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The impact of EU-US sanctions on China-Russia energy trade in the post-2014 geopolitical context: a gravity model perspective

S. Lin ✉, N. B. Davidson
Ural Federal University, Ekaterinburg, Russia; ✉ 1249821454@qq.com

ABSTRACT
Relevance. China-Russia bilateral energy trade increased from $29.9 billion in 2014 to $95.0 billion in 2023, yet existing research lacks systematic analysis of the differentiated impacts of sanctions imposed in 2014 and 2022 across coal, oil and natural gas markets.
Research Objective. This study systematically evaluates the differentiated impacts of EU-US sanctions imposed in 2014 and 2022 on China-Russia energy trade across trade flows and energy categories.
Data and Methods. Using China-Russia energy trade data from 1994 to 2023 (UN Comtrade), we construct an extended gravity model that incorporates governance quality and dual sanction variables informed by trade diversion theory. The model is estimated using Ordinary Least Squares with heteroskedasticity-robust standard errors, alongside stationarity and cointegration tests.
Results. The 2014 sanctions caused a 97% decline in energy trade, whereas the 2022 sanctions led to a 131% increase, illustrating a dynamic reversal. The effects of sanctions are asymmetric: 2022 measures suppressed exports while boosting imports. Sensitivity also varies across energy types: oil trade is the most vulnerable, natural gas remains resilient due to pipeline infrastructure and long-term contracts, and coal responds within capacity limits. Improvements in Russian governance and exchange rate appreciation positively influence trade, with stronger effects on imports.
Conclusions. This study provides new empirical evidence for trade diversion theory and sanctions economics, demonstrating that the impact of sanctions depends on infrastructure development, contract structures, and governance quality. To reduce the impact of sanctions, it is necessary to tailor risk prevention to each energy type, strengthen governance, and coordinate financial systems. The findings also highlight the need for Russia to diversify trade and reduce reliance on natural resources.

KEYWORDS
EU-US sanctions, China-Russia energy trade, gravity model of trade, differentiated effects of sanctions; energy categories, sensitivity to sanctions

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Влияние санкций ЕС и США на торговлю энергоресурсами между Китаем и Россией в геополитическом контексте после 2014 года: перспектива гравитационной модели

Ш. Линь ✉, Н. Б. Давидсон
Уральский федеральный университет, Екатеринбург, Россия; ✉ 1249821454@qq.com

АННОТАЦИЯ
Актуальность. Двусторонняя торговля энергоресурсами между Китаем и Россией увеличилась с 29,9 млрд долларов в 2014 году до 95,0 млрд долларов в 2023 году, однако существующие исследования не содержат систематического анализа дифференцированного воздействия санкций, введенных в 2014 и 2022 годах, на рынки угля, нефти и природного газа.
Цель исследования. Данное исследование оценивает дифференцированное воздействие санкций ЕС и США, введенных в 2014 и 2022 годах,

КЛЮЧЕВЫЕ СЛОВА
санкции ЕС и США, энергетическая торговля Китая и России, гравитационная модель торговли, дифференцированные эффекты санкций, катего-

на торговлю энергоресурсами между Китаем и Россией в разрезе торговых потоков и категорий энергоресурсов.
Данные и методы. Используя данные UN Comtrade за 1994–2023 гг., мы строим расширенную гравитационную модель, включающую качество управления и переменные санкций, на основе теории переориентации торговли. Применяется метод наименьших квадратов с устойчивыми стандартными ошибками и тесты на стационарность и коинтеграцию.
Результаты. Санкции 2014 года привели к снижению торговли на 97 %, а санкции 2022 года — к росту на 131 %, демонстрируя динамический разворот. Санкции асимметричны: санкции 2022 года подавляют экспорт, но стимулируют импорт. Категории энергоресурсов демонстрируют различную чувствительность: нефть показывает наивысшую уязвимость, природный газ проявляет устойчивость благодаря трубопроводной инфраструктуре и долгосрочным контрактам, а уголь демонстрирует ограниченность из-за мощностей. Улучшение управления и повышение курса положительно влияют на торговлю, в большей мере воздействуя на импорт.
Выводы. Исследование предоставляет эмпирические доказательства для теории переориентации торговли и экономики санкций, демонстрируя, что воздействие санкций зависит от развития инфраструктуры, контрактных структур и качества управления. Создание дифференцированных систем предотвращения рисков, повышение эффективности управления и углубление финансовой координации снижают воздействие санкций. Результаты подчеркивают необходимость снижения зависимости России от природных ресурсов и диверсификации торговли.

рии энергоресурсов, чувствительность к санкциям

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2014年后地缘政治背景下欧美制裁对中俄能源贸易的影响：引力模型视角

林胜府 ✉, **戴维森·娜塔莉亚·鲍里索夫娜**
乌拉尔联邦大学，叶卡捷琳堡，俄罗斯； ✉ 1249821454@qq.com

摘要
现实性：中俄双边能源贸易从2014年的299亿美元增长至2023年的950亿美元，但现有研究缺乏对2014年与2022年制裁差异化影响的系统分析，特别是在煤炭、石油和天然气市场方面存在研究空白。
研究目标：本研究旨在系统评估2014年和2022年欧美制裁对中俄能源贸易在不同贸易流向和能源类别上的差异化影响。
数据与方法：我们使用联合国商品贸易统计数据库1994–2023年中俄能源贸易数据，结合贸易转移理论构建包含治理质量和双重制裁变量的扩展引力模型。方法上采用异方差稳健标准误的普通最小二乘法（OLS）回归，并结合平稳性检验和协整检验。
研究结果：2014年制裁导致能源贸易下降97 %，而2022年制裁促进了131 %的增长，表明制裁效果的动态逆转。制裁对进出口产生非对称影响，2022年制裁抑制出口但促进进口。不同能源类别对制裁敏感度不同：石油贸易表现出最高脆弱性，天然气贸易因管道基础设施和长期合同而显示韧性，煤炭贸易则因运力限制而受限。俄罗斯治理改善和汇率升值对贸易产生积极影响，且对进口的影响更强。
结论与启示：本研究为贸易转移理论和制裁经济学提供了新的实证证据，表明制裁效果取决于基础设施发展、合同结构和治理质量。我们建议根据能源类别的制裁敏感度构建差异化风险防范体系，提升治理效率，深化金融协调。研究结果强调俄罗斯需要减少资源依赖并实现贸易多元化。

关键词
欧美制裁；中俄能源贸易；贸易引力模型；制裁的差异化影响；能源品类；制裁敏感度

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Introduction

In the 21st century the frequency of use and scope of sanctions have substantially expanded, and academic research on economic sanctions has surged to match this tendency (Hufbauer & Jung, 2021; Morgan et al., 2023; Drezner, 2024; Felbermayr et al., 2025). However, existing literature mostly focuses on the unidirectional impact of sanctions on sanctioned countries (Felbermayr et al., 2020), or is limited to bilateral interactions between sanctioning and sanctioned countries. Therefore, it is necessary to analyze the impact of sanctions on bilateral trade between sanctioned countries and third countries and their structural adaptation mechanisms, thereby providing empirical evidence for trade security strategy design under geopolitical risks.

Following the 2014 Ukraine crisis and the 2022 Russia-Ukraine conflict, the EU and US imposed unprecedented energy sanctions on Russia, including bans on crude oil imports, asset freezes, and oil price caps (Chen et al., 2023; Batzella, 2024). These measures have reshaped global energy trade and triggered regional supply chain restructuring. China-Russia energy trade, as a major component of global flows, offers a key case for studying the impact of sanctions.

