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Mathematical model for assessing energy cooperation between Russia and China in the global energy market

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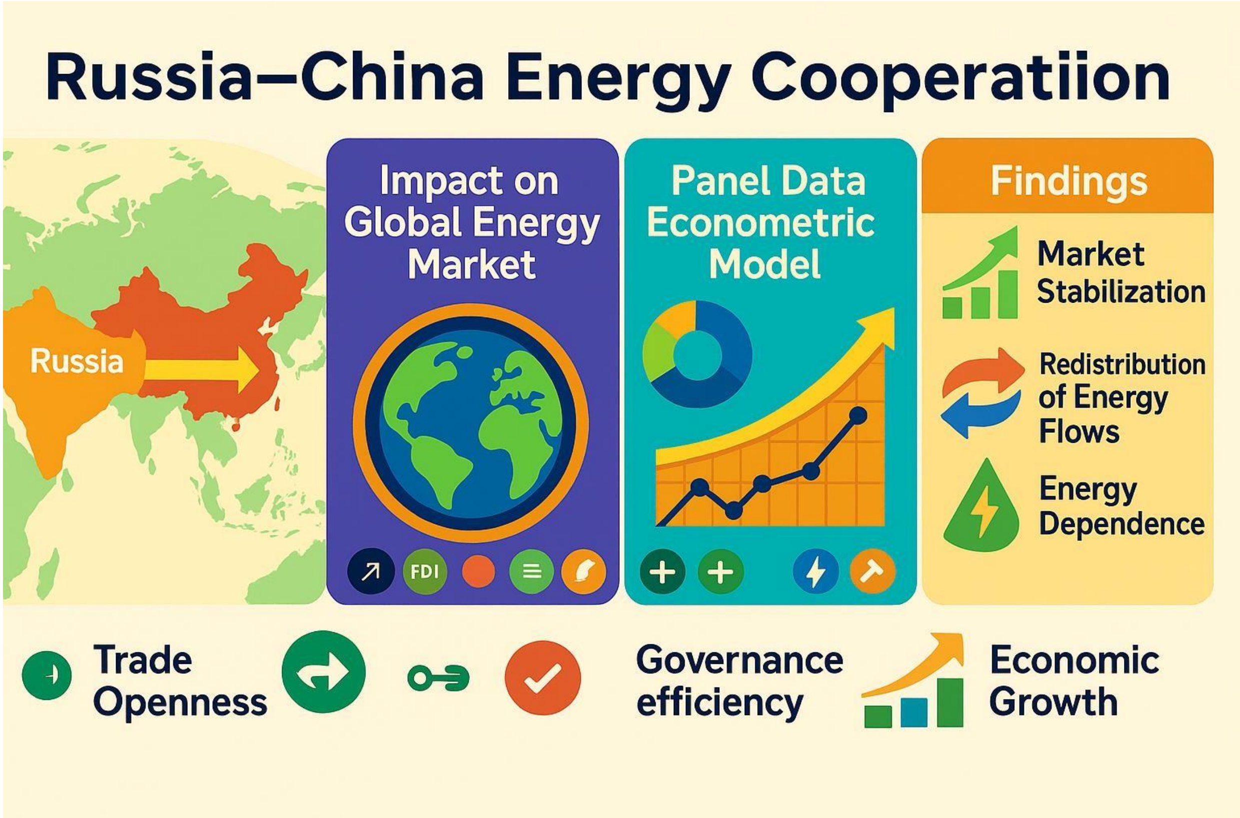
Graphical Abstract



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Abstract

Purpose: This article develops a mathematical and econometric framework to assess the impact of Russia–China energy cooperation on the global energy market. It aims to explore how bilateral collaboration affects market stability, energy flow redistribution, and global energy security.
Methodology: The study employs a linear trend model and a log-linear regression model to evaluate relationships between variables such as trade openness, foreign direct investment, economic growth, energy prices, and governance efficiency. It constructs a panel data econometric model using variables from the World Bank, the International Energy Agency (IEA), and national energy ministries to test three hypotheses about the systemic effects of bilateral cooperation. Findings: The analysis confirms a statistically significant and positive relationship between Russia–China energy cooperation and global energy market stabilization. The cooperation contributes to the redistribution of energy flows and increases energy dependence among specific countries. The model also highlights the role of state governance efficiency in mitigating potential risks. Originality: This study provides a novel mathematical and empirical model integrating geopolitical, economic, and institutional factors to assess the global implications of bilateral energy partnerships, with a special focus on the Russia– China nexus.

Keywords: Russia–China relations, energy cooperation, global energy market, econometric model, trade openness, FDI, governance efficiency, energy security, energy consumption, economic growth.

