The Impact of Multiple Shocks on Global Crude Oil Trade Based on the GTAP Model

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Abstract. Due to the fact that global crude oil trade is jointly affected by various factors such as geopolitical conflicts, trade protectionism, and shortage of transportation capacity, in order to systematically evaluate the economic effects of global crude oil trade under multiple shocks, this paper uses the GTAP model to simulate three shock scenarios and a combined scenario: the increase in maritime distance, the increase in tariff barriers, and the decline in the coefficient of maritime technology progress. The study found that the simulation results of different scenarios have significant asymmetric and nonlinear amplification characteristics, among which the decline in the coefficient of technological progress has the greatest impact on global crude oil trade. The global flow of crude oil trade is moving towards "regionalization", and the demand for long-distance crude oil trade is decreasing. The overall economic performance of countries and the impact on industries are not completely consistent. Based on the simulation results, this paper proposes that proactive measures should be taken to address various challenges faced by energy trade.

Keywords: GTAP model, crude oil trade, multiple shocks, trade impact.

1 Introduction

Crude oil holds a pivotal position in the global energy system, serving as the primary power source for modern transportation and military industries, and acting as the main artery of the world economy. Over the past five years, the annual growth rate of China's energy imports is approximately 3.5%, and the degree of reliance on imports exceeds 70%. The complexity and fragility of the global crude oil commodity logistics supply chain make it vulnerable to systemic risks. Currently, crude oil trade is situated in a complex environment where multiple international policies are highly intertwined and mutually influence each other. Energy and trade policies, sanctions and compliance policies, environmental and maritime policies, geopolitics and regional policies all have direct impacts on the cost structure, trade flow and transportation capacity pattern of crude oil transportation. Specifically, the Red Sea crisis has led some shipowners to choose to take a detour around the Cape of Good Hope to avoid navigation risks; recently, the successive sanctions measures introduced by various countries have disrupted the order of crude oil trade, causing supply imbal-

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ance; a new round of trade war has begun, significantly increasing the cost of crude oil imports and possibly changing the direction of crude oil trade and the crude oil demand of various countries. Therefore, conducting progressive scenario simulation analysis of the current severe situation faced by crude oil trade is conducive to exploring how the global crude oil trade system and related national economies respond and reconstruct under different types and intensities of transportation and trade shocks.

Current research indicates that supply chain disruptions lead to an increase in transportation costs and have a negative impact on the economy. Ruibin Si et.al designed intentional attack scenarios based on historical disruption scenarios such as the conflict between Russia and Ukraine, and the results showed that geopolitics would lead to the relocation of global crude oil transportation centers and regional reorganization, and significantly affect the average path cost.[1]Ferrari et.al incorporated refined maritime cost data into the CGE framework and successfully simulated the significant negative impact of rising maritime freight costs on the global economy, and the heterogeneous response characteristics of different transportation methods, regions, and commodity categories were clearly evident.[2]This research provides a benchmark analytical framework for understanding the general equilibrium effects of capacity shortages and rising freight costs. Additionally, trade policies can also have an impact on the energy economy and trade pattern. Liu et al. focus on Australia and revealed the interaction effect between oil price shocks and tax policies, indicating that resource-exporting countries face significant trade condition risks in the face of energy price fluctuations.[3]Zhijiao Liu et al. pointed out that there is a significant dynamic positive correlation between the returns of major global stock markets and the International Crude Oil Market.[4]Furthermore, Muhammad et al. studied the dynamic price transmission between the international crude oil market and the retail markets of petroleum, light diesel oil and kerosene, and revealed the transmission path of crude oil prices.[5]

Although the existing studies have laid a solid methodological and empirical foundation, there is still room for expansion in the simulation of the synergistic effects of multiple shocks and the application of energy security. This paper's contributions are as follows: First, it focuses on the crude oil industry and constructs a composite shock analysis framework. Second, it deepens the analysis of the micro-conducting mechanism, extending from the macro economy to the crude oil sub-sectors.