From a supply-demand perspective, in 2023, Russia accounted for 11.5% of global oil production and held 14.4% of global natural gas reserves, making it the world's third-largest oil exporter and second-largest natural gas exporter[1]. China has maintained its position as the world's largest energy importer for 15 consecutive years since 2010, with crude oil external dependence expected to reach 78.4% in 2025 and natural gas dependence exceeding 44%[2]. This structural interdependence provides a foundation for bilateral energy cooperation.

From the perspective of trade scale dynamics, China-Russia energy trade value increased from $29.9 billion in 2014 to $95.0 billion in 2023, with an average annual growth rate of 21.8%[3], significantly strengthening bilateral energy trade interdependence. After 2014, long-term agreements such as the China-Russia Eastern Route Natural Gas Purchase and Sale Agreement marked the start of an institutionalized phase in bilateral energy cooperation (Paik, 2015).

From the perspective of regional impact, the deepening of China-Russia energy cooperation directly influences energy pricing mechanisms in the Asia-Pacific. In response to sanctions, Russia accelerated its "Turn to the East" strategy, leading to a surge in China-Russia energy trade. China's crude oil imports from Russia reached $62.1 billion in 2022, nearly 50% higher than in 2021[4].

Finally, from the perspective of global impact, the spillover effects of EU-US energy sanctions on Russia on LNG and crude oil markets have also profoundly affected world energy security (Lambert et al., 2022).

Therefore, this study aims to systematically evaluate the differentiated impact mechanisms of EU-US sanctions imposed in 2014 and 2022 on China-Russia energy trade. Based on trade diversion theory, we construct an extended gravity model incorporating governance quality and dual sanction variables to verify the differentiated sanction effects across these two critical periods, and to reveal the heterogeneous characteristics of sanction effects across different trade flows and energy categories. This approach enables us to provide empirical evidence for trade security strategy design under geopolitical risks.

This research addresses five key tasks:

1) Reviewing the theoretical foundations of gravity model applications in energy trade and sanctions economics, and identifying existing research gaps;

2) Assessing the differentiated impacts of the 2014 Crimea crisis sanctions and the 2022 Russia-Ukraine conflict sanctions on China-Russia energy trade, and verifying how these effects vary across periods;

3) Analyzing the asymmetric effects of sanctions on China-Russia energy imports and exports, highlighting mechanisms such as payment risks and substitution effects;

4) Comparing the sensitivity of coal, oil, and natural gas to sanctions, and examining the moderating roles of logistics characteristics and contract structures;

5) Testing the buffering effects of improvements in Russian governance and changes in the RMB-RUB exchange rate on sanction shocks.

In international trade theories analyzing the impact of sanctions on trade, gravity models focus on quantifying the effects of sanctions on bilateral trade flows, while trade diversion theory specifically analyzes how sanctions lead to the reconfiguration of trade directions. Trade diversion

[1] Energy Institute (EI). (2024). Statistical Review of World Energy 2024. Retrieved from: https://www.energyinst.org/statistical-review (date of access: 02.06.2025).

[2] General Administration of Customs of China. (2025). China's customs statistics. Retrieved from: http://www.customs.gov.cn (date of access: 02.06.2025).

[3] UN Comtrade Database. (2025). United Nations Commodity Trade Statistics Database. Retrieved from: https://comtrade.un.org (date of access: 02.06.2025).

[4] UN Comtrade Database. (2025). United Nations Commodity Trade Statistics Database. Retrieved from: https://comtrade.un.org (date of access: 02.06.2025).

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theory argues that when normal trade routes are obstructed by political or economic barriers, trade will shift toward suboptimal but politically feasible alternative pathways. Haidar (2017)'s study on Iranian sanctions found that sanctions led to a significant redirection of Iranian exports toward non-sanctioning countries, validating the existence of export deflection phenomena. The integration of the gravity model with trade diversion theory offers a more effective explanation of how trade relationships between sanctioned countries and third parties evolve.

Drawing on the above-described theoretical framework, we propose three core hypotheses:

H1: EU-US sanctions on China-Russia energy trade demonstrate differential effects in 2014 and 2022, with 2014 sanctions producing short-term suppression effects due to infrastructure constraints, while 2022 sanctions trigger long-term promotion effects due to mature trade substitution networks.

H2: Sanctions have significantly asymmetric impacts on China-Russia energy imports and exports, with greater impact on imports than exports.

H3: The sanction sensitivity of different energy categories exhibits heterogeneity, with maritime-dependent energy (oil) greater than pipeline-dependent energy (natural gas), and greater than railway-dependent energy (coal).

To test the hypotheses, this study collected 30 years of time-series data from 1994 to 2023, adopted the gravity model of trade as the analytical framework, and developed an empirical system comprising nine models through three extensions of the traditional gravity model.

The structure of the study is as follows: Section 2 reviews the theoretical foundations of the gravity model, examines literature on energy trade and sanctions, and discusses the selection of governance quality and exchange rate variables, identifying existing research gaps. Section 3 describes data sources, processing methods, model specifications, and estimation techniques. Section 4 presents empirical results and analyzes underlying mechanisms. Finally, Section 5 summarizes the conclusions and offers policy implications.

Theoretical Framework

Theoretical Foundations of Gravity Model of Trade

Among international trade models, we selected the gravity model as the analytical framework for its theoretical and empirical suitability. While the Ricardian comparative advantage model explains the basic drivers of trade, it struggles to account for externalities such as institutional shocks and policy interventions. The Heckscher-Ohlin model highlights differences in factor endowments but offers limited insight into service and intermediate goods trade. New trade theory incorporates economies of scale and product differentiation but is often too complex for empirical analysis of bilateral flows. By contrast, the gravity model combines theoretical simplicity with strong empirical explanatory power and flexibility, allowing the integration of multidimensional variables such as exchange rates, institutional quality, and infrastructure.

The gravity model of trade has become the core analytical framework for explaining international bilateral trade flows since Tinbergen (1962) first proposed it. Anderson (1979) established a solid microeconomic foundation for the gravity model, proving that the model could be derived from expenditure system theory, while Anderson and van Wincoop (2003) further introduced multilateral resistance terms, solving the problem of traditional models ignoring third-country effects. Aitken (1973) and Leamer (1974) extended the explanatory variables of gravity model of trade by introducing dummy variables such as membership in the same trading bloc, preferential trade agreements, and trade barriers. Since then, increasingly more researchers have attempted to add different variables to traditional gravity model of trade to strengthen their application in solving various international trade problems. Head and Mayer (2014) further confirmed that gravity models have unique advantages in analyzing trade policy effects, particularly in quantifying the impacts of policy tools such as tariffs, non-tariff barriers, and sanctions. According to Yotov et al. (2016), the structural gravity model effectively addresses econometric challenges such as endogeneity, selection bias, and zero trade flows, making it well suited for analyzing complex geopolitical shocks

Special Characteristics of Energy Trade

Compared to general commodity trade, energy trade is characterized by high political sensitivity, strong infrastructure dependence, prevalence of long-term contracts, and high price volatility (Goldthau & Witte, 2010). These features pose unique challenges for extensions of the gravity model. Von Hirschhausen and Neumann (2008) note that the low price elasticity and high asset specificity of energy, such as irreversible investments in pipeline infrastructure, require models to account for long-term contracts and market structure variables. Additionally, the political nature of energy trade has led to the concept of "energy security partnerships," in which importing countries establish institutional ties with specific exporters to reduce supply risks (Al-Saidi, 2023; Novikau, 2023; Żuk & Żuk, 2022). These developments justify differentiating energy categories and including governance quality variables in this study. Furthermore, globalization and the rise of non-traditional trade barriers have prompted model extensions to incorporate factors such as institutional quality (Anderson & Marcouiller, 2002), exchange rate volatility (Abeysinghe & Yeok, 1998), and geopolitical shocks (Felbermayr et al., 2020).