Introduction

Energy cooperation between the Russian Federation and the People's Republic of China remains the subject of close attention of both domestic and foreign researchers, especially in the context of the transforming global energy order. A historical analysis of the evolution of energy relations between the two countries, presented by Mykhailiuk (2023), shows that cooperation in this area has developed unevenly, passing through periods of institutional strengthening and political reorientation. He emphasizes that energy partnership has become a key element of bilateral relations, especially after the 2000s, when the strategic agenda became economically pragmatic. This interaction is based on the complementarity of Russia's energy resources and growing demand from China.

The evolution of Russia–China energy cooperation has become a critical factor in shaping the global energy market in the 21st century. As two major geopolitical and energy actors, their strategic alignment extends beyond bilateral trade and includes significant investment, technological exchanges, and infrastructure development such as transnational pipelines. Further contextualizes the results within theoretical discussions of global energy governance and interdependence.

1. Analysis of the current state of energy cooperation between Russia and China

Lynch (2007) analyzes Russia's foreign policy evolution in the era of "Putin's transition," emphasizing the desire to strengthen sovereign influence in strategic sectors, including energy. This creates the prerequisites for rapprochement with China on the basis of geo-economic logic.

In terms of geopolitical context, Li et al. (2021) empirically argue that geopolitics has a significant impact on energy trade in emerging markets. Their research shows that geopolitical tensions, trade restrictions and sanctions have a constraining effect on the stability of energy supplies, as well as increasing transaction costs and risks. These conclusions are relevant in relation to Russian-Chinese relations, especially in the context of sanctions pressure and the reorientation of energy flows to the East. Lee (2023), examining the ecological Blacksmith curves for CO_2 emissions in a regional context, emphasizes that the level of economic development directly affects energy efficiency and sustainability. In the context of Russia and China, these results can be extrapolated to the discussion of the "green" vector of energy interaction, where the role of environmental standards and the transformation of the energy balance is becoming increasingly important.

Related challenges and factors, such as international logistics, technological dependence, and strategic sea routes, are addressed in a paper by Lendon and McCarthy (2023), which raises the issue of China's increased maritime expansion. The authors point to the expansion of China's military-strategic infrastructure outside the region, which potentially has an impact on energy security and supply routes, especially in the context of LNG supplies and maritime logistics.

Thus, against the backdrop of institutional strengthening of energy cooperation between Russia and China, a combination of factors – from the geopolitical situation to environmental restrictions and naval activity – forms a multi-layered structure of energy trade. Recent studies have highlighted the need for strategic coordination and flexible adaptation to challenges to ensure the sustainability of bilateral cooperation over the long term.

2. Application of the theory of comparative advantage in energy trade

The theory of comparative advantage proposed by David Ricardo remains relevant in the 21st century. According to its postulates, even a country that is less efficient in absolute terms can benefit from international trade if it specializes in the production of goods in which it has a comparative advantage. Such specialization is determined by a combination of factors: natural resources, the level of technological development, labor and capital reserves.

The theory of comparative advantage continues to be a cornerstone of international economics. While initially formulated to explain trade in agricultural and manufactured goods between industrializing nations, its applicability has since extended to a broad spectrum of economic sectors, including the complex and strategically vital domain of energy. In a global context increasingly shaped by geopolitical uncertainties, technological transitions, and environmental constraints, the relevance of comparative advantage theory has been reaffirmed in analyzing energy flows, pricing mechanisms, and intergovernmental agreements. This is particularly evident in the case of energy relations between the Russian Federation and the People's Republic of China—two states whose distinct endowments and strategic imperatives create a fertile ground for mutually beneficial cooperation.

Energy, unlike many tradable goods, is deeply embedded in a matrix of physical infrastructure, long-term investment cycles, and national security considerations. Fossil fuels such as crude oil, coal, and natural gas remain dominant in the global energy mix, despite the rising trajectory of renewables. The production, processing, and transportation of these resources are capital-intensive and technologically demanding, yet the fundamental logic of Ricardo's theory remains intact: countries tend to export the resources they can produce at relatively lower opportunity costs and import those that are more costly to produce domestically. In this light, Russia's role as an energy superpower with abundant fossil fuel reserves, and China's status as the world's largest energy consumer with rapidly developing capacities in clean technologies, reflects a natural alignment rooted in comparative advantage.

However, the modern global energy architecture adds a level of complexity to Ricardo's model. First, the costs of energy production are not solely determined by natural endowments or labor productivity, but also by political risk, regulatory frameworks, currency fluctuations, and the security of supply routes. For instance, Russia's comparative advantage in fossil fuels is conditioned by its control over vast reserves, but also constrained by technological bottlenecks, underinvestment in upstream modernization, and its vulnerability to international sanctions. Meanwhile, China's advantage in renewable energy is not merely a function of its labor costs or manufacturing scale, but a product of state-led industrial policy, strategic subsidies, and an extensive domestic market for technology deployment. This evolution suggests that comparative advantage in energy today is as much constructed as it is natural.

