic variables and oil price volatility.

Various researchers have utilized this model to investigate asymmetric impacts in different contexts. For instance, the asymmetric consequences of the urban earnings and global oil market on Chinese consumption were examined by Long and Zhang (2022). The outcome of asymmetries in oil price movements on Chinese exports was studied by Liu et al. (2021). Ibrahim et al. (2023) looked at how changes in oil prices asymmetrically affected inflation. The asymmetric long- and short-term link between the original real price and the US-Canadian conversion rate was examined by Jung et al. (2020). Furthermore, Zhang and Baek (2022)

investigated the connection between variations in the cost of oil and the real currency values of Asian nations relative to the US dollar. These studies serve as examples of the widespread adoption of the NARDL model for analyzing asymmetric phenomena.

The NARDL model was appropriate to examine how fluctuations in global crude oil prices asymmetrically affected China's industrial economic growth. By incorporating dummy variables, the NARDL model could test whether the introduction of the SCOF market moderated the relationship between global oil price fluctuations and China's economic growth. This feature provided valuable insights into the role of the SCOF market in stabilizing China's economy in this thesis.

2.3.4 SVAR model

Vector Autoregressive (VAR) model, introduced by Sim in 1980, is a system of linear equations that analyzes current variables based on several lagged values of all variables in the system. The Structural Vector Autoregressive (SVAR) model is an extension of the VAR model, incorporating the structural relationships among the variables to better capture their interdependencies.

At present, the SVAR model and its extensions are widely used in the disciplines of macroeconomics, monetary finance, energy economics and agricultural economics. For example, a SVAR model was employed by Kilian (2009) to analyze the world market for crude oil and how it interacts with the demand for industrial goods worldwide. Meanwhile Elbourne (2008) used the SVAR model to analyse the

conveyance of monetary policy through the UK real estate market. The SVAR model was applied by Śmiech et al. (2015) to study the impact of real and financial processes of the macroeconomy in the euro area on commodity prices. Particularly, the SVAR model is also preferred by scholars when examining the connection between macroeconomic activity and the volatility of oil prices (Baek and Yoon, 2022, Liu et al., 2020, Ali Ahmed and Wadud, 2011). Recently, Zribi et al. (2023) applied the time-varying parametric structural vector autoregressive model with stochastic volatility (TVP-SVAR-SV) to investigate how climate change affects cryptocurrency by using time-varying parameters in the SVAR model, testing the predictive role of natural disasters and global warming in shaping the environmental concerns of cryptocurrencies and the ecological footprint of Bitcoin. Ma (2024) analyses the US's major macroeconomic indicators' dynamic reaction to the Fed's unconventional monetary policy using an instrumental variable SVAR framework and found that by bringing down both the cost of credit and the unemployment rate, the Fed's skewed policy effectively supported the economic recovery. Using the SVAR approach, Baek and Yoon (2023) examined how changes in global demand, oil-specific demand, and oil supply shocks affected China's trade balance with its three main trading partners: South Korea, the United States, and Japan.

The studies mentioned above demonstrate that the SVAR model is an effective tool for analyzing the structural relationships between economic variables. In this thesis, the SVAR model was been chosen to examine how shocks to SCOF prices propagate through the economy and affect China’s macroeconomic indicators.

2.4 Empirical evidence

This section reviews the empirical evidence, focusing on relevant studies related to crude oil prices and the crude oil futures market.

2.4.1 Spillover effects between crude oil price and stock markets

Crude oil is an important commodity and changes in the price of crude oil can impact global equity markets through expected cash flows and discount rates (Mensi et al., 2023). Scholars have discovered spillover effects and dynamic linkages between the stock markets and crude oil (Liu et al., 2020, Chkili et al., 2014, Mensi et al., 2022).

Scholars have used different approaches when analyzing how the stock market and the crude oil market are affected by each other. Among them, Yilmaz (2010) examined the reliance on the stock markets in East Asia using a Forecast Error Variance Decomposition (FEVD) of Vector Autoregression and found that the spillover index of stock markets in East Asian became significant during the financial crisis. In addition, using a bivariate BEKK-generalized autoregressive conditional heteroskedasticity (BEKK-GARCH) model, Sarwar et al. (2020) also showed the spillover effect between crude oil and stock returns, and further confirmed a unidirectional, bidirectional, and mixed spillover impact on the stock markets of Karachi, Bombay, and Shanghai stock markets. Meanwhile, by applying Transfer Entropy and the Kernel method Granger Causality Index, Xiao and Wang (2020) found that there is a bi-directional causality in the form of non-linearity between oil

and stock markets and concluded that the WTI and Brent crude oil prices have not played the same role in their interaction with multiple stock markets. The dynamic co-movement between the oil and stock markets of six highly oil-related nations was analysed by Jiang and Yoon (2020) using the two wavelet transform techniques, and the findings revealed a feedback link between the oil and stock markets. Additionally, Alamgir and Amin (2021) examined the nexus between stock market in South Asia and oil prices by applying a nonlinear distributed lag model with autoregressive function, and found that the stock market and oil prices are positively correlated. Furthermore, Zeng et al. (2022) analysed the dynamic trilateral relationship among returns on the world's crude oil markets, Chinese stock markets, and the USD/CNY exchange rate by using Vine-Copula-CoVaR and multivariate GARCH models to identify somewhat volatility spillovers between the three markets. Using the dynamic conditionally correlated skewed Student Copula model and Diebold and Yilmaz's (2012) connectivity index, Escribano et al. (2023) analysed the connectivity between the crude oil price and several financial stock markets, highlighting in their analysis the primary distinctions between nations that import and export oil. All the above-mentioned studies have shown that there is an inseparable connection between the prices of the stock markets and crude oil.