Impact of Sanctions on International Trade

Sanctions, as a key policy tool in international relations, and their effects on international trade have long been a focus of academic research. Early studies primarily examined sanction effectiveness and economic costs, with Hufbauer et al. (1990)[5] pioneering a sanctions database and finding that only 34 % of cases achieved their intended policy goals. Economic sanctions, as non-market interventions, operate through three main mechanisms: price effects, substitution effects, and institutional restructuring effects (Hufbauer et al., 1990). Price effects arise from increased transaction costs, such as financial blockades that force buyers and sellers to use local currencies or barter, raising exchange rate risks (Crozet & Hinz, 2020). Substitution effects occur when sanctioned countries shift to new trade partners. Institutional restructuring effects emerge when sanctions compel countries to adjust trade rules, exemplified by Russia's creation of the SPFS payment system to bypass SWIFT restrictions.

In recent years, some studies have begun introducing sanction variables as resistance terms in gravity model of trade to conduct research on different topics. Khalid et al. (2024) analyzed the impact of sanctions on the environment using gravity model of trade, finding that most sanctions are detrimental to environmental quality improvement. Taralashvili (2024) used gravity model of trade containing sanction variables to study the impact of interstate soft conflicts on bilateral migration, finding that sanctions have persistent adverse effects on bilateral migration. Liu & Qiu (2024) used structural gravity models to explore the impact of international sanctions on food security and sustainable development goals, emphasizing the harm of international sanctions to food security and sustainable development.

Some studies have also begun focusing on the heterogeneous characteristics of sanction impacts. Afesorgbor (2019) distinguished between threatened sanctions and imposed sanctions, finding that the trade suppression effects of the threat stage are often greater than those of the implementation stage. Nguyen and Do (2021) incorporated economic sanctions and counter-sanctions as two dummy variables into Russia's import-export gravity model of trade. Their analysis results showed that sanctions and counter-sanctions led to declines in Russian exports and imports respectively. Gaur et al. (2023) further confirmed that the attenuation of sanction effects is closely related to the establishment of alternative trade routes.

Existing research mostly focuses on bilateral effects between sanctioning and sanctioned countries, with less attention to spillover effects on third countries. Sedrakyan (2022) used gravity model of trade to analyze and found that EU-US sanctions on Russia had significant negative spillover effects on trade between Russia and 27 transition economies. Carril-Caccia (2025) showed that sanctions led to a 13.5 % decline in cross-border merger and acquisition activities between sanctioning and sanctioned countries. However, these studies mainly focus on negative spillovers, with insufficient attention given to positive trade diversion effects.

Moderating Effects of Governance Quality and Exchange Rates in Trade

Institutional economics theory emphasizes that a good institutional environment is an important factor in reducing transaction costs and promoting international trade. The institutional change theory proposed by North (1990) argues that formal and informal institutions jointly influ-

[5] Hufbauer, G. C., Schott, J. J., & Elliott, K. A. (1990). Economic sanctions reconsidered: History and current policy (Vol. 1). Peterson Institute.

ence the behavioral choices of economic actors[6]. In the field of international trade, international trade flows may decrease due to increased transaction costs resulting from institutional deficiencies and poor governance quality (De Groot et al., 2005). Anderson and Marcouiller (2002) pointed out that institutional deficiencies play a suppressive role in trade no less than tariffs, and ignoring governance quality indicators would lead to biased results in typical gravity model of trade. Anderson and van Wincoop (2003) proved through introducing multilateral resistance terms that institutional friction can explain approximately 30 % of trade flow variation.

The Worldwide Governance Indicators (WGI), developed by the World Bank, are widely regarded as the standard measure of national governance quality (Kaufmann et al., 2010). D'Souza (2012) incorporated corruption indices from global governance indicators into a gravity model of trade and found that the 1997 OECD Anti-Bribery Convention indirectly raised the costs of trading with high-corruption importing countries, reducing signatory exports to these countries while increasing exports to low-corruption countries. Gani and Scrimgeour (2016) used the gravity model with WGI data and showed that good governance in Asian countries positively affected New Zealand's trade. Hussain et al. (2021) analyzed 51 Belt and Road countries and found that governance quality significantly influences renewable energy investment, moderated by trade openness. However, these studies do not examine the role of governance quality in trade under sanction conditions.

Traditional elasticity theory holds that domestic currency depreciation promotes exports and suppresses imports, while appreciation has the opposite effect, but empirical research finds this relationship does not always hold. Abeysinghe and Yeok (1998) showed that when export ratios are high, exchange rate appreciation's promotion effect on imports is usually greater than its suppression effect on exports, with this asymmetry stemming from importers having stronger price-setting power. At the same time, lower import prices can reduce domestic production costs, potentially offsetting the negative impact of currency appreciation on exports. In China-Russia trade, the promotion of RMB-RUB direct settlements may have altered exchange rate transmission mechanisms, but empirical research on this effect remains limited.

Limitations of Existing Research

The existing literature has three main shortcomings. First, theoretically, most sanction studies rely on static frameworks, overlooking the dynamic evolution of sanction effects and externalities such as governance improvements and exchange rate volatility. In particular, the differentiated impacts of the 2014 and 2022 Russian sanctions lack adequate theoretical explanation. Second, methodologically, studies often rely on cross-sectional or short-term panel data, limiting their ability to capture long-term effects and adaptive responses. Many analyses focus on total trade flows, ignoring heterogeneous effects across commodity categories and trade directions. Finally, empirically, research on sanctions' effects on third-country trade is limited, especially in the energy sector. For major bilateral relationships like China-Russia, there is a lack of detailed analysis of category heterogeneity, period-specific impacts, and the role of governance quality improvements and bilateral local currency settlement mechanisms.

Method and Data

Research Design and Analytical Framework

This study employs a quantitative analysis method based on an extended gravity model to systematically evaluate the different impact mechanisms of EU-US sanctions in 2014 and 2022. The study followed a five-step procedure. First, comprehensive data from 1994 to 2023 were collected from authoritative international databases. Second, the dataset was log-transformed, tested for stationarity, and cleaned for missing values. Third, econometric models were constructed by incorporating sanctions, governance, and exchange rate variables into the traditional gravity model framework. Fourth, the models were estimated using ordinary least squares and subjected to robustness tests. Finally, the differentiated impacts of the 2014 and 2022 sanctions and their heterogeneous mechanisms were analyzed based on regression results.

Data Source and Processing

We collected annual time series data from 1994 to 2023, covering variables including Chi-

[6] North, D.C. (1990). Institutions, institutional change and economic performance. Cambridge University.

