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Research paper

Impact assessment of energy sanctions in geo-conflict: Russian–Ukrainian war

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ABSTRACT

Since the geopolitical conflict between Russia and Ukraine, Western countries led by the United States and the European Union have launched several energy sanctions against Russia. How will sanctions and countersanctions on energy trade affect the EU-Russia and the world's energy trade pattern? This paper sets six energy trade scenarios based on the degree of energy sanctions and counter-sanction measures imposed by the EU and Russia. We use the global multi-region comparative static CGE model to simulate the changes in macroeconomic indicators in major countries worldwide. The diversion effect of energy trade and the impact on the national economy caused by geographical risks quantitatively analyzes. The results show: (1) Energy sanctions will cause economic damage to both sides, in the worst-case scenario, the EU economic loss reaches 1.488%, the Russian loss reaches 4.8%, and worldwide inflation will rise; (2) Russia's counter-sanctions will have a direct economic impact on the EU, but will not improve its economic situation; (3) Energy sanctions will bring about a direct energy trade transfer effect, the EU's energy imports will be diverted to non-Russian markets, and Russian energy exports will also shift to Asian markets, and energy trade between the two economies will be significantly reduced; (4) Energy supply will have a profound impact on the world's economy and society, leading to social instability and a decline in total output of 2.895%. Energy games will have a negative impact on the world's carbon emission reduction and energy consumption structure transformation. Through quantitative analysis of the impact of energy sanctions on the world economy and society, the energy game caused by the geopolitical crisis will harm both parties involved in the game and the world economy. The world pattern will return from the development pattern of cooperative division of labor to a situation of conflict and confrontation, which is not conducive to the transformation of energy trade and consumption structure under market rules.

1. Introduction

Energy trade has been dominated by geopolitics, and energy sanctions are an extension of the political game. The Russia–Ukraine conflict has led to several rounds of sanctions in the Western world, mainly the United States and the European Union, including individual, economic, and financial sanctions (Chepeliev et al., 2022; Mahlstein et al., 2022). The sanctions are aimed at weakening Russia's economy, making it unable to pay for its high military spending, and forcing Russia out of Ukraine. The most important of the measures should be sanctions on Russia's energy trade. The consequences of the energy sanctions imposed by Western countries against Russia significantly impact the economy and society of the EU and Russia more than other stakeholders. This is mainly because the EU is highly dependent on Russian energy imports, and Russia's primary energy export market is also in Europe. Economic entities urgently want to know what impact the energy game caused by geopolitical conflicts will have on the world economy and social stability and what kind of impact it will have on the world energy trade pattern.

Geopolitical risks (GPRs) will directly affect energy trade, leading to energy security (Liu et al., 2021). The industrial production of human society is highly dependent on fossil energy consumption. Still, the geological distribution of fossil energy determines that the world's energy consumers and suppliers are in a state of separation. Therefore, geopolitical turmoil in energy-exporting regions directly affects the energy security of the world's energy-consuming countries (Inshakov et al., 2019; Vasylkivskyi et al., 2020). Many scholars have conducted detailed research on energy security issues arising from geopolitical conflicts (Ang et al., 2015; Bompard et al., 2017; Kruyt et al., 2009). These studies focus on several aspects. One is the impact of geopolitical conflicts on

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energy trade (Inshakov et al., 2019; Liu et al., 2021). The second is the impact of geopolitical conflicts on energy prices (Gong et al., 2022; Liu et al., 2019; Zhang et al., 2022). The third is the countereffect of energy consumption structure transformation on geopolitics (Dutta and Dutta, 2022; Salameh, 2014; Su et al., 2021). The research on the impact of geopolitical conflicts on energy trade is mainly carried out from two aspects. First, suppose the regional geopolitical risk of the energy-consuming country occurs. In that case, it will lead to a decline in its energy demand, triggering a reduction in the country's dependence on global energy trade. Geopolitical conflicts in such energy-consuming countries have a relatively limited impact on international energy trade (Lee et al., 2017). On the other side is the geopolitical conflict between energy exporters. Political instability in energy-exporting countries can directly impact global energy supply through supply chains such as energy output and transportation (Yang et al., 2014). In GPRs research, a more critical research direction is the impact of GPRs on energy prices and will combine oil price fluctuations with the energy security of energy-importing countries. However, there are still differences in academic research on the mechanism of GPRs on oil prices. Cunado et al. (2019) show that only a higher GPR drives up oil prices through dynamic research on GPR versus actual oil returns between 1974 and 2017. Noguera-Santaella (2016) found through an analysis of essential oil price fluctuations and interventions in different geopolitical events that geopolitical events had different impacts on oil prices in 2000. With the conclusion of carbon emission reduction agreements around the world, the world's major energy-consuming countries have begun to change their energy consumption structure, gradually increasing the proportion of renewable energy and reducing fossil energy consumption (Vakulchuk et al., 2020). The transformation of the energy structure has had a considerable impact on the world's geopolitical conflicts. Since 2010, many scholars have noted that renewable energy consumption may bring new geopolitical conflicts. Scholars' research views on this issue are also divided. On the one hand, they believe that the energy transition is unlikely to reduce energy-related conflicts (Escribano, 2018; Freeman, 2018; Hurd et al., 2012; Jacobson et al., 2017; Raman, 2013). The other side believes that energy-related conflicts will decrease as the energy transition deepens and the proportion of energy self-sufficiency in countries gradually increases (Pierri et al., 2017; Scholten and Bosman, 2016; Smith Stegen, 2018), the increased use of renewable energy reduces the influence of oil and gas exporters in global politics (Su et al., 2021).

The impact of geopolitical conflicts on capital markets and social welfare is also an important theoretical and empirical research direction. Energy price fluctuations have a heterogeneous effect on importing and exporting countries. For energy-consuming countries, rising energy prices mean higher production and transportation costs while affecting capital market liquidity through inflation and interest rates, reducing social welfare levels (Antonakakis et al., 2017). On the other hand, energy suppliers have seen rising incomes, leading to higher domestic consumption, investment, and productivity, more liquidity in capital markets, and higher overall social welfare (Apergis et al., 2015). At the same time, GPRs have a significant impact on market sentiment, investment, and decision-making behavior in energy markets, and these effects are ultimately reflected in energy price fluctuations (Humphreys, 2005; Ji et al., 2019a,b).

Previous research on geopolitical conflict and energy security has focused on using empirical analysis methods to analyze the relationship between GPRs and energy security indices or energy price indices. The impact of energy sanctions on world energy trade has rarely been studied from the perspective of geopolitical conflicts by the GTAP model. The tensest Russia–Ukraine conflict has triggered a political game around the world. Unlike the past world energy security problems caused by GPRs, this contest between the EU and Russia in the energy field will likely reshape the world energy trade pattern. So, in the energy game caused by geopolitical conflicts, what is the EU's and Russia's macroeconomic impact? What is the diversion effect of conflict on world energy trade? What impact will it have on transforming the world's energy structure? These are all issues of great concern to decision-makers worldwide and need to be solved urgently. This study uses the GTAP model to evaluate the impact of different levels of energy sanctions on energy trade and macroeconomics on both sides of sanctions. The study finds that: (1) Energy sanctions will bring macroeconomic losses to both sides of the game, and Russia's economic losses are more serious, but the EU will bear a higher level of inflation, and the world will be plagued by high inflation; (2) Russia's energy counter-sanctions can produce specific effects, but at the cost of deteriorating its economic situation; (3) energy sanctions will lead to a decrease in direct energy trade between the two countries, but an increase in indirect energy trade; (4) The energy game between the two sides will directly drag down the development of the world economy, lead to a decline in total world output, and adversely affect carbon emission reduction and energy consumption structure transformation.

The marginal contribution of this paper is: First, under the framework of the global trade model, it quantitatively reveals the global impact of the energy game between the EU and Russia caused by geopolitical conflicts, measures the impact effect of energy sanctions on both sides, and from the results of the escalation of the energy game, the two sides can only lose in this game; Second, in the global integration pattern, the competition between energy consuming countries and energy supplier countries will be weakened through the transfer effect of energy trade, and diversified energy demand and supply will become the central theme of world energy trade in the future; Third, it provides new evidence for studying the mechanism of geopolitical conflicts on energy prices. The remainder of this paper is structured in the following manner. The second part provides an overview of the state of energy trade between the EU and Russia. The third part introduces the methods and data used in this paper. The fourth part analyzes the empirical results of the article. Part V draws conclusions based on the results of the analysis.

2. Overview of energy trade between the EU and Russia

2.1. Comparison of EU and Russian aggregate indicators

As a member of the Political and Economic Community, the EU has 27 member States and a total population of approximately 446 million. The purpose of the EU is "to promote the balanced economic and social development of member States through establishing a space without internal boundaries, the coordinated development of the economy and society, and establishing an economic and monetary union leading to a unified currency". Since its inception, the European Union has been at the center of the world economy and politics. The total GDP of the EU in 2021 ranks third in the world after the United States and China, ranking third in the world economy, and the entire trade volume of the EU has also reached 13,082.447 billion dollars. As can be seen from Table 1, the EU's large-scale economic activities require massive energy consumption, and the total primary energy consumption of the EU in 2020 reached 55.74 exajoules, accounting for 10.01% of the world's total immediate energy consumption. However, the EU's own fossil energy reserves are insufficient, with oil reserves accounting for only 0.1% of the world's oil reserves, natural gas reserves accounting for 0.2% of the world's total, and coal reserves accounting for 7.3% of the world's resources. The enormous

Table 1
Comparison of EU and Russian aggregate indicators for 2021.
Source: World Bank, energy reserves data from BP World Energy Statistical Yearbook 2021.