2 Method

This paper quantitatively assesses the impact of multiple scenarios on global crude oil trade within the framework of the general equilibrium theory-based GTAP model. This model characterizes the behaviors of various sectors such as residents, enterprises, and governments through corresponding equation functions, and connects these sectors into an interacting economic system.

2.1 Data Processing and Update

The study conducts empirical simulations using the latest GTAP11 database. In terms of regional division, this paper bases on the actual situation and refers to the major source countries of China's crude oil imports as statistically provided by the General Administration of Customs of China in 2024 for regional division. At the same time, it supplements the regional division by referring to the "World Energy Statistical Yearbook", and divides them into the following 12 regions: Russia (RUS), Middle East (ME), China (CHN), Central and South America (CSA), Northwest Africa (NWA), USA, Canada (CAN), European Union (EU), Australia (AUS), Southeast Asia (SEA), India (IND), Rest of World (ROW). In terms of industry classification, in order to better reflect the actual situation, This article provides a detailed classification of crude oil and its related sectors. Specifically, it is divided into the following 11 industries: Coal, crude oil, petroleum, gas, maritime transportation, other modes of transportation, communication and warehousing, manufacturing, agriculture, forestry and fishing, energy-intensive industries, other service industries.

To make the simulation results more in line with the real situation, this paper utilizes the latest forecast data provided by the French Centre for International Economic Studies (CEPII) to calculate the rate of change of various macroeconomic factors, and conducts a dynamic recursive analysis of the GTAP model.

2.2 Scenario Design

To predict the impact of different forms of shocks on the crude oil trade of countries and regions, this paper has set up the following four scenarios for the shocks, and the specific simulation plan is shown in Table 1:

Table 1. Scenario Setups.

Scenario	Detailed scenario description
S1	The distance of crude oil transportation by sea has increased
S2	Increased trade barriers related to tariffs on crude oil and other energy products
S3	The technical trade barriers in crude oil transportation have increased
S4	The above scenario is realized simultaneously.

3 Result

3.1 Impact on the Macroeconomy

Table 2 shows the extent to which GDP and welfare in each region are affected under four scenarios. In the S1 scenario, it has a broad inhibitory effect on the global macro economy. For oil-importing countries, detouring through the Cape of Good Hope leads to an increase in transportation costs, with India experiencing the largest decline in GDP, at 0.91%. Oil-exporting countries also suffer from the "distance penalty", as

the increase in maritime transportation distance leads to an increase in the cost of oil exports and a decrease in export competitiveness. In the S2 scenario, it shows the asymmetric impact of tariffs on the global economy. The United States and China are the most severely affected, while third-party economies generally benefit from the trade diversion effect. In the S3 and S4 scenarios, the welfare flows show a distinct feature of shifting from energy-importing countries to energy-exporting countries. Oil-exporting countries generally benefit, mainly because the decline in transportation efficiency has increased the landed cost of oil, achieving an increase in national income through the price effect. Oil-importing countries such as China, the European Union, and India suffer macroeconomic damage, mainly due to the increase in energy import costs squeezing production and consumption in other sectors and deteriorating trade conditions. S4 shows that the compound shock has a relatively severe nonlinear synergy effect on macro welfare, intensifying the profit and loss disparity between energy-importing and energy-exporting countries based on the S3 scenario. Especially in Northwest Africa, GDP growth is 53.17%, as the "regional crude oil supply security port" closest to Europe, the scarcity of crude oil resources directly drives up the offshore price.