Table 1

Variable definitions and data sources

Name	Definition and measurement	Data sources
lnTotal_Trade	Logarithm of China-Russia energy trade volume	UN Comtrade
lnTotal_Exp	Logarithm of China's energy exports to Russia	UN Comtrade
lnTotal_Imp	Logarithm of China's energy imports from Russia	UN Comtrade
lnCoal_Exp	Logarithm of China's coal exports to Russia	UN Comtrade
lnPetro_Exp	Logarithm of China's oil exports to Russia	UN Comtrade
lnGas_Exp	Logarithm of China's natural gas exports to Russia	UN Comtrade
lnCoal_Imp	Logarithm of China's coal imports from Russia	UN Comtrade
lnPetro_Imp	The logarithm of China's oil imports from Russia	UN Comtrade
lnGas_Imp	Logarithm of China's natural gas imports from Russia	UN Comtrade
lnGDP	Logarithm of the product of China and Russia's GDP (in current US dollars) (Aksenov, et al.,2023)	World Bank WDI[8]
lnRMB_RUB	Logarithm of the annual average of the RMB/RUB exchange rate	IMF IFS database[9]
lnRGE	Quality of governance in Russia (logarithm of government effectiveness index + 1)	World Bank WGI[10]
Sanc2014	2014 sanctions dummy variable (after sanction = 1, otherwise = 0)	GSDB
Sanc2022	2022 sanctions dummy variable (after sanction = 1, otherwise = 0)	GSDB

Source: Compiled by the authors

na-Russia categorized energy trade volumes, GDP, Russian government efficiency index, and RMB-RUB exchange rates. Energy trade data are classified based on SITC codes: coal (32), oil (33), and natural gas (34). To distinguish the heterogeneous impacts of 2014 sanctions and 2022 sanctions on China-Russia energy trade, we construct two sanction dummy variables based on the Global Sanctions Database (GSDB)[7], representing post-2014 Crimea crisis sanctions and post-2022 Russia-Ukraine conflict sanctions respectively. We use two separate variables rather than a single sanction variable because the two rounds of sanctions differ significantly in intensity, scope, and targets, and sanction effects may undergo structural changes over time, requiring separate identification. The specific variable definitions and data sources are shown in Table 1.

In the application of gravity model of trade, researchers typically take logarithms of both sides of the model to linearize the model and reduce outlier phenomena in the data, thereby making the model easier to analyze while improving model fit and predictive accuracy (Siliverstovs & Schumacher, 2009). Since zero and negative values cannot be logarithmically transformed, data preprocessing is required. In the case of zero Chinese natural gas exports to Russia from 1994–2004, this reflects the actual trade situation (China-Russia natural gas trade had not yet commenced at that time). To achieve logarithmic transformation, these zero values were set to 0.000001. For random missing values in trade volumes in individual years, we employed linear interpolation. For the case of negative values in the Russian government efficiency index, we added 1 to the index values for each year before performing logarithmic transformation.

Table 2 presents the descriptive statistics of the variables. Except for lnRGE, all other variables exhibit negative skewness, indicating left-skewed distributions with a higher frequency of smaller values. These left-skewed distribution are mainly due to the deepening of China-Russia energy trade, the depreciation of the ruble, and the fluctuation of Russia's GDP under EU-US sanctions, which has led to higher values in some post-sanc-

[7] The Global Sanction Database (GSDB) (2025). Drexel University. Retrieved from: https://www.globalsanctionsdatabase.co (date of access: 02.06.2025).

[8] World development indicators (2025). World Bank. Retrieved from: https://datatopics.worldbank.org/world-development-indicators/ (date of access: 02.06.2025).

[9] Dataset: Exchange Rates (ER) (2025). IMF DATA. Retrieved from: https://data.imf.org/en/Data-Explorer?datasetUrn=IMF. STA: ER (4.0.1) (date of access: 02.06.2025).

[10] Worldwide Governance Indicators (2024). World Bank. Retrieved from: https://www.govindicators.org (date of access: 02.06.2025).

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Table 2

Descriptive statistics

Data name	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Obs
lnTotal_Trade	22.538	23.106	25.278	18.953	2.010	–0.544	1.906	30
lnTotal_Exp	18.485	18.757	19.743	15.154	1.099	–1.273	4.500	30
lnTotal_Imp	22.497	23.087	25.275	18.565	2.059	–0.570	1.947	30
lnCoal_Exp	13.285	14.281	17.071	7.410	2.323	–0.918	3.174	30
lnPetro_Exp	18.414	18.748	19.743	14.014	1.256	–1.744	6.516	30
lnGas_Exp	1.739	9.929	13.393	–13.82	12.090	–0.527	1.312	30
lnCoal_Imp	18.886	19.804	23.391	8.500	3.370	–0.920	3.931	30
lnPetro_Imp	22.412	23.047	24.950	18.492	2.011	–0.632	1.982	30
lnGas_Imp	15.907	17.470	23.183	4.263	4.950	–0.470	2.317	30
lnGDP	56.564	57.193	58.964	53.722	1.898	–0.298	1.429	30
lnRMB_RUB	1.356	1.416	2.487	–0.887	0.938	–0.993	3.221	30
lnRGE	–0.632	–0.618	0.024	–1.246	0.334	0.014	2.364	30

Source: compiled by the authors using UN Comtrade data (Retrieved from: https://comtrade.un.org (date of access: 02.06.2025)).

tion years. Therefore, the left-skewed distribution of these variables is closely related to geopolitical risks and economic fluctuations and has important economic significance.

Model Building

Based on the aforementioned theoretical analysis and variable selection, we construct the following extended gravity model:

$$InTrade_t = \alpha + \beta_1 InGDP_t + \\ + \beta_2 InRMB\_RUB_t + \beta_3 InRGE_t + \\ + \gamma_1 Sanc2014_t + \gamma_2 Sanc2022_t + \epsilon_t, \quad (1)$$

where $InTrade_t$ represents the dependent variable, covering total trade volume (lnTotal_Trade), disaggregated import and export volumes (lnTotal_Exp/lnTotal_Imp), and import and export volumes by energy categories including coal, oil, and natural gas; GDP_t represents the product of China and Russia's GDP; RMB_RUB_t represents the RMB-RUB exchange rate; $InRGE_t$ represents the Russian governance quality variable; $Sanc2014_t$ and $Sanc2022_t$ represent the 2014 and 2022 sanction dummy variables respectively; ϵ_t represents the error term. Based on this benchmark model, we construct an empirical analysis system containing nine models, presented in Table 3.

The above models correspond to the hypotheses in Section 2. Models 1–3 verify H1 and H2, Models 4–9 verify H3. The exchange rate and governance quality variables are incorporated as control variables to examine their moderating effects on sanction impacts. The contribution of our modeling approach is reflected in the following three aspects. The first contribution is the identification mechanism for sanctions imposed in two time-periods. While existing literature mostly studies single sanctions, this study separates the 2014 and 2022 sanction variables to differentiate between their effects. The second contribution is taking into account the asymmetric moderating effect of governance quality on sanction impacts between im-

Table 3

Model system and variable settings

Model	Dependent variable	Independent variable
Model 1	lnTotal_Trade	lnGDP, lnRMB_RUB, lnRGE, Sanc2014, Sanc2022
Model 2	lnTotal_Exp	lnGDP, lnRMB_RUB, lnRGE, Sanc2014, Sanc2022
Model 3	lnTotal_Imp	lnGDP, lnRMB_RUB, lnRGE, Sanc2014, Sanc2022
Model 4–6	lnCoal_Exp, lnPetro_Exp, lnGas_Exp	lnGDP, lnRMB_RUB, lnRGE, Sanc2014, Sanc2022
Model 7–9	lnCoal_Imp, lnPetro_Imp, lnGas_Imp	lnGDP, lnRMB_RUB, lnRGE, Sanc2014, Sanc2022

Source: compiled by the authors.

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ports and exports. While existing literature mostly adopts the sum or average of governance quality from both trading parties, this study employs independent governance indicators for China and Russia (lnCGE and lnRGE). After testing, lnCGE has a small and insignificant impact on bilateral energy trade, therefore, the final model only introduces the Russian governance variable, focusing on how Russian governance quality asymmetrically moderates the impact of sanctions on China-Russia energy imports versus exports. The third contribution is the heterogeneous modeling of energy categories. Targeting the differences in logistics attributes and contract structures of coal, oil, and natural gas, separate import and export models are established (Models 4–9). Through category subdivision, different energy sources risk resistance gradients can be identified, providing a basis for China-Russia differentiated energy security strategies.