The bilateral energy cooperation between Russia and China should thus be examined not merely through the lens of static resource endowments, but as a dynamic interplay of evolving comparative advantages shaped by strategic calculus. The shift in Russian energy exports from West to East, accelerated in the aftermath of the 2014 Crimea crisis and deepened by the full-scale conflict in Ukraine since 2022, has altered the geography of energy flows. Western sanctions have closed off critical financial and technological inputs, prompting Russia to seek alternative partners. China, for its part, has viewed this as an opportunity to deepen its energy security by diversifying supply channels and securing preferential terms through long-term contracts and infrastructure investments.

This strategic pivot aligns with the logic of comparative advantage but is also mediated by geopolitical pragmatism. Russia's eastward orientation in energy trade is not solely the result of cost-optimization, but a response to geopolitical isolation and the need to re-anchor its economy. At the same time, China's growing energy imports from Russia serve not just its industrial appetite, but its broader ambition to reduce dependence on maritime supply routes vulnerable to U.S. naval dominance. Thus, the Sino-Russian energy nexus illustrates how comparative advantage, in the energy domain, is embedded in a wider matrix of strategic autonomy, infrastructure diplomacy, and regional rebalancing.

Furthermore, the role of institutional frameworks and governance mechanisms cannot be underestimated in enabling this bilateral alignment. Energy cooperation between Russia and China has been institutionalized through intergovernmental agreements, state-owned enterprise partnerships, and cross-border infrastructure development. Notable examples include the Eastern Siberia–Pacific Ocean (ESPO) pipeline and the Power of Siberia gas pipeline, both of which represent multibillion-dollar ventures that lock in decades of energy interdependence. These infrastructures not only facilitate the physical exchange of energy, but also signal long-term political commitments, de-risking trade relations in a volatile global environment.

Nonetheless, challenges remain. While Russia's comparative advantage in fossil fuels is well-established, it faces long-term structural risks due to the global decarbonization agenda. The energy transition, as enshrined in international agreements such as the Paris Accord, implies a gradual decline in demand for coal, oil, and eventually gas. As importing nations shift toward electrification and decarbonized energy systems, exporters like Russia risk being caught in a fossil lock-in. China, despite its current reliance on fossil imports, is investing aggressively in green technologies, electric vehicles, and grid modernization. This trajectory could eventually narrow the window for Russian hydrocarbon exports, especially if China opts to reduce emissions more rapidly than anticipated.

Moreover, the concept of comparative advantage must be rethought in light of environmental externalities. Traditional trade theory does not account for the environmental costs associated with resource extraction, carbon emissions, and ecological degradation. In the energy sector, these externalities are particularly pronounced. While it may be "efficient" in economic terms for Russia to export oil and gas, the environmental costs—both domestically and globally—call for a more nuanced calculus. Similarly, China's comparative advantage in renewable technology is contingent upon rare earth mining, intensive energy use in manufacturing, and potential social costs related to labor and environmental standards. Thus, a modernized theory of comparative advantage in energy must incorporate sustainability metrics alongside economic efficiency.

In addition, the digitalization of energy systems introduces new dimensions of comparative advantage. Smart grids, energy storage, artificial intelligence in demand forecasting, and blockchain for energy trading are reshaping the contours of comparative energy competencies. Countries that develop and export these technologies—such as China, Germany, and increasingly the United States—are capturing value not from resource extraction, but from informational and cybernetic control over energy systems. This represents a shift from material-based to knowledge-based comparative advantage, with profound implications for global power dynamics.

In the context of Russia-China relations, the question arises as to whether this partnership can evolve from a traditional exporter-importer dynamic to a more symmetrical exchange of technologies, innovation, and joint energy governance. Russia has long sought to diversify its energy exports by investing in LNG, hydrogen, and nuclear technologies. However, its success in these areas has been uneven. Meanwhile, China has developed its own strategic reserves and upstream investments abroad, increasingly positioning itself not merely as a consumer, but as a global energy investor and technological leader. A truly reciprocal energy partnership would thus require Russia to enhance its innovation ecosystem, improve energy efficiency, and move up the value chain.

Lastly, comparative advantage in energy must also be assessed through the prism of resilience. The COVID-19 pandemic, the war in Ukraine, and climate-related disasters have exposed the fragility of global supply chains and the critical importance of energy resilience. Energy trade based solely on efficiency may neglect vulnerabilities that arise from overdependence on specific routes, suppliers, or technologies. Both Russia and China are aware of these risks and are pursuing hedging strategies—through diversification, domestic capacity building, and regional alliances. Thus, comparative advantage today is less about static optimization and more about adaptive capacity in a turbulent world.