Variable	EU	Russian	ROW
Population size (billion)	4.47	1.43	72.46
GDP(billion dollars)	170886.2	17757.99	772356.72
GDP per capita (USD)	32755.38	10219.75	10460.55
Merchandise imports(billion dollars)	64568.86	3039.27	158314.62
Merchandise exports(billion dollars)	66255.61	4940.25	152734.68
Oil reserves (Thousand million barrels)	2.4	107.8	1622.2
Coal reserves (Million tonnes)	78590	162166	833352
Natural gas reserves (Trillion cubic meters)	0.4	37.4	150.3
Primary energy consumption (Exajoules)	55.74	28.31	472.58

energy consumption by economic development and the lack of funds determine that the EU cannot achieve self-sufficiency in energy and needs to purchase a large amount of energy from outside. Russia's total energy consumption is relatively low compared to the EU's. The GDP of the Russian Federation is only 11th in the world GDP ranking in 2021, and it has a population of about 143 million. Although the level of economic activity is not high, Russia has abundant energy and mineral resources, of which, as of 2020, proven oil reserves account for 6.2% of the world's reserves, natural gas reserves account for 19.9% of the world's resources, and coal reserves account for 15.1% of the world's reserves, so it also determines Russia's economic structure based on energy exports.

2.2. EU energy structure analysis

Since the implementation of the first climate change plan in 2000, the total primary energy consumption of the EU has been on a downward trend since 2006. Due to the impact of the pandemic, EU energy consumption fell sharply in 2020 until it rebounded sharply in 2021. According to Fig. 1, the perspective of the EU's energy consumption structure, the proportion of crude oil consumption has been declining from 41.35% in 2000 to 35.46% in 2021, the proportion of renewable energy and natural gas consumption is rising, the proportion of renewable energy consumption has increased sharply from 0.9% to 13.17%, and natural gas consumption has increased from 19.94% to 23.75%. Although the EU's energy reform policy has achieved the goal of reducing the total primary energy consumption, there is still a gap between the energy structure transformation goal of reducing the proportion of fossil energy consumption and increasing the ratio of renewable energy consumption to 20%. The analysis of EU fossil energy reserve indicators shows that the EU's economic development needs energy imports from external markets.

From the perspective of the structure of the EU energy import trade, Russia is the leading importer of EU energy. In 2020, the EU relied on imports for 58% of its energy consumption, and its self-sufficiency rate was only 42%. While the EU has been trying to wean itself off Russian energy imports, Russia is the EU's leading supplier of gas, oil, and coal. In 2021, the EU's oil, refined oil, and coal imports from Russia accounted for 29.64%, 38.44%, and 48.08% of its various energy imports. As the primary fossil energy supporting the EU's green energy transformation, natural gas imports mainly include pipeline imports and liquefied imports, of which pipeline natural gas transportation accounts for 68.26% of the total natural gas imports. In 2021, natural gas from Russia accounted for 71.74% of EU pipeline transport imports, and liquefied natural gas imports accounted for 20% in Russia. The main reason the EU depends on Russian energy is related to Russia's abundant energy reserves, low prices, and low transportation costs, especially the construction of gas transportation pipelines, such as Nord Stream 1 and Nord Stream 2.

Combined with the current situation of the EU energy trade, the EU's short-term implementation of severe energy sanctions against Russia will cause a more serious energy shortage in the EU.

2.3. Energy trade in Russia

Russia occupies a critical position in the world's energy supply chain as a country with relatively rich energy reserves. According to data published by the Russian Federal Customs Service, global oil demand shrank sharply in 2020 due to the epidemic's impact. Russia and Saudi Arabia have implemented production cuts, and oil and gas exports have hit new lows — resulting in a 36.6% reduction in exports of energy goods. Even with a sharp decrease in energy demand, the share of energy goods exports in Russia's export trade fell from 62.1% in 2019 to 49.6% in 2020, which is still the highest. In other words, Russia's foreign trade structure is still dominated by the export of energy commodities. By the end of 2020, crude oil accounted for the most significant proportion of Russia's trade value of different energy types, accounting for 47.51% of the total energy trade, followed by the export of crude oil products, accounting for 30.62% of the total. As shown in Fig. 2, Russian crude oil export destinations are concentrated in Europe and Asia, of which oil exports to Europe account for 53.05% of the total value of oil exports, and Asia accounts for 45.22%. Among the Asian destinations for Russian crude exports, China is its largest buyer, importing 32% of Russia's crude. In continental Europe, the Netherlands imports 12.4% of Russian crude oil, and Germany imports 8.57% of Russian crude oil. The export trade structure of Russian crude oil products is more dependent on the European market. The value of crude oil products exported by Russia to European countries accounted for 60.37% of the total export value, while Asia accounted for 26.59%. The refined oil imports of the Netherlands, France, and Germany accounted for 14.1%, 6.08%, and 4.62% of Russia's exports, respectively. Russia's petroleum gas export trade is more dependent on the European market, which consumes 71.92% of Russia's petroleum gas, and the rest is almost entirely exported to the Asian market. Coal exports are of relatively small value and more dispersed than the top three energy commodity destinations. An analysis of Russia's energy trade structure shows that Europe and Asia are the main markets for its energy trade. The European market is currently more important than the Asian market. This energy trade structure will shift significantly with the EU's energy sanctions against Russia.

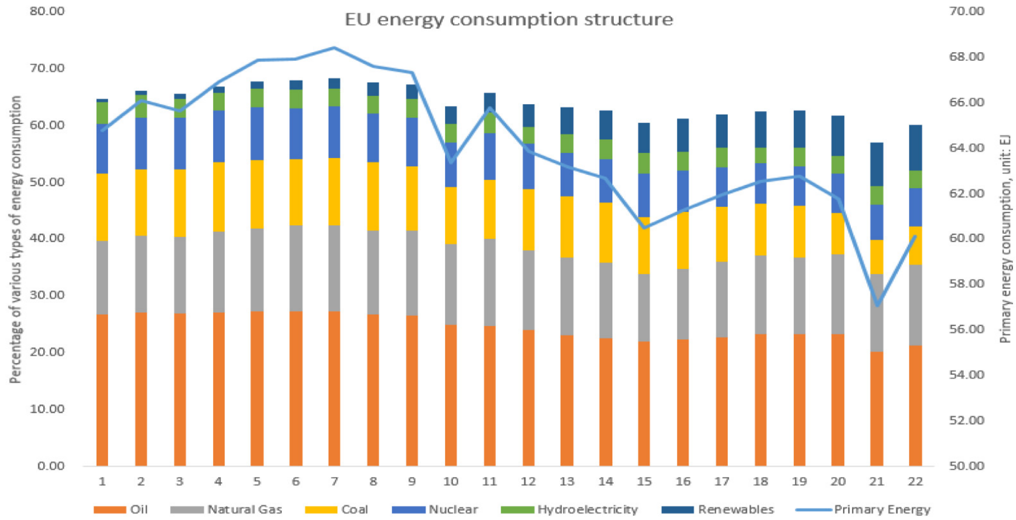

Fig. 1. EU energy consumption structure.

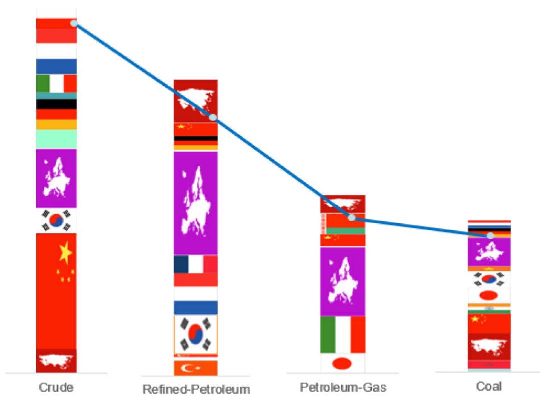

Fig. 2. Russian energy trade structure.

2.4. Analysis of the EU's dependence on Russian energy

Through the analysis of EU energy consumption and the structure of Russian energy export trade, it can be seen that the EU is highly dependent on energy commodities provided by Russian energy, and Russia's foreign energy trade is also dependent on the European market. Through the analysis of the EU's energy consumption and the structure of Russia's energy export trade, the EU is highly dependent on energy commodities provided by Russian energy. In contrast, Russia's foreign energy trade also depends on the European market. There are three main reasons for the EU's dependence on Russian energy. First, the geographical advantage between Russia and the EU makes it the most convenient for the EU to obtain energy from Russia with the lowest transportation cost. Second, the EU's aggressive energy transition policy has led to the withdrawal of traditional energy sources from the market too quickly, resulting in large fluctuations in the internal energy supply. Third, the development speed of renewable energy is not as fast as expected, and the stability is poor. Through the analysis of the EU's energy reserve data, it can be seen that the EU's energy reserves are not enough to support economic development needs. The geographical location between Russia and the EU is more advantageous than other energy suppliers in the world, and the two major economies have reduced the cost of energy transportation through the construction of oil and gas transportation pipelines, which has formed the physical basis of the EU's dependence on Russian energy. With the increasing importance of ecological and environmental issues in the EU, it has proposed a radical energy consumption structure transformation plan. In this plan, increasing the proportion of renewable energy and reducing traditional fossil energy are essential indicators. The implementation of the policy has led to the large-scale closure of coal-fired thermal power plants in Euro member countries, turning to natural gas and renewable energy. In the energy transformation process, natural gas, as a cleaner energy source compared to other fossil energy sources, has been used in large quantities to meet the set emission reduction targets. Russia has exported a large amount of natural gas to the EU through Nord Stream 1 and 2 pipelines to complete the transformation of the EU's energy consumption structure. Whether or not the EU undergoes an energy transition, it will be challenging to eliminate its dependence on cheap Russian energy. Therefore, the EU's energy ban on Russia will directly affect its energy security. In the short and medium term, it will be difficult for the EU to find a suitable energy supply organization to replace Russia. The diversion effect of energy trade will lead to a rapid increase in energy prices, affecting the welfare and social and political stability of EU member states.