Estimation Method

This study employs OLS regression with heteroskedasticity-robust standard errors as the estimation method, utilizing White heteroskedasticity-corrected standard errors to address the common heteroskedasticity problem in time series data. This methodological choice is based on the following theoretical and empirical considerations. First, this study uses time series data with a relatively small sample size (N = 30), and employing dynamic panel models may lead to over-identification problems due to excessive instrumental variables, making static models more suitable for this study's data characteristics (Hayashi, 2011)[11].

Second, regarding the stationarity issue of time series data, ADF tests show that all variables follow I (1) processes, passing the stationarity test at the 5% significance level after first differencing. Crucially, Johansen cointegration tests confirm the existence of stable long-term equilibrium relationships among variables. Taking the core model as an example, the trace statistics for the total trade model is 49.42, significantly exceeding the 5% level critical values (47.21), which indicates the presence of cointegration relationships. Similarly, other models also demonstrate strong cointegration evidence. According to the cointegration theory of Engle & Granger (1987), when cointegration relationships exist among non-stationary variables, using level values for regression is theoretically sound, as cointegration relationships ensure the stationarity of regression residuals, effectively avoiding spurious regression problems. As demonstrated by Johansen (1988), OLS estimators of long-term relationship parameters in cointegration systems possess super-consistency, meaning convergence rates faster than standard cases, which implies that even in relatively small samples, estimates of long-term equilibrium relationships maintain good statistical properties.

The adjusted R^2 values in some models of this study exceed 0.95, which requires careful interpretation in time series analysis. Granger & Newbold (1974) first pointed out that non-stationary time series regressions may produce spurious high R^2. However, in the presence of cointegration relationships, high R^2 has different economic implications. According to Stock (1987), high R^2 in cointegration systems reflects the strength of genuine long-term equilibrium relationships among variables, rather than spurious correlations caused by trends. Phillips & Durlauf (1986) further demonstrate that when regression residuals pass stationarity tests, high R^2 represents the manifestation of cointegration relationship strength.

To verify the reliability of results, we conducted systematic diagnostic tests. First, White heteroskedasticity-corrected standard errors (vce (robust)) were employed to enhance estimation robustness and address common heteroskedasticity problems in time series data (White, 1980). Second, Ljung-Box Q test results show that except for Models 4 and 6, other model residuals exhibit no significant autocorrelation, indicating reasonable model specification without the need to introduce lagged terms (Ljung & Box, 1978). Finally, multicollinearity diagnosis was conducted using variance inflation factors (VIF), with all retained variables having VIF values below 5, indicating that models do not suffer from serious multicollinearity interference (Hair et al., 2019)[12]. Additionally, we performed ADF stationarity tests on regression residuals, confirming their stationarity, further validating the effectiveness of cointe-

[11] Hayashi, F. (2011). Econometrics. Princeton University Press.

[12] Hair, J.F., Black, W.C., Babin, B.J., & Anderson, R.E. (2019). Multivariate data analysis (8th ed.). Harlow, England: Pearson Education Limited.

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Table 4

Regression results of the China-Russia energy trade model

Variables	1. Total	2. Export	3. Import	4. Coal Export	5. Oil Export	6. Gas Export	7. Coal Import	8. Oil Import	9. Gas Import
lnGDP	0.795*** (0.052)	0.432*** (0.048)	0.808*** (0.056)	–0.519 (0.470)	0.425*** (0.055)	6.743*** (0.837)	1.748*** (0.363)	0.781*** (0.060)	2.111*** (0.192)
lnRMB_RUB	0.727*** (0.118)	0.556* (0.243)	0.752*** (0.131)	–0.680 (0.703)	0.772* (0.348)	–0.439 (1.434)	–0.571 (0.599)	0.780*** (0.140)	0.342 (0.630)
lnRGE	0.868* (0.353)	–0.799 (0.490)	1.071* (0.446)	–1.205 (2.431)	–0.903 (0.575)	0.255 (4.344)	1.613 (2.258)	1.123* (0.472)	–0.681 (1.113)
Sanc2014	–0.970** (0.274)	–0.485 (0.362)	–1.096** (0.322)	1.686 (1.968)	–0.604 (0.425)	–3.236 (3.962)	–0.565 (1.386)	–1.158** (0.341)	0.484 (1.248)
Sanc2022	1.310*** (0.363)	–0.890† (0.474)	1.508** (0.451)	3.439 (2.879)	–1.091† (0.579)	–1.823 (4.712)	2.414 (2.229)	1.365** (0.477)	1.304 (1.212)
Constant	–22.616*** (2.925)	–6.974** (2.592)	–23.279*** (3.158)	42.010 (26.920)	–6.945* (2.850)	–377.692*** (47.544)	–78.146*** (19.264)	–21.845*** (3.394)	–104.628*** (10.852)
Obs	30	30	30	30	30	30	30	30	30
R^2	0.9826	0.8281	0.9797	0.4107	0.8019	0.8765	0.8570	0.9756	0.8262
F-statistic	452.95***	74.72***	383.60***	6.43***	50.97***	196.18***	62.00***	309.43***	122.70***

Notation: standard errors are indicated in parentheses. Significant level marked with ***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1.

Source: compiled by the authors using UN Comtrade data (Retrieved from: https://comtrade.un.org (date of access: 02.06.2025)).

gration relationships and the rationality of model specification.

Results and Discussion

Regression results

The empirical results for models 1–9 are shown in Table 4. Overall, these models better explain energy imports than exports.

From the perspective of economic scale, *lnGDP* is highly significant and positive in all models except Model 4 ($\beta_1 > 0$, $p < 0.001$), in line with the gravity model of trade, indicating that China-Russia energy trade is positively correlated with their economic scale. The coefficient of the total trade model is 0.795, implying that a 1 % increase in the economic size of the two countries leads to a 0.795 % rise in energy trade. In addition, the lnGDP coefficient of the import model (Model 3: β_1 = 0.808***) is much higher than in the export model (Model 2: β_1 = 0.432***), indicating that economic growth in both countries has a more pronounced effect on China's energy imports from Russia compared to energy exports to Russia. This asymmetric response reflects China's position as a major energy importer, where domestic economic expansion directly drives overall energy consumption, while exports are constrained by Russia's limited demand for refined energy products. Among them, the *lnGDP* elasticity of the natural gas import model is 2.111, reflecting that China's economic development has a strong demand for Russian natural gas imports.

Differentiated impacts of EU-US Sanctions in 2014 and 2022

Based on the empirical results in Table 4, the coefficient of *Sanc2014* is significantly negative in the total trade model ($\gamma_1 = -0.970$, $p < 0.01$), the import model ($\gamma_1 = -1.096$, $p < 0.01$) and the oil import model ($\gamma_1 = -1.158$, $p < 0.01$), reflecting the temporary suppression of China's energy imports in the early stage of EU-US sanctions. However, *Sanc2022* is significantly positive in the total trade model ($\gamma_2 = 1.310$, $p < 0.001$), the import model ($\gamma_2 = 1.508$, $p < 0.01$) and the oil import model ($\gamma_2 = 1.365$, $p < 0.01$), indicating that after the Russian-Ukrainian conflict, China increase its energy imports from Russia, reflecting "cooperation in crisis". The impact of EU-US sanctions on China-Russia energy trade shows a significant dynamic reversal feature. This finding contrasts sharply with the conclusions of Chen et al. (2023), who show a persistent inhibitory effect of sanctions on Russian-European energy trade. The differentiated effects of the 2014 and 2022 sanctions can be explained through a three-part mechanism.