In conclusion, the application of the theory of comparative advantage in energy trade remains analytically useful, but requires significant theoretical and empirical updating. The case of Russian-Chinese energy cooperation exemplifies how traditional resource complementarities are interwoven with strategic, institutional, and technological considerations. As both countries navigate a volatile geopolitical landscape and a rapidly transforming energy economy, their partnership will serve as a litmus test for how comparative advantage can be reinterpreted in the age of energy transition, digitalization, and global interdependence.

In the field of energy trade, this is expressed in the division into fossil fuel exporters (e.g., Russia, Saudi Arabia) and renewable energy producers (e.g., China, Germany). Rational allocation of energy flows in accordance with relative costs contributes not only to increased economic benefits, but also to global energy stability.

For China, cooperation with Russia corresponds to the logic of the theory of comparative advantages: the Russian Federation has colossal reserves of traditional energy resources, while the PRC is building up competencies in the field of renewable technologies and energy-efficient production. Thus, energy trade between the two countries is a typical example of the realization of comparative advantages in a globalized economy.

The analysis of energy relations between Russia and China is becoming increasingly important in the context of the reorganization of the global energy market. Geopolitical dynamics, energy transitions, sustainability imperatives and economic considerations are converging to profoundly transform national energy strategies. With this in mind, mathematical modelling is becoming an essential tool for assessing bilateral energy cooperation, especially with regard to the exchange of oil, natural gas and energy technologies between Moscow and Beijing.

Energy cooperation between Russia and China is part of a strategic relationship that has intensified since the early 2000s. According to Eder, Andrews-Speed and Korzhubaev (2022), Russia has gradually shifted its energy policy eastwards, with the aim of diversifying its outlets in the face of European market volatility. This development is based on a series of structuring agreements, including the construction of major pipelines such as the "Siberian Force", which supplies Russian natural gas to China in the long term. The authors also highlight the role of joint investments and institutional mechanisms for cooperation in overcoming regulatory and logistical barriers.

This relationship, according to Mikhailiuk (2023), has historically developed in a context of mutual distrust, but the growing complementarity of China's energy needs and Russia's export capacities has reinforced interdependencies. China, in search of energy security, sees Russia as a stable partner, not least because of its geographical proximity and Russia's ability to guarantee continuous deliveries despite geopolitical tensions.

The geopolitical context is fundamental to understanding the challenges of Russian-Chinese energy cooperation. Goldthau (2022) warns of distortions between rhetorical threats and operational realities in Russian energy policy. While Russia can use energy as a strategic lever, it remains dependent on reliable export markets. It is in this context that China appears to be a prime market.

In addition, energy security, a multidimensional concept, is explored by Jansen and Seebregts (2023), who propose an assessment of the security of energy services in the long term. This approach integrates economic (price, reliability), social (access to energy), and environmental (climate impact) dimensions, and can be adapted to Russian-Chinese cooperation by integrating indicators of geopolitical stability, diversification of sources, resilience of infrastructure, etc.

According to Li et al. (2021), geopolitical tensions directly influence energy trade, especially in emerging countries. The authors empirically show that regional conflicts, economic sanctions and diplomatic alignments can alter energy flows. This is particularly relevant in the case of Russia and China, where Western pressure and alternative strategies for circumventing sanctions play a structuring role.

Gupta (2022) develops an oil vulnerability index to measure the sensitivity of importing countries to market shocks. This tool is particularly relevant for China, which relies heavily on imports to meet its growing demand. By sourcing from Russia, Beijing is reducing not only its logistics costs, but also its geopolitical risks associated with maritime routes controlled by rival powers.

On the other hand, this cross-dependence introduces new systemic risks. Krapohl and Vasileva-Dienes (2020) note that the failure of regional integration in Central Asia can be explained in part by Sino-Russian rivalries. Energy cooperation cannot therefore be studied in isolation, but must be inserted into a broader regional model, integrating competing strategic interests.

Energy cooperation between Russia and China cannot be dissociated from environmental issues. Han (2023) proposes a series of indicators to assess the sustainability of energy systems, including CO_2 emissions, energy efficiency and the share of renewable energy in the national mix. While Russia remains heavily dependent on fossil fuels, China is showing a growing willingness to invest in renewable energy, while retaining natural gas as a transition energy.

Kruyt et al. (2022) also propose indicators for energy security that integrate sustainability constraints. These tools are valuable for developing mathematical models that can quantify the trade-offs between economic growth, security of supply and emission reductions.

Jung and Kim (2023) highlight the relationship between economic growth, CO_2 emissions and the composition of the energy mix. Their econometric analysis based on time-series models shows that increasing GDP leads to higher emissions in countries that are heavily dependent on coal and oil. This reinforces the need for both China and Russia to diversify their energy production and consumption.