In summary, as an essential demand side and supply side in the world energy pattern, the impact and changes in energy trade between the two countries will have a spillover effect on the global energy trade pattern, which will affect the stability of the worldwide energy trade network structure. The energy game between the two economies is bound to disrupt the existing energy trade network and threaten global energy security. Therefore, it is necessary to quantitatively analyze the energy game between the EU and Russia to understand the effects of world energy trade and the macroeconomic impact caused by the conflict between the two countries.

3. Method and data

3.1. Method

To simulate the impact of energy sanctions and countersanctions between the EU and Russia on the two major economies and the world economy under geopolitical conflicts, this paper conducts an empirical analysis based on the global multi-region comparative static CGE model, known as the Global Trade Analysis Project (GTAP), developed by Purdue University. The project is widely used in the study of international trade disputes (Cui and Song, 2017; Itakura, 2014). To study the impact of energy

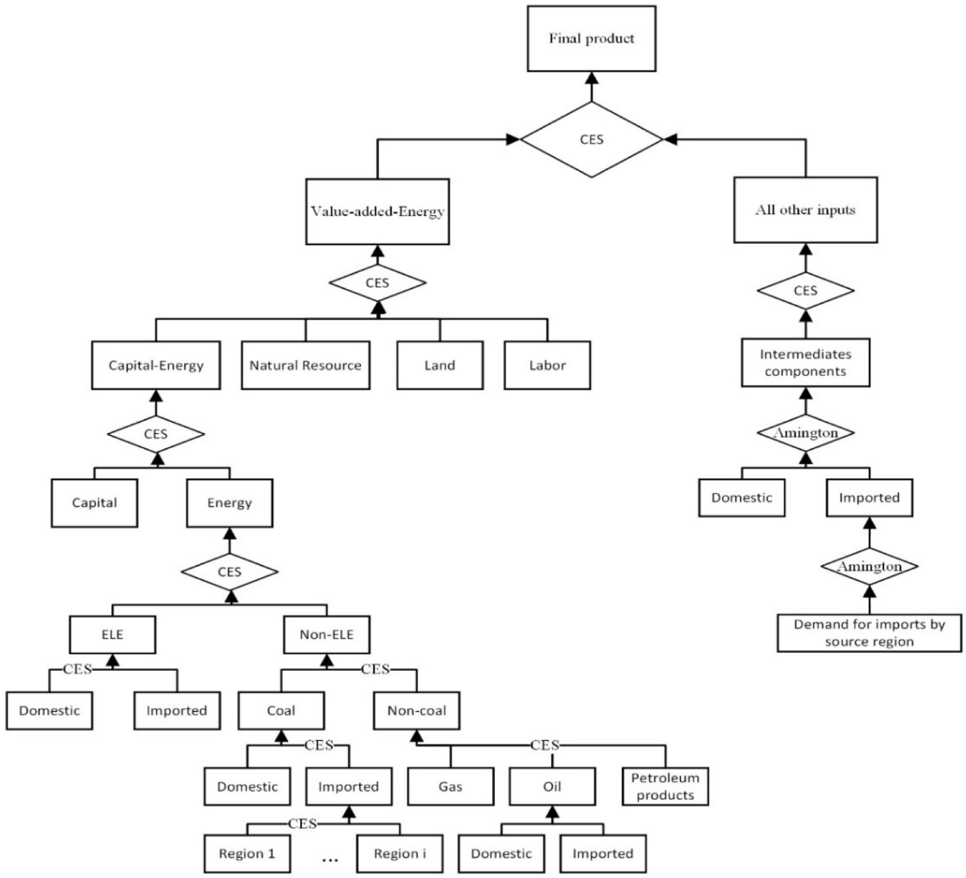

Fig. 3. The basic structure of the production module in GTAP-E.

sanctions on economies and energy trade, this paper uses the GTAP-E model. The GTAP-E model is an extended application of the GTAP standard model in the field of environment. The GTAP-E model incorporates energy as a factor input into the production structure, introduces carbon tax variables and carbon emissions trading mechanisms, and modifies the modules of production, consumption, carbon tax, and welfare decomposition. The basic structure of the specific production module is shown in Fig. 3.

The production module of the GTAP-E model is embedded with multiple levels of conversion substituted elastic (CES) production functions, and capital and energy products can be substituted for each other. The basic production factors of the GTAP-E model include not only land, labor, and natural resources, but also capital–energy composite elements. Capital and energy can be substituted for each other, and this module uses the CES production function to characterize that if energy prices rise relative to capital prices, companies will replace capital inputs with energy products. Energy products are further divided into electricity and non-electricity composite elements, which can be further decomposed into coal, crude oil, natural gas, and petroleum products, and each stage composite structure adopts the CES production function. Different from the traditional GTAP model, the GTAP-E model distinguishes the energy input in the production module from other non-energy intermediate inputs, considering the substitution of energy inputs with other basic production factors. On this basis, the GTAP-E model can accurately trace the energy consumption in the production process to investigate the "economic-energy-carbon emission" impact of policy changes. Therefore, the GTAP-E model is an important tool for energy policy and climate policy simulation.

In the past, when simulating the EU-Russia energy embargo, scholars used the form of shock tariff variables (tms) to change the volume of a particular country's trade in a specific commodity (Chepeliev et al., 2022). They directly transferred the tax revenue to the importing country. However, the energy game between the EU and Russia is mainly to now cut off energy trade between the two countries in the form of an executive order, so this paper divides the tariff revenue from the exporting country based on the import tariff adjustment to ensure that the simulation results are more realistic.

3.2. Data

The impact simulations in this study are based on GTAP-E data, the most recent data for the current period, and the simulation base period is 2014. The GTAP-E version of the database subdivides the world into 141 regions, each containing 65 production departments. To study the impact of the energy game between the EU and Russia on both sides and the world's major countries, this paper divides the 141 countries in the database into the European Union, Russia, the United Kingdom, Turkey, China, India, the United States, the Eurasian Economic Union (EEU), other Middle East and North Africa countries (XMN), OPEC member countries (OPEC), the Association of Southeast Asian Nations (ASEAN), and the rest of the world (ROW). To study the heterogeneous impact of shocks on different levels of dependency, the 27 EU member states were classified as highly dependent (EUhdR), moderately reliant on Russian energy (EUmdR), and low dependent (EUldR) according to their dependence on Russian energy.[1]

[1] National energy dependence: based on the percentage of total imports of fossil fuels from Russia.

Table 2
Energy sanctions and counter-sanctions scenario setting.

	Scenario description
S1	The EU cuts off coal imports from Russia.
S2	The EU cut off coal imports from Russia; Russia reduced its gas supply by 30%.
S3	The EU cut off coal imports from Russia; Russia reduced its gas supply by 50%.
S4	The EU cut off coal imports from Russia; EUldR and EUhdR ban the import of Russian crude oil and refined oil products; EUhdR reduce by 70%.
S5	The EU cut off coal imports from Russia; EUldR and EUhdR ban the import of Russian crude oil and refined oil products; EUhdR reduce by 70%; Russia reduced its gas supply by 80%.
S6	The EU and Russia cut off energy trade.

To study the heterogeneous impact of energy trade restrictions on different industries in the EU and Russia, the 65 production sectors in the GTAP-E database were divided into 12 industry groups. At the same time, the energy game between the EU and Russia occurred in 2022, and the entry into force of sanctions on specific energy projects also happened in that year, so the base year of the simulation was set as 2022. However, the base year of the GTAP-E database is 2014, so the actual GDP, population, capital stock, and labor force data of the Econmap database of the French World Economic Research Center are used to dynamically recurse the data from 2014 to 2021, according to the research method (Ahmed et al., 2020).

3.3. Conflict scenarios setting

As the war between Russia and Ukraine continues to escalate, EU sanctions against Russia are also changing. Considering the energy trade structure of the two economies and the EU's energy sanctions, this article sets up six short-term scenarios, as shown in Table 2. From the perspective of the energy trade structure of the two major economies, the EU is highly dependent on Russian energy imports. In Russia's trade structure, energy exports are the backbone of its economy. To sanction Russia for waging war in Ukraine, the EU has reduced or banned imports of Russian energy goods to combat its economy. In the scenario S1 setup, we set the EU to voluntarily cut off coal imports from Russia following the EU's Fifth package of sanctions proposed on April 8, 2022. In S2, Russia took countermeasures in response to EU energy sanctions. Since the EU highly depends on Russian natural gas energy, Russia will use natural gas exports as a countermeasure. Russia will reduce its gas exports to the EU by 30%. S3 said that Russia retaliated against the EU energy ban. If the EU strictly enforced the prohibition of Russian coal exports, Russia would reduce its gas exports to the EU by 50% in retaliation for various EU sanctions. In the S4 scenario, if the EU has not prevented the escalation of the situation in Russia and Ukraine after passing previous sanctions against Russia. The EU will increase the sanctions based on the original sanctions. The new sanctions include related products such as crude oil and refined oil products. Considering the different degrees of dependence of EU member states on Russian energy, the implementation of sanctions will vary. The EUldR and EUmdR countries in the EU will completely ban imports of Russian crude oil and refined oil products, but the EUhdR countries will reduce Russian crude oil and refined oil products imports by 70%. In the S5 scenario, Russia would reduce its natural exports to the EU by 80% in response to the escalation of EU sanctions. The S6 scenario simulates the extreme scenario of a two-way game, in which the EU completely bans energy products from Russia, and Russia cuts off gas exports to the EU.

4. Results and discussion

4.1. Direct effects of energy sanctions

4.1.1. GDP and GDP deflator

Table 3 shows the real GDP and GDP deflator changes in the EU regions, Russia, and corresponding world regions. A complete cessation of energy trade between the EU and Russia would lead to a 2.895% drop in world GDP. The shock results of different scenarios show that the impact on economies of whether or not to embargo oil and petroleum products varies widely. When the EU bans Russian coal in scenario S1, the economic damage to the EU is up to 0.099% and 0.891% to Russia. Russia's counter-sanctions measures can blow the EU economy, but they cannot improve the economic losses caused by sanctions. Once the EU imposes sanctions on Russian crude oil and crude oil products, the economic losses to both sides will skyrocket. In the scenario of a hard decoupling of energy trade between the two sides (S6), the economic losses of the EU consortium would reach 1.488%, while the GDP losses of Russia would get 4.8%. In the game between the two sides, there is no economic winner, and the sanctions of both sides will cause economic damage to the other, but the economic losses for Russia will be higher. At the same time, other participants in this event, such as the members of the G7 group, have been less affected in the energy game between the EU and Russia (such as the United Kingdom, the highest loss is only −0.0712%), or even benefited. For example, the United States has maintained positive economic growth. As the game between the two sides intensifies, its economic growth degree has increased, reaching a maximum of 0.1165%.