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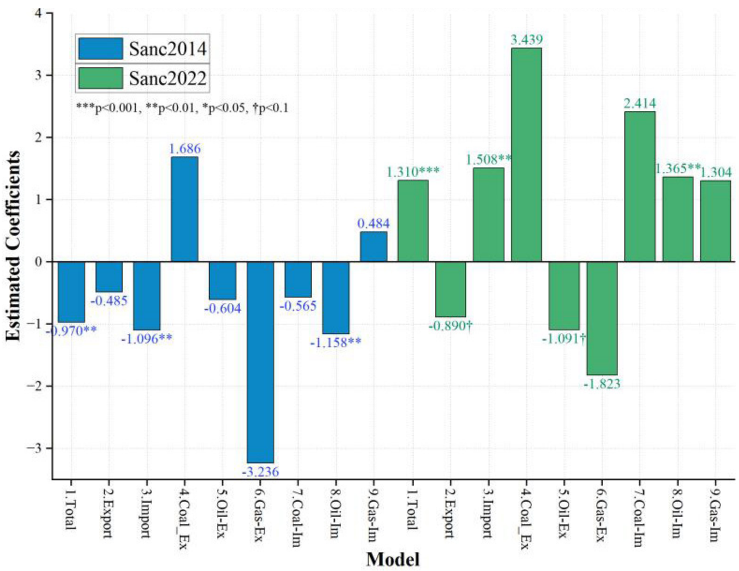

Figure 1. *Differentiated impact of Sanctions on China-Russia energy trade*
Source: compiled by the authors based on own calculations.

The first mechanism is the infrastructure lock-in effect in China-Russia energy trade. At the onset of the 2014 sanctions, China-Russia energy transport relied on rail and sea routes. The sanctions increased infrastructure financing costs, limiting the ability to divert trade. However, by 2022, with key infrastructure like the Power of Siberia gas pipeline and the ESPO oil pipeline in place, Russia's natural gas exports to China in 2022 increased by 152 % year-on-year[13], verifying Jentleson's (2019)[14] theory on the "asset specificity" of pipeline politics.

The second mechanism is the de-dollarization of the China-Russia settlement system. In 2014, RMB-RUB direct settlement accounted for only 3.1 % of bilateral trade, but currently it exceeds 95 %[15]. Local currency settlement reduces the risk of SWIFT disconnection, making the exchange rate variable lnRMB_RUB show a significant positive effect in the total trade model ($\beta_2 = 0.727$, $p < 0.001$), confirming Antoniades' (2017) conclusion that currency settlement independence can enhance trade resilience.

The third mechanism is the buffering role of long-term contracts in China-Russia energy trade. Before the 2022 sanctions, the Far East Natural Gas Purchase and Sales Agreement signed by China and Russia adopted a "Take-or-Pay" clause to lock in supply for the next 20 years. This contract structure allowed natural gas imports to continue to grow under the impact of the 2022 sanctions (Model 9: $\gamma_2 = 1.304$, $p > 0.1$), verifying the risk resistance of long-term contracts.

Asymmetric impact of sanctions on imports and exports

Figure 2 shows the elasticity and significance comparison of *Sanc2014* and *Sanc2022* on China's energy import and export to Russia. Sanctions have an asymmetric impact on import and export of China-Russia energy trade. The impact of sanctions on import is more significant than that on export. Sanc2014 has no significant impact on China's energy exports to Russia, but has a significant negative impact on total energy imports and oil imports. *Sanc2022* has a weak negative impact on China's total energy exports and oil exports to Russia, but has a significant positive impact on total energy imports and oil imports. By comparing the coefficients, it can be found that the elasticity of *Sanc2022* on the import end is greater than that on the export end.

In the export model, *Sanc2014* is not significant, indicating that EU-US sanctions in 2014 had

13 UN Comtrade Database. (2025). United Nations Commodity Trade Statistics Database. Retrieved from: https://comtrade.un.org (date of access: 02.06.2025).

14 Jentleson, B. W. (2019). Pipeline politics: the complex political economy of east-west energy trade. Cornell University Press.

15 Government of China Website. (2024). Joint Communiqué of the 29th Regular Meeting Between the Premiers of China and Russia. Retrieved from: https://www.gov.cn/yaowen/liebiao/202408/content_6969793.htm (date of access: 02.06.2025).

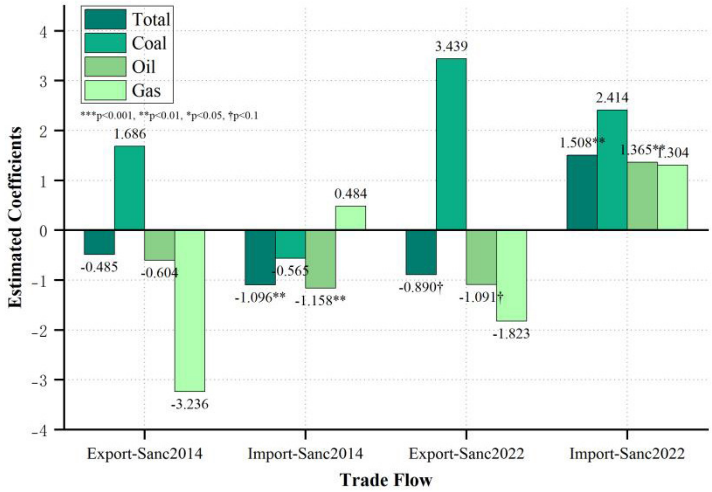

Figure 2. *Asymmetric impact of sanctions on imports and exports*
Source: compiled by the authors based on own calculations.

almost no impact on China's energy exports to Russia. Only *Sanc2022* showed a weak negative impact in the total export model ($\gamma_2 = -0.890$, $p < 0.1$) and the oil export model ($\gamma_2 = -1.091$, $p < 0.1$). This is mainly attributed to the structural constraints on China's energy exports to Russia. As shown in Figure 3, China's energy exports to Russia concentrate in refined products (such as diesel and aviation kerosene), accounting for 98.36 %[16], explaining the negative impact of sanctions is mainly reflected in total exports and oil exports. At the same time, the EU-US sanctions in 2022 excluded Russian banks from the SWIFT system, and Chinese exporters faced ruble settlement risks, which increased transaction costs, thereby inhibiting Chinese small and medium-sized enterprises from participating in China-Russia energy trade.

In the import model, as shown in Figure 4, since oil accounts for 84.5 % of China's energy imports from Russia, the impact of sanctions on import is also mainly concentrated in the total import model and the oil import model. *Sanc2014* showed a significant negative impact in both the total import model ($\gamma_1 = -1.096$, $p < 0.01$) and the oil import model ($\gamma_1 = -1.158$, $p < 0.01$). *Sanc2022* showed a significant positive impact in both the total import model ($\gamma_2 = 1.508$, $p < 0.01$) and the oil import model ($\gamma_2 = 1.365$, $p < 0.01$). This phenomenon is driv-

[16] UN Comtrade Database. (2025). United Nations Commodity Trade Statistics Database. Retrieved from: https://comtrade.un.org (date of access: 02.06.2025).

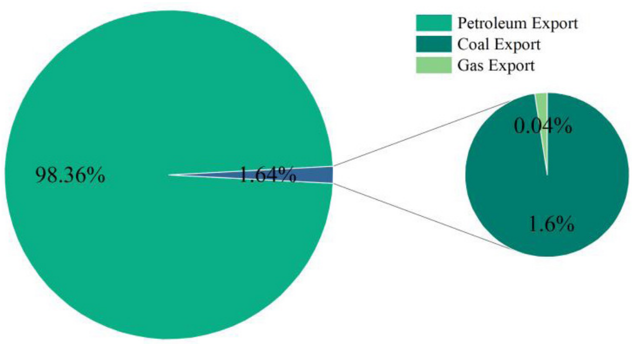

Figure 3. *China's share of various energy exports to Russia*
Source: compiled by the authors using UN Comtrade data (Retrieved from: https://comtrade.un.org (date of access: 02.06.2025)).