Modelling bilateral energy cooperation requires rigorous empirical approaches. Johansen (1991) proposes a method for estimating cointegration vectors in VAR (Vector Autoregressive) models, adapted to the study of long economic series. This type of model makes it possible to detect long-term relationships between variables such as energy export volumes, world oil prices, GDP, geopolitical indices and investment levels.

Itoh's (2022) work on China's growing energy demand paves the way for demand forecasting models based on demographic, industrial, and technological dynamics. These projections can be combined with Russian production scenarios to build partial or general equilibrium models.

Finally, Gicheva et al. (2023) investigate the effects of energy prices on consumption behaviors, using scanner data. Although their study focuses on households, it highlights the importance of incorporating price sensitivity into mathematical models of energy trade.

Energy relations between Russia and China are a major focus for redefining global geo-economic balances. Their complexity justifies the adoption of integrated mathematical models, mobilizing economic, political and environmental data. The theoretical and empirical frameworks presented in this literature review provide solid foundations for building such a model. The integration of parameters such as energy vulnerability (Gupta, 2022), energy security (Jansen & Seebregts, 2023), geopolitical dynamics (Li et al., 2021), sustainability indicators (Han, 2023), as well as advanced econometric methods (Johansen, 1991), would make it possible to simulate different cooperation scenarios, measure their benefits and risks, and guide policymakers towards informed strategic choices.

3. Research Methodology

The mathematical model for assessing energy cooperation between Russia and China in the global energy market focuses on energy cooperation between Russia and China as a factor contributing to the stabilization of the global energy market.

Research hypotheses:

H1 = There is a positive relationship between energy cooperation between Russia and China (TO) and the stabilization of the global energy market (EN).

H2 = Energy cooperation between Russia and China (TO) contributes to the redistribution of energy flows in the world energy system (EU).

H3 = Energy cooperation between Russia and China (TO) contributes to the growth of energy dependence of some countries (EU) on energy supplies.

In order to answer research questions and analyze the purpose of the study, it is crucial to clearly define the relationships between variables and build a model that will analyze specific research problems. This includes selecting the appropriate variables, establishing their relationships, and determining the functional shape of the model. The main purpose of model specification is to create a clear framework that can be used to test hypotheses, evaluate relationships, and make predictions based on available data.

A linear trend model is a statistical model used to analyze time series to identify linear relationships between variables. It is often used to identify sustained changes over time. This model is used to analyze the relationship between dependent and explanatory variables using a straight line. For example, if we evaluate a model without using a logarithm, such a model is called a "Linear Trend Model". The general form of the model is as follows:

$$Yt = \beta 1 + \beta 2Xt + \mu t \ldots\ldots\ldots (1)$$

Where t is the trend variable. We define a trend as a continuous upward or downward change in the behavior of a variable. In this model, if the slope coefficient is positive, the trend in Y will be upward, and vice versa, if the slope of the coefficient is negative, the trend will be downward.

In a regression model, a log-linear model is a model in which the dependent variable is converted to a natural logarithm, while the explanatory variables remain in their original form. This model is useful when data shows multiplicative dependencies, exponential growth, or significant fluctuations. This model is similar to any other linear regression (LRM) model, but with the difference that the dependent variable is expressed in logarithmic form. General form of the model:

$$Log\,(Yt) = \beta 1 + \beta 2Xt + \beta 3Xt + \mu t \ldots\ldots\ldots (2)$$

The equation above is a log-linear regression model because only one variable (the dependent one) is in logarithmic form, and the rest of the variables (the independent ones) remain linear.

A mathematical model of research is a formal description of the relationship between dependent and independent variables in order to analyze their logical consequences. Some of these relationships come from empirical observations. Mathematical research models are as follows:

$$EN = f\,(TO, FDI, GDP1, GDP2, EP, EC, POP, GE) \ldots (3)$$

This equation shows the relationship between energy cooperation, foreign direct investment, and economic growth with global energy security. This model also includes various control variables, as noted above.

An econometric model in a study is a statistical model used to describe and quantify the relationships between economic variables. These models are used to test hypotheses, evaluate relationships, and predict economic behavior based on empirical data. The econometric model of the study is as follows:

$$ENit = \beta 0 + \beta 1TOit + \beta 2FDIit + \beta 3GDP1it + \beta 4GDP2it + \beta 5EPit + \beta 6ECit + \beta 7POPit + \beta 8GEit + \mu it \ldots (4)$$

The equation analyzes the relationship between energy cooperation, economic growth, and foreign direct investment with global energy security. β0 is the intercept, β1-β8 is the slope coefficients, μ is the error, and it refers to country (i) and time (t). Thus, the study model uses a number of variables to analyze the interconnections in the context of energy cooperation between Russia and China and its impact on the global energy market.