The change in the GDP deflator shows that energy sanctions will increase the cost of energy prices in EU member states, leading to higher inflation. Judging by the data on energy trade between the EU and Russia, the EU's energy consumption is highly dependent on Russian energy imports, especially natural gas. Therefore, the EU's sanctions on Russian energy will directly cause a massive gap in the energy supply, leading to a rapid rise in energy prices and production costs of energy-intensive industries. As seen in scenarios 1 to 3 from Table 4, the EU GDP deflator increased from 0.137% to 0.287%. As a sanctioned party, Russia suffered a decline of up to 0.442% in the GDP deflator due to setbacks in foreign trade, which may trigger deflation at home. This is only a scenario in scenarios S1–S3 that does not involve sanctions on crude oil and crude oil products. If the EU imposes sanctions against Russia's strict embargo on crude oil products, the impact on the price level of both sides will be huge. The EU's GDP deflator rose directly to 0.502%, while Russia's GDP deflator fell instantly to 4.022%. The deflationary impact of sanctions on Russia will be stronger than the inflationary effect of the EU. Due to member states' different degrees of dependence on Russian energy within the EU, there will be significant differences in the level of shocks. EU member states highly dependent on

Table 3
Changes in GDP in different scenarios.

GDP	S1	S2	S3	S4	S5	S6
EUhdR	−0.064	−0.080	−0.084	−0.731	−0.971	−1.215
EUmdR	−0.005	−0.006	−0.009	−0.138	−0.152	−0.231
EUldR	−0.003	−0.004	−0.006	−0.027	−0.029	−0.041
EU	−0.071	−0.090	−0.099	−0.897	−1.152	−1.488
UK	−0.002	−0.002	−0.002	0.068	−0.068	−0.071
TUR	0.002	−0.004	−0.007	0.074	0.058	0.061
RUS	−0.141	−0.598	−0.891	−2.833	−2.104	−4.800
CHN	0.001	0.002	0.002	0.039	0.041	0.047
IND	0.002	0.001	0.000	0.068	0.066	0.079
USA	0.013	0.014	0.015	0.100	0.105	0.117
EEU	0.002	0.002	0.005	1.185	1.206	1.382
XMN	0.015	0.043	0.080	0.169	0.342	0.393
OPEC	0.016	0.000	0.011	0.360	0.411	0.449
ASEAN	0.001	0.006	0.010	0.028	0.045	0.052
ROW	0.006	0.017	0.024	0.101	0.135	0.153
WORLD	−0.226	−0.698	−0.952	−1.433	−2.068	−2.895

Table 4
Changes in GDP deflator in different scenarios.

GDP deflator	S1	S2	S3	S4	S5	S6
EUhdR	0.254	0.458	0.534	0.877	0.931	1.049
EUmdR	0.095	0.116	0.131	0.242	0.250	0.262
EUldR	0.041	0.086	0.118	0.075	0.072	0.076
EU	0.137	0.2408	0.287	0.429	0.451	0.502
UK	0.001	0.002	0.002	0.087	0.088	0.095
TUR	0.001	−0.004	−0.007	0.066	0.052	0.055
RUS	−0.191	−0.344	−0.442	−3.144	−3.627	−4.022
CHN	0.001	0.002	0.003	0.037	0.041	0.046
IND	0.002	0.001	0.000	0.070	0.068	0.080
USA	0.013	0.014	0.015	0.102	0.107	0.118
EEU	0.000	0.003	0.006	0.941	0.958	1.102
XMN	−0.015	0.041	0.077	0.166	0.334	0.384
OPEC	−0.016	0.000	0.011	0.355	0.405	0.441
ASEAN	0.001	0.007	0.010	0.029	0.046	0.054
ROW	0.006	0.017	0.023	0.097	0.129	0.147
WORLD	−0.039	−0.141	−0.206	1.093	0.204	1.113

Russian energy will suffer the most from the sanctions imposed. At the same time, countries with low dependence will have a lower impact, which will also be a key factor affecting whether sanctions can be agreed upon in the EU. Looking at the effects of the EU's energy sanctions on Russia from the perspective of the international economy, we can draw a bare conclusion that is, the implementation of energy sanctions will directly promote the general rise in energy prices around the world, increasing the world GDP deflator.

4.1.2. Changes in welfare levels

In the GTAP model, changes in resident welfare are measured in the form of equivalent variation changes (EVs). EU energy sanctions against Russia will lead to losses in world welfare levels, up to 40,860.18 million dollars. After Russia suffers energy sanctions, the welfare of residents drops significantly, especially when crude oil and crude oil products are sanctioned, which has a significant negative impact on the welfare of residents in Russia. Through the decomposition of changes in the welfare of residents, the most critical factor affecting the decline in the welfare of Russian residents is the change in the terms of trade, which contributed more than 70% of the negative impact. The EU's complete cut-off of trade with Russian energy products (S6) will lead to a decline in EU residents' welfare level by 13938.58 million dollars. Unlike the reasons for the decline in the welfare level of Russian residents, the reduction in the level of welfare of EU residents is due to allocative effects. The allocative effect is mainly generated by the impact of energy restrictions on regional production and household consumption. Due to the high dependence of the EU on Russia for energy consumption, the implementation of an energy ban will lead to a shortage of regional energy supply, making the supply of raw materials for energy-intensive industries insecure, so the output of the related industries will decline. Energy restrictions will also cause the cost of living to rise rapidly. According to EU statistics, inflation in the EU region was as high as 9.6% in July 2022 after implementing energy restrictions. A rapid rise in the price index and a rapid decline in output in energy-intensive industries will lead to a significant decrease in household welfare. The increase in sanctions between the two sides will improve the welfare of residents of other energy export organizations, the most obvious of which is the EEU, the Eurasian Economic Union, as a Russian-led economic organization, played a role in energy re-export when Russia was sanctioned, and played a positive role in the trade export volume of member countries (see Table 5).

4.1.3. Changes in terms of trade and import trade

The sanctions imposed by the EU and G7 member states have severely impacted Russia's terms of trade(tot), and as the sanctions are carried out, the terms of trade of EU member states have also been damaged. As shown in Table 6, in the

Table 5
Changes in equivalent variation in different scenarios.

EVs	S1	S2	S3	S4	S5	S6
EUhdR	−264.13	−75.62	−296.29	−4391.76	−3470.19	−4947.25
EUmdR	−219.44	−1133.43	−1714.66	−1627.66	−4387.39	−5314.13
EUldR	−29.91	−182.89	−280.39	−2794.73	−3275.44	−3677.19
EU	−513.49	−1391.95	−2291.35	−8814.16	−11133.03	−13938.58
UK	24.97	−23.79	−54.67	−428.25	−578.03	−773.53
TUR	20.82	18.08	42.77	269.46	156.70	134.94
RUS	−173.42	−4219.48	−7015.26	−13984.64	−27151.26	−31712.15
CHN	162.56	298.35	385.94	1105.94	1521.94	1711.65
IND	4.44	47.67	80.84	521.29	678.88	701.02
USA	379.22	238.47	151.34	478.63	892.62	1088.51
EEU	19.45	92.46	139.45	2868.79	3109.43	3525.68
XMN	117.00	220.38	434.62	1053.65	2061.09	2329.13
OPEC	128.73	123.73	−121.49	2575.16	2607.33	2764.63
ASEAN	18.16	11.59	7.37	499.99	486.33	526.50
ROW	286.87	795.77	1121.74	4402.34	5960.86	6720.56
WORLD	−38.13	−5180.63	−9410.01	−18265.93	−32520.12	−40860.18

Table 6
Changes in tot in different scenarios.

tot	S1	S2	S3	S4	S5	S6
EUhdR	−0.495	−0.507	−0.632	−1.051	−0.920	−1.134
EUmdR	−0.064	−0.346	−0.534	−0.666	−0.719	−0.935
EUldR	−0.009	−0.011	−0.012	−0.201	−0.206	−0.232
UK	0.001	0.002	0.002	−0.364	−0.363	−0.401
TUR	0.000	0.000	0.001	0.190	0.191	0.210
RUS	−0.191	−0.133	−0.097	−4.833	−4.710	−5.151
CHN	0.000	−0.001	−0.002	0.417	0.422	0.463
IND	0.002	0.003	0.004	0.349	0.346	0.382
USA	0.001	−0.007	−0.011	1.146	1.163	1.280
EEU	−0.013	−0.016	−0.018	0.407	0.398	0.490
XMN	0.001	0.005	0.008	0.103	0.092	0.102
OPEC	0.001	0.001	0.002	0.154	0.156	0.172
ASEAN	0.004	0.007	0.009	−0.073	−0.066	−0.071
ROW	0.004	0.005	0.006	−0.232	−0.228	−0.249

S1 and S4 scenarios, Russia's tot deteriorated by 0.191% and 4.833%, respectively. Due to restrictions on Russian energy imports and the impact of Russian countersanctions, the EU's tot continued to deteriorate in scenarios S2 and S3. Although Russia's counter-sanctions have served the purpose of its policy, the cost is two-way, and it has adversely affected its tot. Suppose the EU strictly implements energy sanctions against Russia, which eventually leads to the interruption of energy trade between the two sides. In that case, it will significantly negatively impact the tot between the two sides. The EU's persistent energy supply shortage will have a contagion effect on the trade of other EU industries, such as energy-intensive industries, agriculture, chemical industries, etc., and the EU's tot will further deteriorate. For additional energy exporters, the energy game between the EU and Russia has caused international oil prices to rise, boosting their energy exports and incomes. To compensate for the energy gap, the EU has correspondingly reduced tariffs on energy imports from other countries, which has promoted the improvement of other countries' tot to a certain extent.