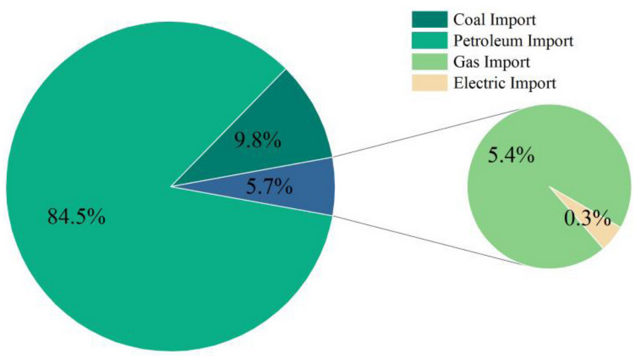

Figure 4. *China's share of different energy imports from Russia*
Source: compiled by the authors using UN Comtrade data (Retrieved from: https://comtrade.un.org (date of access: 02.06.2025)).

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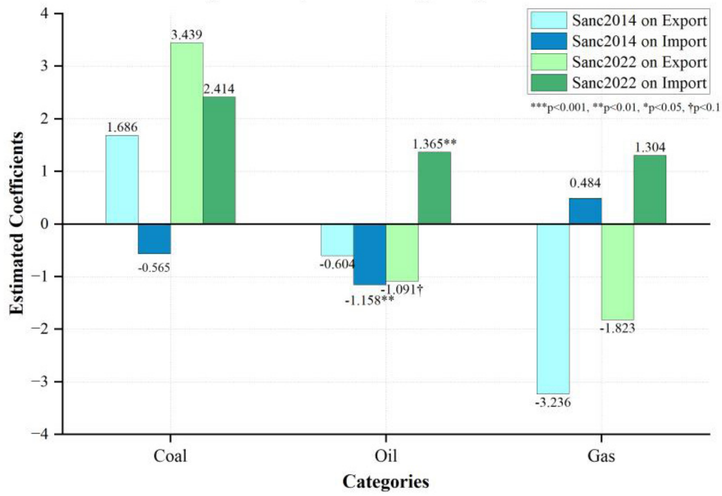

Figure 5. *Heterogeneous responses of energy categories to sanctions*
Source: compiled by the authors based on own calculations.

en by substitution effects and price advantages. First, the price gap between ESPO crude oil contract price and Brent crude oil widened after the sanctions. This price advantage effectively offset the increase in transaction costs caused by the sanctions, allowing China's oil imports to maintain growth. In addition, this is also related to the two sides seeking to circumvent the impact of sanctions and strengthen energy cooperation. Russia has shifted its excess production capacity to the Asian market due to a sharp drop in energy exports to Europe. At the same time, since energy is a homogeneous commodity with high import substitution elasticity, China can quickly switch supply sources, reducing imports from traditional energy suppliers such as the Middle East, and shifting more imports to Russia.

Heterogeneous responses of energy categories to sanctions

As shown in Figure 5, the regression results of energy trade by categories show that there are significant differences between *Sanc2014* and *Sanc2022* in the impact on coal, oil, and natural gas import and export trade, and their directionality and statistical significance are highly dependent on the transportation attributes and contract structure of energy. The impact of *Sanc2014* and *Sanc2022* on coal import and export is not significant. Coal transport mainly depends on rail and sea. *Sanc2014* didn't directly restrict coal trade and sea transport. *Sanc2022* spurred China-Russia coal trade due to Europe's embargo, but after the Russia-Ukraine conflict, Black Sea route risks and Suez Canal costs rose, leading to a higher rail transport proportion. However, trade growth is limited by rail capacity, highlighting how infrastructure bottlenecks restrict trade diversion.

In contrast, in terms of oil trade, the impact of sanctions is particularly significant. *Sanc2014* and *Sanc2022* show strong significance and asymmetric impact on oil imports and exports. Specifically, *Sanc2014* has a negative impact on both oil exports (Model5: $\gamma_1 = -0.604$, $p = 0.168$) and imports (Model8: $\gamma_1 = -1.158$, $p = 0.002$), but the impact on the import side is significant while the impact on the export side is not significant. This is mainly because the EU-US sanctions in 2014 mainly hit Russian energy financing, and China's oil imports from Russia declined, but oil exports were not significantly affected. *Sanc2022* has a significant inhibitory effect on oil exports ($\gamma_2 = -1.091$, $p = 0.072$), but at the same time significantly promotes oil imports ($\gamma_2 = 1.365$, $p = 0.009$). This is because the increase in marine insurance costs has caused a serious impact on oil exports. In contrast, the import side has avoided risks and maintained a growth trend due to the adoption of pipeline transportation.

China-Russia natural gas trade showed low sensitivity to both *Sanc2014* and *Sanc2022.* The 2014 sanctions had limited impact as the China-Russia East Route Pipeline hadn't started operation until 2019, and natural gas trade was small in scale and depended on short-term LNG contracts. As for the 2022 sanctions, the "take-or-pay" clause in the China-Russia Far East Natural Gas Purchase and Sale Agreement locked in 20 years of supply, and the asset specificity of natural gas pipelines made it hard to change the physical flow, highlighting the impact of infrastructure on the shock-resistance of energy trade.

Governance Quality and Exchange Rate Transmission Mechanism

Research shows that Russia's governance quality exhibits asymmetric regulatory effects on energy trade between China and Russia. Specifically, while Russia's governance quality (*lnRGE*) has an insignificant impact on China's energy exports to Russia, it positively affects overall energy trade (Model 1: $\beta_3 = 0.868$, $p = 0.022$), total energy imports (Model 3: $\beta_3 = 1.071$, $p = 0.024$), and oil imports (Model 8: $\beta_3 = 1.123$, $p = 0.026$). This implies that better Russian governance enhances China's energy imports from Russia and mitigates external sanction risks. This conclusion aligns with the findings of Anderson and Marcouiller (2002), underscoring the importance of governance quality for international trade.

The study finds a two-way difference in exchange rate transmission between China and Russia. Specifically, the increase in the RMB-RUB exchange rate has a strong driving effect on import growth, with a 1 % rise leading to a 0.752 % import increase (Model 3: $\beta_2 = 0.752$, $p < 0.001$), but only weakly promotes exports (Model 2: $\beta_2 = 0.556$, $p < 0.05$). This disparity stems from the purchasing power of the RMB and ruble. Due to sanctions, the ruble is volatile while the RMB is stable. Ruble depreciation strengthens the RMB purchasing power over Russian goods, spurring imports, but reduces Russia's demand for imports. This uneven currency power structure heightens import exchange rate elasticity, explaining the difference. This pattern aligns with Abeysinghe and Yeok (1998)'s asymmetric exchange rate pass-through theory.

Conclusions

Main research conclusions

Based on an extended gravity model of trade using China-Russia energy trade data from 1994–2023, this study systematically evaluates the differentiated effects of sanctions imposed in 2014 and 2022, category heterogeneity, and the moderating effects of governance and exchange rates on the impact of sanctions on China-Russia energy trade. The main conclusions can be summarized in the following three aspects.

First, sanctions imposed in 2014 and 2022 demonstrate significantly differentiated effects, validating the H1 hypothesis. Quantitative analysis shows that the 2014 sanctions led to a 97.0 % decline in total China-Russia energy trade ($\gamma_1 = -0.970$, $p < 0.01$), responding to questions about traditional sanction suppression effects raised in the introduction. However, the 2022 sanctions promoted a 131.0 % increase in total trade volume ($\gamma_2 = 1.310$, $p < 0.001$). The reversal of the sanction effects can be explained through three adaptive effects including infrastructure lock-in, improvement of local currency settlement systems, and long-term contract buffering.