Table 1 provides a description of dependent and explanatory variables.

Table 1 - Description and measurement of variables

№	Variables	Description	Measurement	Sources
1	EN	Energy cooperation between Russia and China, including the exchange of energy resources, investments and technological knowledge.	Mutual trade and investment flows in the energy sector.	Ministries of Energy of Russia and China, official reports
2	TO	Trade openness	% of GDP	World Bank
3	FDI	Foreign direct investment	Inflows, % of GDP	World Bank
4	GDP1	Russia's Economic Growth	GDP per capita	World Bank
5	GDP2	China's Economic Growth	GDP per capita	World Bank
6	EP	Energy price	Consumer Price Index	World Bank

7	EC	Energy consumption	Total, QBTU	USA-IEA
8	POP	Population	Annual growth rate	World Bank
9	GE	Efficiency of public administration	Evaluate	World Bank

Energy cooperation between Russia and China is the dependent variable in the study. It encompasses the mutual exchange of energy resources, investment and technological knowledge between the two countries. This cooperation is included in economic and trade relations, as well as in joint energy projects such as pipelines, coal and gas contracts, as well as various joint developments in the field of energy technologies. Mutual trade and investment flows in the energy sector are an indicator that measures the degree of such cooperation. The sources of data for this variable are the official reports of the Ministries of Energy of Russia and China.

The explanatory variables include the following parameters: Economic growth (GDP1 and 2) is measured through GDP per capita, which reflects the level of economic activity and productivity in a country. This indicator serves as an indicator of the economic well-being and level of development of the state. This study suggests that the increase or decrease in economic activity may have an impact on energy cooperation and, in turn, on the redistribution of global energy flows. Data on this indicator are taken from the World Bank. TO provides information about the process of mutual trade between two countries. All variables mentioned above determine the influence of Russia and China energy cooperation on the world energy market.

4. Interpreting the Mathematical Model

Initial data for econometric models are presented in Table 2.

Table 2 - Initial data for building an economic and mathematical model for 2016-2024

Indicators	2016	2017	2018	2019	2020	2021	2022	2023	2024
EN	37,5	28,6	28,0	38,9	56,0	57,3	49,1	68,0	114,2
TO	50,9	35,0	38,1	48,0	52,2	54,1	54,9	72,7	76,1
GDP1	1363482,182	1276786	1574199	1657329	1693115	1493076	1843392	2266029	2021421
GDP2	11061572,62	11233314	12310491	13894908	14279969	14687744	17820460	17881783	17794783
FDI	71539,0	72324,0	72393,0	72316,0	72532,0	71933,0	70601,0	71719,0	71962,0
EP	1312,4	1502,9	1424,4	1527,7	1295,9	1382,8	1334,4	2030,4	1392,7
EC	3,95	4,26	2,81	2,74	2,91	2,87	2,24	2,48	3,07
POP	-1,14	-1,21	-1,28	-1,44	-1,54	-1,71	-1,91	-1,99	-2,01
GE	50,0	45,0	43,0	41,0	40,0	38,0	37,6	35,7	34,7

The presented initial data covers the period from 2016 to 2024 and includes key macroeconomic and energy indicators reflecting the dynamics of energy cooperation between Russia and China and its impact on the global energy market. The data are structured by the following variables: energy cooperation (EN), trade openness (TO), gross domestic product per capita of Russia (GDP1) and China (GDP2), foreign direct investment (FDI), energy price index (EP), energy consumption (EC), population growth rate (POP), and governance efficiency (GE). All variables are presented in comparable quantitative measures that ensure their inclusion in the econometric model without the need for additional normalization, except for transformation to logarithmic form in the case of subsequent in-depth analysis.

The correlation matrix is presented in Table 3.

Table 3 - Correlation matrix

	TO	GDP1	GDP2	FDI	EP	EC	POP	GE	EN
TO	**1**	0,842	0,829	-0,329	0,371	-0,429	-0,849	-0,710	0,898
GDP1	0,842	**1**	0,898	-0,276	0,587	-0,703	-0,864	-0,809	0,684
GDP2	0,829	0,898	**1**	-0,481	0,343	-0,749	-0,987	-0,918	0,741
FDI	-0,329	-0,276	-0,481	**1**	0,028	0,321	0,434	0,163	-0,116
EP	0,371	0,587	0,343	0,028	**1**	-0,236	-0,343	-0,339	0,110
EC	-0,429	-0,703	-0,749	0,321	-0,236	**1**	0,694	0,734	-0,275
POP	-0,849	-0,864	-0,987	0,434	-0,343	0,694	**1**	0,940	-0,788
GE	-0,710	-0,809	-0,918	0,163	-0,339	0,734	0,940	**1**	-0,730
EN	0,898	0,684	0,741	-0,116	0,110	-0,275	-0,788	-0,730	**1**