From the perspective of the impact of energy sanctions on the import and export trade of the two sides, both sanctions and countersanctions significantly impact the import and export trade of the two sides, mainly on exports for Russia and imports for EU member states. Implementing sanctions on energy imports by EU member states will directly reduce the total energy imports of the EU, which will reduce the total EU imports. In the simulation, total EU imports fell the most at S6, reaching 2.404%, shown in Table 7. Considering the practical dilemma of the EU in adjusting the energy trade structure in the short term, energy import restrictions will become the most significant hidden danger to the EU's energy security. The energy ban has an even more substantial impact on Russia's import and export trade, with total imports falling by 6.23% and exports by 8.56% in the S6 scenario. According to the policy simulation results, EEU, an economic cooperation alliance led by Russia, has seen a significant increase in its import and export volume during the sanctions period. In the S6 scenario, EEU imports increased by 5.82%, and exports increased by 5.32%. Russia can transfer energy trade through the EEU and other countries. Although there is a change, the import and export of the rest of the world's nations are insignificant.

4.2. Indirect effects of energy sanctions

4.2.1. Energy trade transfer effects

Fig. 4 shows the diversion effect of the energy ban on the EU's energy import trade. With the escalation of EU energy sanctions against Russia, energy trade between the two sides will decline significantly. In the S1 scenario, energy trade between the EU and Russia fell by 5.26% after EU sanctions on Russian coal imports. With the counter-sanction measures imposed by Russia, EU gas supplies will be limited, negatively impacting energy trade between the two sides. In the S3 scenario, the EU energy trade with Russia will fall by 10.19%. There is no significant energy transfer

Table 7
Changes in export and import in different scenarios.

	Export						Import					
	S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
EUhdR	−0.35	−0.58	−0.60	−2.04	−2.15	−2.92	−0.12	−0.14	−0.15	−1.57	−1.63	−2.23
EUmdR	−0.14	−0.17	−0.19	−1.57	−1.66	−1.68	−0.02	−0.04	−0.05	−0.23	−0.28	−0.28
EUldR	−0.01	−0.11	−0.11	−0.27	−0.28	−0.39	0.00	0.00	0.00	0.07	0.08	0.10
EU	−0.50	−0.86	−0.90	−3.88	−4.09	−5.00	−0.15	−0.17	−0.19	−1.73	−1.83	−2.40
UK	0.00	0.00	−0.01	0.22	0.21	0.22	0.00	0.00	0.00	0.22	0.23	0.25
TUR	0.00	0.00	0.01	0.21	0.22	0.24	0.00	0.01	0.02	0.17	0.20	0.22
RUS	−0.39	−0.97	−1.35	−4.66	−5.42	−6.23	−0.30	−0.91	−1.30	−3.92	−5.78	−8.56
CHN	0.00	0.00	0.00	0.11	0.10	0.11	0.00	0.00	0.00	0.02	0.02	0.03
IND	0.00	0.00	0.00	0.23	0.24	0.27	0.00	0.01	0.01	0.27	0.30	0.35
USA	0.03	0.02	0.01	0.19	0.15	0.16	0.04	0.02	0.01	0.11	0.05	0.05
EEU	0.05	0.23	0.35	4.55	5.12	5.82	0.04	0.20	0.31	4.17	4.68	5.32
XMN	−0.02	0.05	0.10	0.22	0.43	0.49	−0.02	0.05	0.09	0.18	0.37	0.42
OPEC	−0.02	0.00	0.02	0.42	0.50	0.55	−0.02	0.00	0.01	0.34	0.40	0.44
ASEAN	0.00	0.00	0.00	0.05	0.04	0.04	0.00	0.00	0.00	0.03	0.02	0.03
ROW	0.01	0.05	0.08	0.25	0.38	0.43	0.01	0.05	0.07	0.17	0.29	0.34

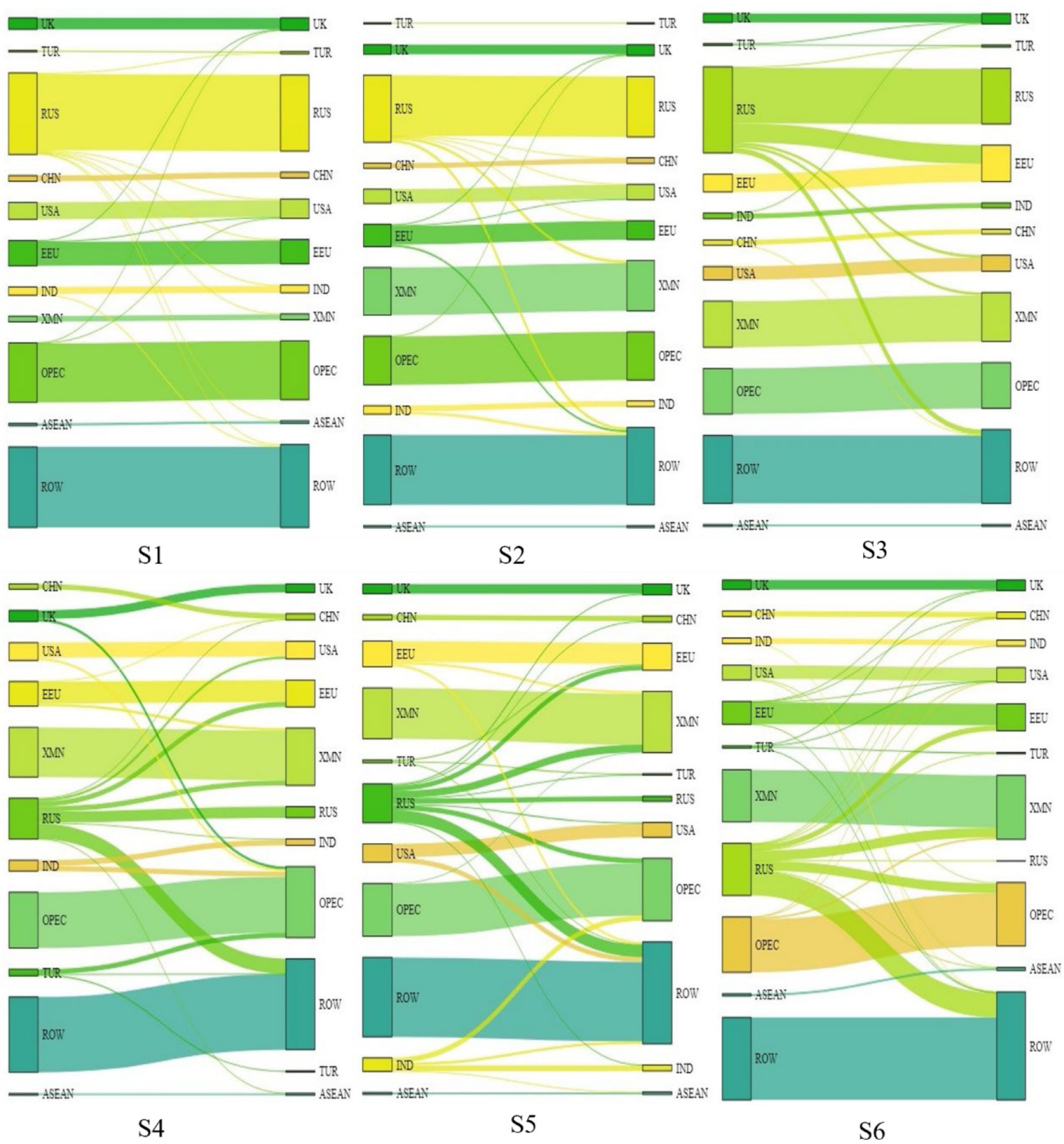

Fig. 4. The transfer effect of EU energy trade in different scenarios.

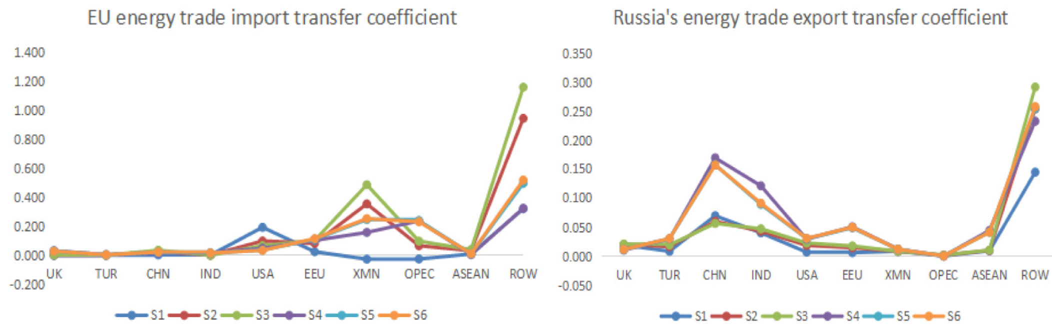

Fig. 5. The energy trade transfer coefficient in different scenarios.

effect when sanctions are imposed only on Russian coal. The EU's energy market is still dominated by Russian energy, but there are also signs of energy transfer. In S3, Russia's energy gap with the EU will be transferred to the EU through the EEU. At the same time, the EU will look for alternatives to Russia's energy gap worldwide. The more significant phenomenon is that OPEC, XMN, and ROW account for a substantial increase in the EU's energy structure.