Table 2. Macroeconomic changes under various scenarios.

region	GDP (%)				EV ($ US million)			
	S1	S2	S3	S4	S1	S2	S3	S4
RUS	-1.07	0.03	1.88	0.88	-2908.48	58.08	10463.99	7853.11
ME	-0.03	0.06	2.94	3.03	-290.60	107.07	23354.81	23634.55
CHN	-0.05	-0.07	-0.71	-0.84	-7787.19	-2712.81	-41327.96	-52595.89
CSA	0.07	0.05	0.29	0.41	-257.22	365.89	1822.76	2032.79
NWA	1.80	0.46	50.91	53.17	1091.67	282.57	30355.82	31568.43
USA	0.10	-0.03	0.00	0.08	-2705.69	-1570.16	-12531.11	-16944.28
CAN	0.13	0.08	0.72	0.96	142.17	390.67	3804.52	4454.86
EU	-0.01	0.03	-0.29	-0.28	-10287.20	510.32	-35458.28	-45570.93
AUS	-0.15	0.03	-0.09	-0.21	-713.07	66.98	-1554.94	-2206.53
SEA	-0.15	0.03	-0.27	-0.40	-3789.13	202.98	-6262.80	-9959.04
IND	-0.26	0.04	-0.96	-1.20	-5237.80	94.72	-12581.66	-17928.90
NOW	0.08	0.03	-0.09	0.02	281.98	1068.35	-24718.10	-23451.23

3.2 Impact on Bilateral Trade Volume of Crude Oil

Figure 1 presents the bilateral global crude oil trade volume under four scenarios. In the S1 scenario, the increase in shipping distances led to a reduction in long-distance crude oil imports by countries that rely heavily on maritime transportation, such as China and India, while the export volume to these countries increased for energy-exporting countries via land or pipeline routes, such as Russia and the Middle East, highlighting the advantage of pipeline transportation in avoiding the risks associated with maritime distances. In the S2 scenario, it reflects that the energy trade between the United States and the Middle East is highly sensitive to tariff barriers, and some crude oil flows and related trade activities naturally flow to relatively neutral markets. China further diversifies its crude oil import risks and becomes more actively engaged in trade relations with Russia, the Middle East, and Canada. Under the influence of S3, the trade logic shifts from a single "cost-oriented" model to a "safety and efficiency-oriented" model. Core supply countries further expand their share of the crude oil market by leveraging their complete infrastructure and diverse logistics advantages: Russia's exports to China increased by 7.73%. The supply chain crisis has led to the prosperity of alternative trade routes between the "Pacific" and "Atlantic". Canada's exports to China and the EU both increased. In regions with weak infrastructure, such as Northwest Africa, crude oil trade volume has decreased due to low port efficiency, aging fleets, and issues related to resource quality. Under the influence of S4, the final crude oil model is most similar to S3, but to a deeper extent.