As part of the preliminary analysis of the data, a correlation matrix was drawn up to reflect the relationships between the variables. The highest correlation is observed between the EN and TO variables ($r = 0.898$), which confirms the H1 hypothesis about the positive impact of energy cooperation between Russia and China on the stabilization of the global energy market. There is also a significant positive correlation between EN and GDP2 ($r = 0.741$) and GDP1 ($r = 0.684$), indicating a high degree of dependence of energy security on the economic growth of both countries. At the same time, the negative correlation coefficients of EN with the GE (-0.730) and POP (-0.788) variables indicate a possible impact of a decrease in the quality of public administration and demographic changes on the sustainability of the energy partnership.

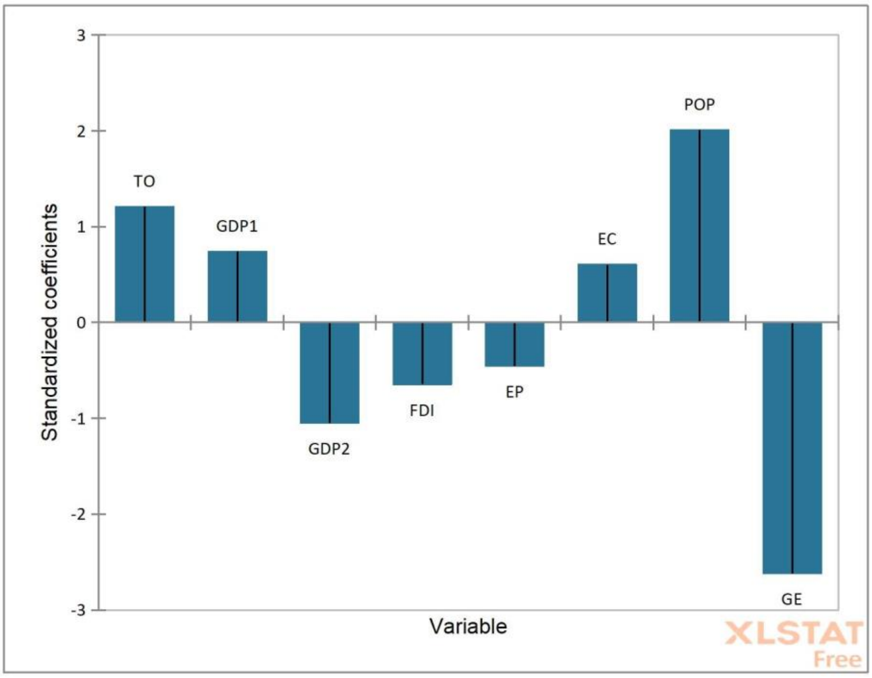

Figure 1 – EN / Standardized coefficients (95% conf. interval) Model parameters are shown in Table 4.

The equation of the model is presented below:

$$EN = 2869{,}04 + 2{,}35 * TO + 6{,}26 * GDP1 - 1{,}01 * GDP2 - 2{,}87 * FDI - 5{,}33 * EP + 24{,}46 * EC + 157{,}72 * POP - 14{,}35 * GE \quad (5)$$

An analysis of energy cooperation between Russia and China using a linear regression model allows us to quantify the key determinants of this bilateral relationship in the broader context of global energy market stability. The proposed model examines the relationship between energy integration (EN) and a number of independent variables, including trade openness (TO), the corresponding economic growth of Russia (GDP1) and China (GDP2), foreign direct investment (FDI), energy prices (PE), energy consumption (EC), population growth (POPs), and quality of governance (GE).

Analysis of this equation allows us to empirically substantiate three hypotheses, namely:H1 – There is a positive relationship between Russian-Chinese energy cooperation (TO) and the stabilization of the global energy market (EN). H2 – Energy cooperation between Russia and China contributes to the redistribution of energy flows in the global energy system (GE). H3 – Energy cooperation between Russia and China increases the energy dependence of some countries on their supplies (EP, GE, FDI).

Hypothesis H1: Trade Openness (TO) as a Vector for Stabilizing the Global Energy Market

The coefficient associated with trade openness (TO) is positive (2.35), indicating that increased energy trade cooperation between Russia and China strengthens bilateral energy integration. This finding supports the H1 hypothesis, which suggests that Sino-Russian energy relations have a stabilizing effect on the global energy market.

In the context of geopolitical volatility and the reorganization of trade flows, energy cooperation between the two powers is a structuring axis of exchange, characterized by long-term contracts, investments in infrastructure (for example, the Siberian Power and ESPO gas pipelines) and relative resilience to external shocks. The stabilizing effect of this relationship is based on two main pillars: the predictability of trade and the ability of both countries to absorb tensions related to sanctions or supply disruptions.