The EU continues escalating energy sanctions against Russia, covering crude and crude oil products. Implementing these sanctions will have a non-negligible impact on the EU's short-term energy security and even lead to differences within the EU on sanctions against Russia. In scenario S4, energy trade between the EU and Russia would fall by 81.69%, and if Russia countersanctions against the EU by reducing gas supplies (S5), energy trade between the two would fall by 90.68%. The transfer effect map of energy trade shows that the imposition of severe sanctions on Russian crude oil and crude oil products will significantly change the EU's energy structure. Russia's share of the EU's energy mix is rapidly declining. The EU can only fill the gap in the energy market by increasing energy imports from other energy supply organizations. Russia will transfer exports to the EU through third-party channels, such as the Eurasian Economic Union. And Russia is also actively developing new energy exporters, such as India, China, and other non-Western world countries. In the process of EU sanctions against Russia, Russia's foreign energy trade exports fell from 2.267% in the S1 scenario to 22.818% in the S6 scenario, which played a role in the sanctions against the Russian energy economy. In the simulation, other energy exporters can supplement the EU's energy demand. The total energy supply situation may be worse than the model scenario, so whether the EU will continue to impose energy sanctions on Russia will be decided based on the actual energy supply scenario.

4.2.2. Energy trade transfer coefficient

To study the impact of the EU energy ban on the flow of energy trade between the EU and Russia, we define the energy trade transfer coefficient with reference to the practice of Cui et al. (2018). Use this indicator to find the countries and organizations with the most apparent energy trade diversion effect in sanctions. The EU energy trade import transfer factor is the increase in EU energy imports from third countries divided by the decrease in EU energy imports from Russia. This indicator measures the extent to which the EU's energy imports to other countries expand for every $1 reduction in EU energy imports from Russia. Similarly, the export transfer factor for Russian energy trade is defined as the increase in Russia's energy exports to third countries divided by the decrease in Russia's energy exports to the EU, which reflects the extent to which Russia's energy exports to other countries expand for every $1 reduction in Russia's energy exports to the EU.

Fig. 5 shows the energy trade transfer coefficients between the EU and Russia in different scenarios. The import transfer coefficients of the EU energy trade are all positive, indicating that the EU has a shift in imports of energy trade. In each scenario, the expansion of EU energy imports from the USA, EEU, XMN, OPEC, and ROW is more pronounced. At the same time, the import transfer coefficient of the EU in scenarios S1–S3 is significantly higher than that of energy imports in scenarios S4–S6. Mainly due to the EU's sanctions on Russian crude oil and crude oil products in the S4 scenario, the EU's energy imports from Russia have decreased rapidly, while the increase in imports from third countries has grown at a low rate. This shows that if the EU imposes strict restrictions on Russian crude oil and crude oil products, although it can make up for part of the energy gap by increasing the energy imports of third countries, the energy supply gap will still exist. Energy sanctions will force Russia to transfer more energy to Asian countries. Russia's export expansion to CHN, IND, USA, EEU, ROW, and other regions is more prominent. This simulation is consistent with the real-world adjustment of the Russian energy export trade. According to OECD data, since the EU and G7 imposed sanctions on Russia, Russia's crude oil and crude oil products exported to China have increased by about 55% year-on-year.

4.3. The socioeconomic impact of the energy ban

4.3.1. Impact on residents

The energy ban has had a significant negative impact on the world's inhabitants. Most countries are plagued by inflation while developing countries also need to worry about the food crisis. The most affected are the two sides of the game. The chart below shows the impact of the EU energy ban on commodity prices on both sides. The energy ban imposed by the EU has brought intolerable inflation, especially in EU member states, which are highly dependent on Russian energy. In scenarios S1–S3 shown in Fig. 6, the most significant increase in the price of various commodities in EU member states was natural gas, with gains of 4.22%, 3.42%, and 3.39%, and the costs of other items increased to a certain extent. Starting from scenario S4, the rise of commodities in EU member states began to differ, and the prices of crude oil and crude oil products in EUhdR member countries began to rise rapidly, with the maximum price increase of crude oil products in scenario S6 reaching 20.32% and crude oil prices rising by 15.87%. Prices of other energy-related commodities have also risen significantly. In scenario S6, the electricity prices of EUhdR, EUmdR, and EUldR increased by 10.12%, 6.95%, and 6.77%, respectively. On August 18, 2022, Eurostat released data showing that the annual inflation rate in the EU and the eurozone reached 9.8% and 8.6%, respectively, in July 2022. The reality is that since the imposition of EU sanctions on Russia, energy and electricity prices in EU countries have risen even faster than the settlement results of the model. During this period, the cost of natcostgas,

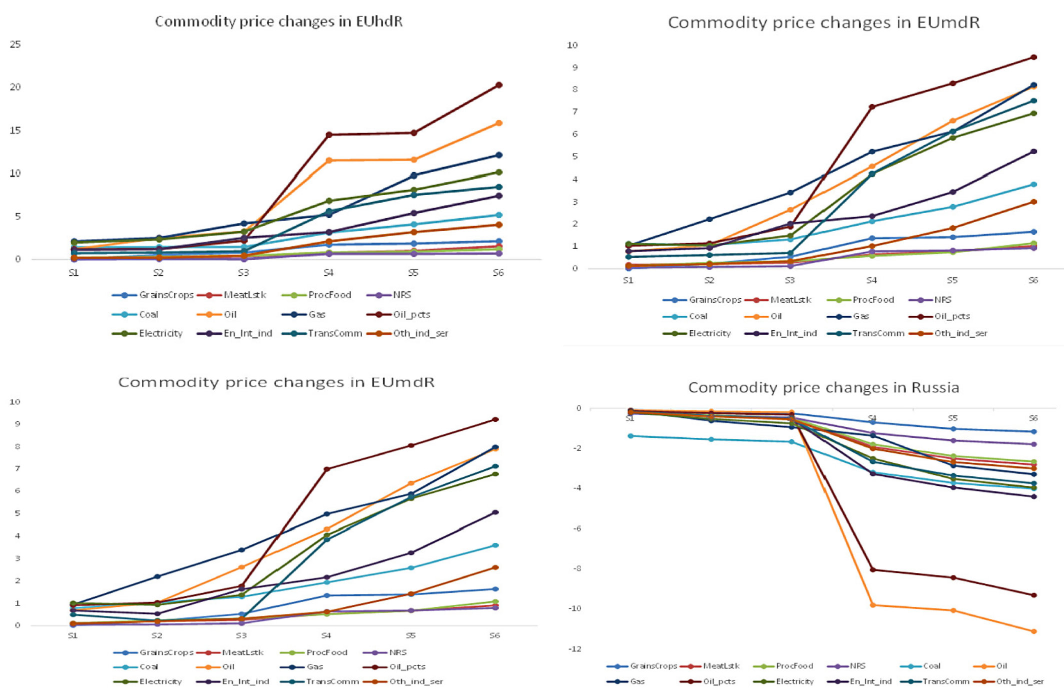

Fig. 6. Changes in commodity prices in different regions in the energy game.

which EU countries mainly rely on, has increased from an average of about 70 euros per megawatt hour per month in February 2022 to a maximum of 300 euros/MWh, an increase of 321.4%, while German electricity prices have exceeded the 700 euro mark for the first time, reaching a record 710 euros/MWh. The rise in energy prices in EU member states is consistent with, or even higher than, the model's simulations, which include uncertain market expectations for the future EU-Russia energy game.

According to the model simulation, the price of various domestic outputs in Russia will see a large-scale price decline due to the restriction of energy exports, among which the cost of energy commodities will fall most obviously. In scenario S6, the price of crude oil falls by 11.12%, the price of crude oil products falls by 9.32%, and the domestic economy should have severe deflation. But Russia has seen historical inflation, with the annualized inflation rate rising to 17.49% year-on-year in the week ending April 8, the highest since February 2002, according to the Russian Ministry of Economic Development. The main reason for this is the rapid and significant depreciation of the ruble. Currency depreciation and the epidemic's impact have caused Russian residents to reduce service consumption and increase consumption of physical goods.

4.3.2. Impact on social output

The energy ban has a heterogeneous impact on social output in the EU and Russia. The negative effect on the output of all sectors of society in the EU member states is consistent, and the impact on the output of the Russian industry is concentrated in the energy sector. The energy ban stimulates the exploitation of the EU's energy reserves. The implementation of the ban has allowed the EU to expand non-Russian energy imports while also turning its attention to internal energy resource reserves. As shown in Table 8, starting with scenario S1, the EU's coal sector output increased by 5.192% to address the gap in coal supply. And with the escalation of the energy ban, the output of the coal industry has maintained a high growth rate. In scenario S6, the coal sector output growth reached 9.434%. At this time, the increase in coal output is more to meet the electricity demand and alleviate the power supply shortage caused by natural gas and crude oil. The most apparent impact of the ban on EU industry output is the power sector, energy-intensive industries, and the output of crude oil products. In scenario S6, the output declines of the three sectors were 5.389%, 6.913, and 5.307, respectively. As the blood of modern industry, the lack of oil will cause the output of all societal sectors to suffer a negative impact. In addition to the obvious negative impact on industries with high energy tightness, the output of the GrainsCrops industry has also been significantly impacted, resulting in a 2.796% decline in industry output, mainly due to the decrease in the production in energy-intensive sectors such as fertilizers.

The energy ban on Russian industry output is mainly concentrated in the energy sector. At the beginning of the ban shown in Table 9, it led to a 14.105% drop in the output of the Russian coal industry. The escalation of the energy ban, it will have a significant impact on the output of Russian crude oil and crude oil products, resulting in a decline in output of 10.421% and 3.546%, respectively. From the perspective of changes in the output of other industries in Russia, in addition to the significant negative impact on the energy industry, the effect on the output of other sectors of society is small, and even the output of the industry has a positive promotion effect. Most notably, the output of energy-intensive industries increased by 14.295% in scenario S6. The main reason for this phenomenon is that when Russia's energy exports encounter obstacles, in addition to opening up export markets outside the EU, it will also moderately reduce the output and export quota of energy resources and use the domestic industrial system to produce and process restricted commodities such as coal and crude oil through energy-intensive industrial systems such as chemical industry, and convert them into other forms of export, to circumvent the international community's ban on energy exports.