In studying the crude oil and stock market spillover effects, most studies have considered the WTI crude oil futures (Mensi et al., 2022, Wang and Li, 2021) and Brent crude oil futures (Tian et al., 2022, Zhang and Zeng, 2023, Cevik et al., 2020) to represent the crude oil market. While, SCOF, the third most traded crude oil

futures, is beginning to attract the interest of researchers (Zhu et al., 2021), however there are no studies yet on the SCOF market's and Asian financial markets' spillover effects from the perspective of crude oil importing countries.

2.4.2 Relationship between new energy markets and crude oil futures markets

As an alternative to traditional energy sources, particularly crude oil, investments in new energy sources are heavily influenced by the price of traditional energy sources (Chen et al., 2020). It has been observed that fluctuations in the price of crude oil are considered one of the most systemic hazards for new energy firms (Reboredo, 2015). Evidence suggests that these fluctuations are correlated with the returns of new energy enterprises (Narayan & Sharma, 2014; Phan et al., 2015), with varying elasticities across different companies in the new energy sector in response to changes in oil prices (Gupta, 2017). Additionally, there is heterogeneity in the responses of new energy firms to oil price changes (Zhu et al., 2019).

With the evolution of the financial industry, crude oil futures prices have increasingly become a pivotal reference for participants in the crude oil business and financial institutions in pricing crude oil spot. Numerous scholars have studied the contagion mechanism between China's new energy markets and the crude oil futures market, aiming to foster high-quality growth within the new energy sector. Scholars generally agree that a strong mutual influence exists between them. For instance, Wen et al. (2012) explored the asymmetry of asset volatility and spillover effects of volatility between the WTI crude oil futures market and the stock market of Chinese

new energy businesses, finding a mutual influence between crude oil prices and new energy stocks. Qu et al. (2021) noted that short-term changes in global crude oil prices affect Chinese new energy stocks. Notably, changes in new energy stocks are subject to a bidirectional influence from crude oil prices (Brini et al., 2017; Padhan et al., 2020). Shah et al. (2018) argued that higher oil prices stimulate increased investment in new energy sources, and monitoring oil price changes can provide insights into the outlook for new energy consumption. However, the impact of fossil energy costs on new energy stock prices is not as significant as anticipated, as suggested by some researchers (Reboredo, 2015; Sun et al., 2019).

While scholars have generated numerous research findings in this field, it is evident that when analyzing the interaction between crude oil prices and new energy stocks as indicators of global oil prices, they often focus on the prices of WTI and Brent crude oil futures. There is comparatively less research on the consistent interplay between the crude oil futures market and the new energy markets.

2.4.3 Relationship between macroeconomic variables and crude oil futures markets

Numerous researchers have done studies looking at the impact of fluctuations in the price of global oil on macroeconomic indicators since the ground-breaking work of Hamilton (1983) on the substantial link between macroeconomic performance and oil price shocks. An et al. (2014) used impulse response functions, for instance, to monitor the results of either positive or negative fluctuations in oil

prices on US indicators of the economy, indicating asymmetry in the macroeconomic effect of oil booms. Similarly, Cunado et al. (2015) discovered the unique effects of structural oil price shocks on economic activity and pricing among the four biggest oil-consuming economies in Asia, by utilizing a VAR model analysis. The connection between policy rates of central banks, monetary aggregates, worldwide industrial production, and oil prices was also studied by Ratti and Vespignani (2016). They found that growing global interest rates were significantly correlated with the rising oil prices and that macroeconomic factors could be asymmetrically affected by oil shocks. Additionally, in a small oil-exporting nation called Azerbaijan, Zulfigarov et al. (2020) investigated to see how macroeconomic variables were affected by fluctuations in oil prices. The results showed that while a negative shock slowed down actual economic activity, an increase in oil prices sped it up. According to Amiri et al. (2021), unanticipated fluctuations in oil prices had a considerable negative influence on macroeconomic performance in countries exporting oil. Specifically, fluctuations in oil prices and increasing revenue from oil caused the monetary base to expand, liquidity to rise, and inflation rates to rise. In Indonesia, growth, inflation, and exchange rates were some of the macroeconomic factors that Baek and Yoon (2022) studied concerning the fluctuations in the price of oil. They evaluated how these factors responded dynamically to demand and supply shocks that caused volatility in oil price. Asymmetric impacts of changes in oil prices on important macroeconomic indicators, including manufacturing production, inflation, currency rates, and stock returns, were discovered more recently by Deheri