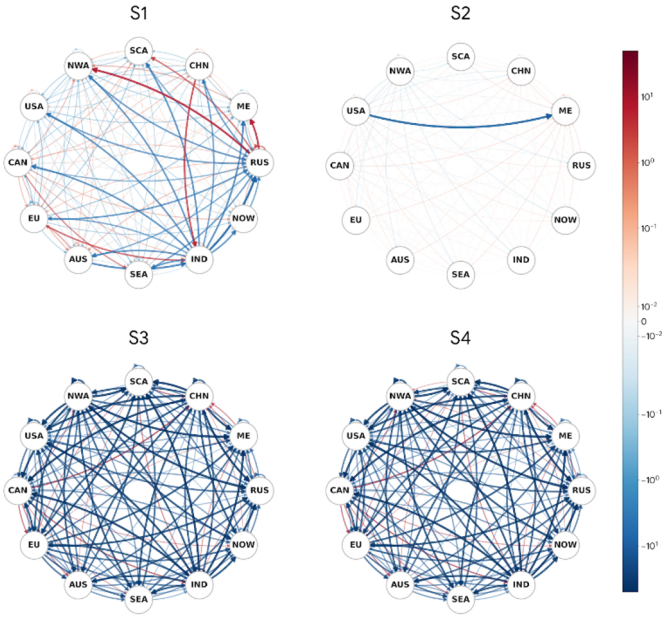

Fig. 1. Changes in bilateral trade volume of crude oil

3.3 Impact on the Crude Oil-related Industries

Figure 2 shows the changes in China's industrial exports under four scenarios. Overall, the export performance of China's economy exhibits the typical characteristics of "raw material supply disruption, with manufactured products emerging victorious". Among them, the impacts of S1 and S2 are limited, while S3 has an increasing effect and S4 further amplifies the trend. The export of crude oil plummeted by approximately 30% due to the soaring import costs, resulting in a shortage of raw materials for refineries; the export of liquefied natural gas increased significantly, and China, with its LNG infrastructure, became a regional stable supplier; the export of coal rose to make up for the loss of crude oil, and the energy export structure shifted from "import processing and re-export" to "direct export of local advantageous energy sources". The exports of manufacturing and energy-intensive industries rose because the global oil and gas crisis pushed up the costs of foreign high-energy-consuming industries, while China's coal-dominated energy structure ensured a relative cost advantage and made it a "stable factory in a turbulent world". The exports of agriculture, forestry, and animal husbandry also improved due to the increase in global fertilizer costs. Supporting industries such as shipping and warehousing grew along with the expansion of trade. The sharp decline in crude oil exports marked the arrival of a global energy crisis, and through the "global relative production cost reconfiguration" mechanism, it unexpectedly created export opportunities for China's manufacturing industry.

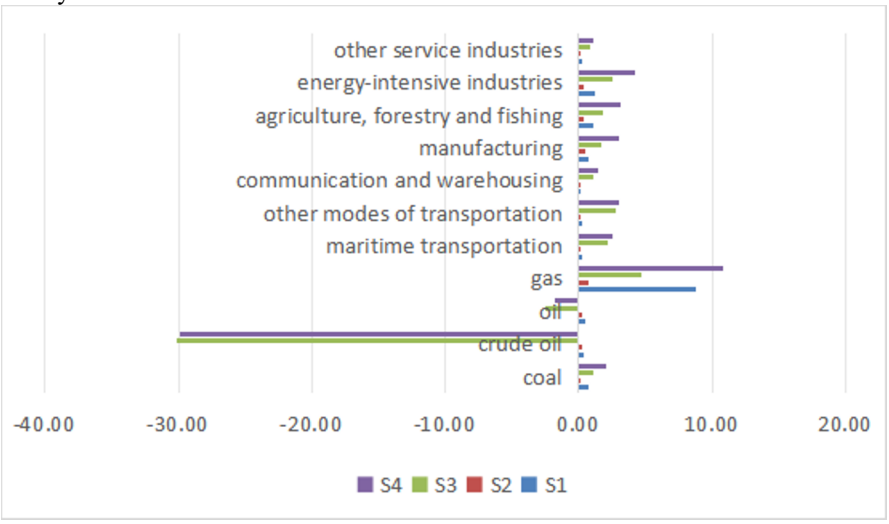

Fig. 2. Changes in export volumes of various departments in China (%).

4 Conclusion

This paper constructs a composite shock framework of "increased transportation distance", "tariff barriers", and "decreased transportation efficiency", and uses the GTAP

model to conduct a rigorous quantitative analysis of the non-equilibrium impacts on the macroeconomics, bilateral trade flows, and industrial outputs of major economies worldwide. The research results show that the synergistic effect of multiple risks superimposed far exceeds the linear superposition of a single shock, thus easily triggering "cascade failure" in the global trade system, and the economic losses are exponentially magnified. More importantly, the same shock has different impacts on energy-exporting and importing countries, on regions with different geographical locations, and on different industries. Among various risk variables, "decreased transportation system efficiency" is the core variable with the strongest reshaping ability. Therefore, in crisis scenarios, the global trade logic undergoes a fundamental reversal: trade flows are no longer solely determined by prices, but are jointly dominated by "transportation reliability" and "geopolitical relations". The value of pipeline transportation and short-distance maritime transportation becomes prominent, while long-distance transoceanic trade shrinks significantly. Based on these research results, we need to construct a "multi-dimensional energy security system that combines both soft and hard aspects" and actively become a shaper of global energy and trade governance, in order to address the energy trade challenges in a highly uncertain environment.

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