4.3.3. Impact on greenhouse gas emissions

As shown in Table 10, in the short term, energy sanctions will reduce greenhouse gas emissions. Simulations of GTAP10-E data show that world CO2 levels have decreased significantly with the escalation of energy sanctions, with world CO2 emissions falling by 10.053% in scenario S6 compared to pre-sanction levels.

Table 8
Changes in EU sector output.

EU	S1	S2	S3	S4	S5	S6
GrainsCrops	−0.120	−0.139	−0.151	−2.072	−2.151	−2.796
MeatLstk	−0.061	−0.091	−0.111	−0.274	−0.366	−0.455
ProcFood	−0.068	−0.109	−0.137	−0.248	−0.373	−0.437
NRS	−0.049	−0.066	−0.077	−0.369	−0.422	−0.496
Coal	5.192	5.575	5.893	6.839	7.838	9.434
Oil	−0.327	−0.482	−0.585	4.610	4.436	3.006
Gas	−0.632	3.951	3.799	4.373	4.948	5.489
Oil_pcts	−0.625	−0.563	−0.528	−5.178	−5.300	−5.307
Electricity	−0.564	−0.670	−0.741	−3.527	−4.223	−5.389
En_Int_ind	−0.415	−0.707	−0.898	−4.753	−5.648	−6.913
TransComm	−0.055	−0.074	−0.086	−1.418	−1.485	−1.854
Oth_ind_ser	−0.058	−0.072	−0.081	0.029	−0.011	0.033

Table 9
Changes in RUS sector output.

RUS	S1	S2	S3	S4	S5	S6
GrainsCrops	0.204	0.391	0.512	1.916	2.490	2.786
MeatLstk	0.073	−0.047	−0.122	0.226	−0.127	−0.202
ProcFood	0.145	0.163	0.176	1.247	1.313	1.425
NRS	−0.065	0.022	0.076	1.406	1.677	1.875
Coal	−14.105	−13.625	−13.445	−9.666	−8.259	−7.506
Oil	0.112	0.339	0.485	−10.097	−9.510	−10.421
Gas	0.255	−0.781	−1.434	3.578	0.489	0.181
Oil_pcts	−0.028	0.049	0.097	−4.502	−4.325	−3.546
Electricity	−0.038	0.093	0.175	1.413	1.819	2.073
En_Int_ind	0.434	1.123	1.564	10.672	12.822	14.295
TransComm	−0.004	−0.111	−0.179	0.695	0.383	0.376
Oth_ind_ser	0.123	0.126	0.129	0.949	0.968	1.043

Energy sanctions have a heterogeneous impact on the degree of carbon reduction in EU member states. The more dependent member states are on Russian energy; the more their carbon emissions will fall as energy restrictions come into effect. Among them, EUhdR countries fell by 4.139% in scenario S6 and EUldR by only 1.707%. Russia's carbon emissions, on the other hand, have continued to rise with the increase in sanctions, with a maximum increase of 2.406%. This is related to Russia's adjustment of industrial output to solve its domestic demand and foreign trade after trade restrictions. The decline in the world's carbon emission level is mainly due to the decrease in carbon emissions in the European Union, but this downward trend is not sustainable. The short-term energy gap has forced the EU to reduce carbon emissions in ways that limit economic activity and reduce residents' energy demand. In solving its energy woes and increasing the share of renewable energy, the EU may choose a cheaper but quicker approach: restart coal-fired thermal power plants that have been phased out. And this phenomenon is happening in most parts of the European Union. A vital part of the EU's energy transition package is using cheap natural gas in Russia. Without the support of Russian gas as a transition, it is difficult to achieve its transition goals by relying on renewable energy alone. If the energy game between the EU and Russia is not adequately resolved in the medium and long term, the purposes of a worldwide climate agreement will not be achieved.

5. Conclusion

The geopolitical conflict caused by the Russian–Ukrainian war was not a dispute between the two countries in the first place. Through direct war between the two sides and indirect economic sanctions from the European Union, the world's major economies have been directly involved in the vortex of conflict, especially when the world economy is recovering from the impact of the epidemic. As the main participants in this geopolitical conflict, the economic war between the European Union and Russia revolves around energy sanctions and countersanctions. This study analyzes the impact of geopolitical conflicts on the EU, Russia, and global energy trade. We use the GTAP-E model to quantitatively evaluate the direct and transfer effects of the EU-Russia energy game by estimating and setting six scenario assumptions about the degree of energy trade between the EU and Russia. The research conclusions are mainly as follows:

1. Energy sanctions triggered by geopolitical conflicts will be a lose–lose or even multiple losses outcome. By simulating the different degrees of disruption in energy trade between the EU and Russia, as the energy game escalates, the economies of both sides will suffer serious negative shocks. In the scenario of a complete disruption of energy trade, the macroeconomic loss in the EU reached 1.488%, the Russian economy reached 4.801%, and the world economy experienced a decline of 2.895%. Under the trend of global trade integration, the energy game between major economies caused by geopolitical conflicts has led to the reshaping of the world energy trade structure. Energy sanctions will push up energy prices worldwide and increase the cost of energy trade between the two sides. It can be seen from the relative changes in terms of trade and import and export trade that the terms of trade of both sides of the sanctions will deteriorate to varying degrees, with the terms of trade organized by the EU falling by 2.033% and the decline in Russia's terms of trade reaching 5.151%. At the same time, the imports, and exports of the two major economies will also adjust significantly, with the EU showing a sharp decline in imports and Russia showing a decline in exports. From the perspective of economic development, the

Table 10
Changes in CO2 emissions.

CO2	S1	S2	S3	S4	S5	S6
EUhdR	0.756	0.546	0.411	−2.144	−2.774	−4.139
EUmdR	−0.347	−0.529	−0.648	−2.716	−3.287	−3.554
EUldR	−0.148	−0.186	−0.212	−1.466	−1.590	−1.707
UK	0.060	0.064	0.067	−0.133	−0.124	−0.192
TUR	0.010	−0.028	−0.052	0.040	−0.072	−0.106
RUS	−0.046	0.046	0.104	1.835	2.131	2.406
CHN	−0.005	0.004	0.010	−0.096	−0.068	−0.070
IND	−0.005	−0.009	−0.012	−0.084	−0.097	−0.106
USA	−0.022	0.042	0.082	−0.275	−0.087	−0.071
EEU	−0.049	−0.612	−0.978	0.309	−1.318	−1.644
XMN	0.020	−0.054	−0.101	0.023	−0.195	−0.242
OPEC	0.012	0.011	0.011	−0.109	−0.111	−0.116
ASEAN	0.008	0.030	0.044	0.022	0.090	0.109
ROW	−0.009	−0.147	−0.234	−0.110	−0.523	−0.623
WORLD	0.235	−0.823	−1.509	−4.902	−8.026	−10.053

economic game between the EU and Russia caused by the Russia-Ukraine conflict has caused a significant negative impact on the world economy, resulting in multiple losses.

2. Geopolitical conflicts will reshape the structure of world energy trade. As a strategic substance in the era of the industrial economy, energy is much more critical than other commodities. Energy security not only affects economic development but also is the foundation of social security and stability. By simulating energy trade between the EU and Russia, the strict implementation of the energy ban will directly threaten the EU's energy security. The energy sanctions between the two sides are divided by whether to sanction crude oil and crude oil products. Sanctions on Russian crude oil and crude oil products will directly affect the energy trade structure of EU member states and cause strong countermeasures from Russia. After the sanctions on Russian crude oil and crude oil products, the EU must look for alternatives to Russian energy worldwide. The more significant phenomenon is that OPEC, XMN, and ROW account for a substantial increase in the EU's energy structure. The calculation of the energy trade transfer factor also supports this conclusion. At the same time, after the setback in energy exports to the EU, Russia will turn its market to countries such as China, India, and the ASEAN Organization. In the model, both the EU and Russia can reduce the impact of the energy ban on both sides by rapidly adjusting their import and export destinations. Still, due to geopolitical games and high levels of world economic uncertainty, this energy trade structural adjustment may not have the desired effect in the short term.

3. The level of social welfare and ecology should not become victims of political games. In geopolitical conflicts, the inhabitants become the bearers of the outcome of political games and wars. Russia's war against Ukraine and the energy ban imposed by the European Union have caused immeasurable losses to residents. The most direct impact of the energy ban on residents of EU member states is the increase in energy prices. The difference in the dependence of EU member states on Russian energy has led to a large difference in the impact of energy bans on residents. In the S6 situation, the electricity prices of EUhdR, EUmdR and EUldR increased by 10.12%, 6.95%, and 6.77% respectively, increasing the cost of electricity prices for residents and causing greater survival pressure on the residents at the bottom. Energy shortages will also affect output across sectors in the EU. The direct effect of the decline in total social output is the loss of residents' welfare level, and the indirect effect is the decline in carbon emissions of the whole society. While carbon emissions will decline in the short term due to restrictions on economic activity, in the medium to long term, it will have a profound impact on the world's energy transition, and governments may make energy security a strategic goal and abandon the Sustainable Development Goals.

4. Reshaping energy trade networks will directly affect the achievement of Sustainable Development Goals. The terms of energy trade directly determine the stability of international energy prices, and energy consumption prices directly affect the production costs of enterprises. The major countries that have announced the implementation of the Sustainable Development Goals have all involved a transformation of their energy consumption structure, based on the basic premise that relatively cheap and clean natural gas is used as a transitional energy source. The uncertainty of world energy trade caused by the energy game directly pushes up energy prices worldwide. In an economic environment with high energy prices, the fiscal and monetary policies of governments around the world to promote sustainable development at the macro level will be greatly reduced, while the micro-enterprise level will be driven by its own interests and risks to reduce investment in green innovation. Therefore, carbon emissions from short-term economic downturns do not contribute to medium- and long-term sustainable development.