Second, sanctions have significantly asymmetric impacts on import and export trade, responding to the H2 hypothesis. Quantitative evidence shows that the 2022 sanctions' suppression effect on Chinese energy exports ($\gamma_2 = -0.890$, $p < 0.1$) contrasts sharply with the promotion effect on imports from Russia ($\gamma_2 = 1.508$, $p < 0.01$), with coefficient differences of 2.398 units. The quantitative manifestation of export-side vulnerability is shown in the oil export model where the 2022 sanction coefficient is –1.091 ($p < 0.1$), reflecting the dual pressure of payment risks and declining Russian import demand. Quantitative evidence of import-side resilience is demonstrated in the oil import model where the 2022 sanction coefficient is 1.365 ($p < 0.01$), indicating that the combined driving forces of substitution effects, price advantages, and long-term contracts exceed sanction costs.

Third, the sensitivity of different energy categories to sanctions exhibits a gradient characteristic of "oil > natural gas > coal," validating the H3 hypothesis. Quantitative data show that oil trade is most sensitive to sanctions, with the oil import model showing 2014 sanction coefficients of –1.158 ($p < 0.01$) and 2022 sanction coefficients of 1.365 ($p < 0.01$), with absolute coefficient values exceeding 1, indicating that oil trade responds most strongly to sanction shocks due to maritime transport dependence. Natural gas trade exhibits low elasticity characteristics, with natural gas import model showing 2014 and 2022 sanction coefficients of 0.484 and 1.304 respectively, both insignificant ($p > 0.1$), indicating that take-or-pay clauses and pipeline infrastructure lock-in

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effects effectively mitigate sanction shocks. Coal trade is constrained by transport capacity bottlenecks, with all sanction coefficients in coal import and export models being insignificant ($p > 0.1$), reflecting that railway transport capacity constraints limit the scale effects of trade diversion. The quantitative findings of category heterogeneity reveal the moderating effects of energy logistics attributes and contract structures on sanction effectiveness.

Fourth, the moderating effects of governance quality and exchange rate variables are also confirmed. Russian governance quality (*lnRGE*) has significant positive impacts on Chinese energy imports, with econometric results showing that the governance quality coefficient in the total import model is 0.868 ($p < 0.05$) and the oil import model coefficient is 1.123 ($p < 0.05$), indicating that improvements in Russian government governance levels effectively promote Chinese energy imports from Russia by reducing contract execution risks. The positive effects of RMB-RUB exchange rate appreciation and asymmetric effects of exchange rate transmission are also quantitatively validated, with RMB-RUB exchange rate appreciation's promotion effect on energy imports ($\beta_2 = 0.752$, $p < 0.001$) being significantly stronger than its promotion effect on exports ($\beta_2 = 0.556$, $p < 0.05$), with a coefficient difference of 0.196, confirming asymmetric exchange rate transmission. This finding extends the applicability of Abeysinghe and Yeok (1998)'s theory of asymmetric exchange rate transmission to the context of bilateral direct settlements.

Policy Implications

The above quantitative findings indicate that China and Russia need to reinforce the institutional resilience of energy cooperation through structural adjustments, with policy design targeting the following strategic directions.

First, China and Russia should construct differentiated trade risk prevention system based on the sensitivity of different energy categories to sanction impacts. Given the low sanction sensitivity of natural gas trade, China and Russia should prioritize expanding the scale of pipeline natural gas cooperation. If China-Russia natural gas trade scale expands, China-Russia energy trade resilience can be significantly enhanced, effectively offsetting the negative impacts of sanctions. Regarding the high sanction sensitivity of oil trade, China and Russia need to reduce maritime dependence and logistics vulnerability through further construction of overland transport networks and regional refining cooperation, thereby reducing oil's sanction sensitivity and improving the stability of bilateral oil trade. Coal has the lowest sanction sensitivity, but trade scale is limited by transport capacity bottlenecks; therefore, China and Russia should explore diversification of coal logistics systems and strengthen development of new transport routes to increase bilateral trade volumes.

Second, Russia should improve governance efficiency to offset the institutional costs of sanctions. Given the positive effect of Russian governance quality on China-Russia energy trade ($\beta_3 = 0.868$, $p < 0.05$), both countries should jointly establish an "Energy Cooperation Transparency Platform" to standardize contract disclosure, logistics tracking, and compliance review. Additionally, a "China-Russia Energy Dispute Rapid Arbitration Court" could be created to resolve disputes within 60 days. These institutional improvements would reduce transaction friction caused by sanctions and attract long-term investment in energy infrastructure.

Third, China and Russia should strengthen coordination of their financial systems to mitigate the asymmetry in exchange rate transmission. Based on econometric analysis findings that RMB-RUB exchange rate's promotion effect on imports ($\beta_2 = 0.752$, $p < 0.001$) is significantly stronger than on exports ($\beta_2 = 0.556$, $p < 0.05$), China and Russia need to establish bilateral financial systems and exchange rate coordination mechanisms. Cooperation between SPFS and CIPS could be strengthened to bypass SWIFT and improve settlement efficiency in bilateral trade. Joint intervention mechanisms may be introduced to smooth extreme volatility, triggering coordination when daily exchange rate fluctuations exceed 3 % and initiating joint intervention when monthly cumulative fluctuations exceed 15 %, thereby enhancing trade stability. Additionally, linking the pricing of energy contracts to exchange rate indices could help mitigate the impact of exchange rate fluctuations.

China and Russia should also strengthen energy infrastructure investment to stabilize energy trade. The reversal of impacts from the 2014 sanctions ($\gamma_1 = -0.970$, $p < 0.01$) and 2022 sanctions ($\gamma_2 = 1.310$, $p < 0.001$) reflects improvements in China-Russia energy infrastructure interconnectivity. Further development should focus on the Arctic shipping corridor and cross-border pipeline networks to reduce sanction risks from traditional maritime routes. Supply chain efficiency can be improved through technical standard coordination, and Russia should work to reduce dependence on natural resources while diversifying its trade.

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Information about the authors

Lin Shengfu — Graduate Student, Graduate School of Economics and Management, Ural Federal University (19 Mira Str, Ekaterinburg, 620002, Russia); ORCID: 0009-0008-5192-6782; e-mail: 1249821454@qq.com

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Natalia B. Davidson — Cand. Sc. (Economics), Associate Professor, Graduate School of Economics and Management, Ural Federal University (19 Mira St., Ekaterinburg, 620002, Russia); ORCID: 0000-0002-6779-9561; e-mail: n.b.davidson@urfu.ru

Информация об авторах

Линь Шэнфу — аспирант, Институт экономики и управления, Уральский федеральный университет (ул. Мира, 19, Екатеринбург, 620002, Россия); ORCID: 0009-0008-5192-6782; e-mail: 1249821454@qq.com

Дэвидсон Наталья Борисовна — кандидат экономических наук, доцент, Институт экономики и управления, Уральский федеральный университет (ул. Мира, 19, Екатеринбург, 620002, Россия); ORCID: 0000-0002-6779-9561; e-mail: n.b.davidson@urfu.ru

作者信息

林胜府——博士在读，研究员，经济与管理学院，乌拉尔联邦大学（邮编：620002，俄罗斯叶卡捷琳堡，米拉大街19号）；ORCID：0009–0008–5192–6782；电子邮箱：1249821454@qq.com

戴维森·娜塔莉亚·鲍里索夫娜——副教授，经济与管理学院，乌拉尔联邦大学（邮编：620002，俄罗斯叶卡捷琳堡，米拉大街19号）；ORCID：0000–0002–6779–9561；电子邮箱：n.b.davidson@urfu.ru

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