This study bridges the gap between geopolitical theory and energy trade practice. However, this paper, like similar literature, is limited by the analytical framework of the model and fails to study the logic between geopolitics, energy trade, and sustainable development goals at the micro level. This study only studies the changes in energy games caused by geopolitical conflicts on economic growth, aggregate output, energy trade diversion effects, social welfare losses, and carbon emission levels at the macro level. In the short term, at the cost of economic losses, the carbon emission target has been exceeded, but a study of the production level of micro-enterprises shows that the instability of energy trade has a very negative impact on the medium- and long-term green transformation of enterprises. Therefore, in the future, we will conduct a more detailed micro-level study on the relationship between energy trade and sustainable development goals, to provide a more complete theoretical and practical basis for sustainable development.

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CRediT authorship contribution statement

Yangyang Chen: Conceptualization, Methodology, Software, Investigation, Formal analysis, Writing – original draft. **Jiexin Jiang:** Data curation, Writing – original draft. **Lei Wang:** Funding acquisition, Resources, Supervision, Writing – review & editing. **Ruisong Wang:** Visualization, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

References

Ahmed, Y.N., Delin, H., Reeberg, B.G., Shaker, V., 2020. Is the RCEP a cornerstone or just collaboration? Regional general equilibrium model based on GAMS. J. Korea Trade 24 (1), 171–207. http://dx.doi.org/10.35611/JKT.2020.24.1.171.

Ang, B.W., Choong, W.L., Ng, T.S., 2015. Energy security: Definitions, dimensions and indexes. Renew. Sustain. Energy Rev. 42, 1077–1093. http://dx.doi.org/10.1016/J.RSER.2014.10.064.

Antonakakis, N., Gupta, R., Kollias, C., Papadamou, S., 2017. Geopolitical risks and the oil-stock nexus over 1899–2016. Finance Res. Lett. 23, 165–173. http://dx.doi.org/10.1016/J.FRL.2017.07.017.

Apergis, N., Aslan, A., Aye, G.C., Gupta, R., 2015. The asymmetric effect of oil price on growth across US States. Energy Explor. Exploit. 33 (4), 575–590. http://dx.doi.org/10.1260/0144-5987.33.4.575.

Bompard, E., Carpignano, A., Erriquez, M., Grosso, D., Pession, M., Profumo, F., 2017. National energy security assessment in a geopolitical perspective. Energy 130, 144–154. http://dx.doi.org/10.1016/J.ENERGY.2017.04.108.

Chepeliev, M., Hertel, T., van der Mensbrugghe, D., 2022. Cutting Russia's fossil fuel exports: Short-term economic pain for long-term environmental gain. World Economy http://dx.doi.org/10.1111/TWEC.13301.

Cui, Lianbiao, Lei, Zhui, Malin, Song, 2018. The economic evaluation of China-US tarde frictions. J. Finance Econ. 44 (12), 4–17. http://dx.doi.org/10.16538/j.cnki.jfe.2018.12.001.

Cui, L.B., Song, M.L., 2017. Designing and forecasting the differentiated carbon tax scheme based on the principle of ability to pay. Asia-Pac. J. Oper. Res. 34 (1), http://dx.doi.org/10.1142/S0217595917400048.

Cunado, J., Gupta, R., Lau, C.K.M., Sheng, X., 2019. Time-varying impact of geopolitical risks on oil prices. 31, (6), pp. 692–706. http://dx.doi.org/10.1080/10242694.2018.1563854.

Dutta, A., Dutta, P., 2022. Geopolitical risk and renewable energy asset prices: Implications for sustainable development. Renew. Energy 196, 518–525. http://dx.doi.org/10.1016/J.RENENE.2022.07.029.

Escribano, G., 2018. The geopolitics of renewable and electricity cooperation between Morocco and Spain. 24, (5), pp. 674–681. http://dx.doi.org/10.1080/13629395.2018.1443772.

Freeman, D., 2018. China and renewables: The priority of economics over geopolitics. Lect. Notes Energy 61, 187–201. http://dx.doi.org/10.1007/978-3-319-67855-9_7.

Gong, X., Sun, Y., Du, Z., 2022. Geopolitical risk and China's oil security. Energy Policy 163, 112856. http://dx.doi.org/10.1016/J.ENPOL.2022.112856.

Humphreys, M., 2005. Natural resources, conflict, and conflict resolution: Uncovering the mechanisms. J. Confl. Resolut. 49 (4), 508–537. http://dx.doi.org/10.1177/0022002705277545.

Hurd, A.J., Kelley, R.L., Eggert, R.G., Lee, M.H., 2012. Energy-critical elements for sustainable development. MRS Bull. 37 (4), 405–410. http://dx.doi.org/10.1557/MRS.2012.54.

Inshakov, O.v., Bogachkova, L.Y., Popkova, E.G., 2019. The transformation of the global energy markets and the problem of ensuring the sustainability of their development. Lect. Notes Netw. Syst. 44, 135–148. http://dx.doi.org/10.1007/978-3-319-90966-0_10/COVER.

Itakura, K., 2014. Impact of liberalization and improved connectivity and facilitation in ASEAN. J. Asian Econ. 35, 2–11. http://dx.doi.org/10.1016/J.ASIECO.2014.09.002.

Jacobson, M.Z., Delucchi, M.A., Bauer, Z.A.F., Goodman, S.C., Chapman, W.E., Cameron, M.A., Bozonnat, C., Chobadi, L., Clonts, H.A., Enevoldsen, P., Erwin, J.R., Fobi, S.N., Goldstrom, O.K., Hennessy, E.M., Liu, J., Lo, J., Meyer, C.B., Morris, S.B., Moy, K.R., et al., 2017. 100% clean and renewable wind, water, and sunlight all-sector energy roadmaps for 139 countries of the world. Joule 1 (1), 108–121. http://dx.doi.org/10.1016/J.JOULE.2017.07.005.

Ji, Q., Liu, B.Y., Fan, Y., 2019a. Risk dependence of CoVaR and structural change between oil prices and exchange rates: A time-varying copula model. Energy Econ. 77, 80–92. http://dx.doi.org/10.1016/J.ENECO.2018.07.012.

Ji, Q., Zhang, H.Y., Zhang, D., 2019b. The impact of OPEC on East Asian oil import security: A multidimensional analysis. Energy Policy 126, 99–107. http://dx.doi.org/10.1016/J.ENPOL.2018.11.019.

Kruyt, B., van Vuuren, D.P., de Vries, H.J.M., Groenenberg, H., 2009. Indicators for energy security. Energy Policy 37 (6), 2166–2181. http://dx.doi.org/10.1016/J.ENPOL.2009.02.006.

Lee, C.C., Lee, C.C., Ning, S.L., 2017. Dynamic relationship of oil price shocks and country risks. Energy Econ. 66, 571–581. http://dx.doi.org/10.1016/J.ENECO.2017.01.028.

Liu, J., Ma, F., Tang, Y., Zhang, Y., 2019. Geopolitical risk and oil volatility: A new insight. Energy Econ. 84, http://dx.doi.org/10.1016/J.ENECO.2019.104548.

Liu, Y., Yu, L., Yang, C., Li, Z., 2021. Heterogeneity of the impact of geopolitical events on energy trade: an empirical study based on regression discontinuity design. Front. Environ. Sci. 9, 322. http://dx.doi.org/10.3389/FENVS.2021.722910/BIBTEX.

Mahlstein, K., McDaniel, C., Schropp, S., Tsigas, M., 2022. Estimating the economic effects of sanctions on russia: an allied trade embargo. World Economy http://dx.doi.org/10.1111/TWEC.13311.

Noguera-Santaella, J., 2016. Geopolitics and the oil price. Econ. Model. 52, 301–309. http://dx.doi.org/10.1016/J.ECONMOD.2015.08.018.

Pierri, E., Binder, O., Hemdan, N.G.A., Kurrat, M., 2017. Challenges and opportunities for a European HVDC grid. Renew. Sustain. Energy Rev. 70, 427–456. http://dx.doi.org/10.1016/J.RSER.2016.11.233.

Raman, S., 2013. Fossilizing renewable energies. Sci. Cult. 22 (2), 172–180. http://dx.doi.org/10.1080/09505431.2013.786998.

Salameh, M.G., 2014. Where is the crude oil price headed? SSRN Electron. J. http://dx.doi.org/10.2139/SSRN.2502056.

Scholten, D., Bosman, R., 2016. The geopolitics of renewables; exploring the political implications of renewable energy systems. Technol. Forecast. Soc. Change 103, 273–283. http://dx.doi.org/10.1016/J.TECHFORE.2015.10.014.

Smith Stegen, K., 2018. Redrawing the geopolitical map: International relations and renewable energies. Lect. Notes Energy 61, 75–95. http://dx.doi.org/10.1007/978-3-319-67855-9_3.

Su, C.W., Khan, K., Umar, M., Zhang, W., 2021. Does renewable energy redefine geopolitical risks? Energy Policy 158, http://dx.doi.org/10.1016/J.ENPOL.2021.112566.

Vakulchuk, R., Overland, I., Scholten, D., 2020. Renewable energy and geopolitics: A review. Renew. Sustain. Energy Rev. 122, http://dx.doi.org/10.1016/J.RSER.2019.109547.

Vasylkivskyi, D., Matiukh, S., Matviiets, O., Lapshyn, I., Babenko, V., 2020. The consequences of the military conflict in eastern ukraine, its impact on international investment attractiveness, economic and demographic development in ukraine. Res. World Econ. 11 (4), 81–89. http://dx.doi.org/10.5430/RWE.V11N4P81.

Yang, Y., Li, J., Sun, X., Chen, J., 2014. Measuring external oil supply risk: A modified diversification index with country risk and potential oil exports. Energy 68, 930–938. http://dx.doi.org/10.1016/J.ENERGY.2014.02.091.

Zhang, Z., He, M., Zhang, Y., Wang, Y., 2022. Geopolitical risk trends and crude oil price predictability. Energy 258, 124824. http://dx.doi.org/10.1016/J.ENERGY.2022.124824.