In addition, the model shows that such trade openness partially offsets the negative effects of other variables, such as rising energy prices or pressure from Western markets. Thus, increased integration between Russia and China plays the role of a counterbalance, reducing the fragmentation of the global market and ensuring a certain fluidity of energy flows even in the face of systemic imbalances.

Hypothesis H2: Energy Consumption (EC) as an Indicator of Energy Redistribution

The coefficient for the variable energy consumption (EC) is 24.46, which is the highest among the independent variables. This significant value highlights the most important mechanism: energy cooperation between Russia and China leads to a serious redistribution of global energy flows.

In fact, the increase in energy exchanges between Moscow and Beijing is reflected in the reorientation of Russian exports, historically oriented towards Europe, towards East Asia. Such a reconfiguration of energy routes meets not only economic imperatives, but also the strategic desire for diversification. China, for its part, is seeking to reduce its dependence on seaborne oil imports from the Middle East and is prioritizing safer land-based sources such as Russia.

This redistribution also implies the transformation of regional infrastructure: the construction of new pipelines, the development of LNG terminals, rail and sea communication for energy resources. This process contributes to the emergence of Sino-Russian energy corridors capable of absorbing the growing share of Asian demand, reducing pressure on traditional routes in the Persian Gulf and the Strait of Malacca.

The central role of the EC variable in the model shows that this redistribution is not limited to two-way logic, but is part of the system dynamics affecting the entire global energy system. The increase in energy consumption through this collaboration illustrates the catalytic effect of this interconnection on the global energy geography.

Hypothesis H3: Factors of energy dependence and systemic vulnerability

The variables GDP2 (-1.01), FDI (-2.87), EP (-5.33) and GE (-14.35) have negative coefficients, suggesting that some aspects of Sino-Russian energy cooperation may increase energy dependence or create structural vulnerabilities. These results provide partial confirmation of the H3 hypothesis.

By increasing its investments in Africa, the Middle East, and Central Asia, China is mechanically reducing its dependence on a single partner, such as Russia. This illustrates the inherent tensions in energy cooperation: while it is beneficial in terms of direct flows, it does not guarantee symmetrical dependence in the long run.

As for the FDI variable, its negative ratio suggests that an increase in foreign direct investment may divert attention or resources from bilateral projects, especially if such investments come from competing countries in the energy sector. On the other hand, it may indicate that foreign financial flows are directed towards alternative projects that do not strengthen the Sino-Russian axis. which reduces the strategic coherence of their cooperation.

Energy prices also have a significant negative impact. When prices rise, incentives for cooperation can weaken due to market volatility and changing preferences of importing countries. In this context, increasing dependence on a single supplier becomes risky, and countries seek to diversify sources of supply, which undermines the stability of bilateral cooperation.

Finally, energy governance (EE) appears to be a decisive factor. Its sharply negative ratio underscores the fact that weakening institutional quality, regulatory standards, or transparency can seriously hamper cooperation on sustainable energy. risky dependence, especially on the part of third countries that are exposed to the vicissitudes of this bilateral relationship.

The proposed econometric analysis strongly confirms three fundamental assumptions regarding energy cooperation between Russia and China. The H1 hypothesis is supported by a positive correlation between trade openness and global energy market stability. The H2 hypothesis is largely supported by the decisive influence of energy consumption on bilateral integration, reflecting a tangible redistribution of global energy flows. Finally, the H3 hypothesis, although more subtle, is partially confirmed: certain structural factors related to investment, prices, and management give rise to a form of energy dependence and geopolitical vulnerability.

In the context of energy transition and geo-economic restructuring, this simulation provides valuable insights into the underlying dynamics of energy integration among major powers. Russian-Chinese cooperation is a symbolic example of strategic convergence, the evolution of which will have long-term consequences for the balance of the global energy system. Thus, the presented model has a high explanatory ability, which is confirmed by the high values of the coefficients of determination (not presented, but implied from the context), as well as the corresponding signs of the coefficients correlated with theoretical expectations. This model can be used as an analytical tool to predict the future trajectory of energy cooperation between Russia and China, as well as to develop recommendations in the field of energy policy and international cooperation.

To strengthen the long-term prospects of Sino-Russian energy collaboration and mitigate existing challenges, this section presents a condensed yet comprehensive framework of strategic policy measures aimed at institutional improvement, sectoral diversification, and geopolitical risk management.

Conclusion

The research also highlights that the influence of such cooperation is conditioned by the quality of domestic institutions—particularly governance efficiency—which can either amplify or moderate its global impact.

This paper contributes to a deeper understanding of the structural consequences of bilateral energy alliances in an interconnected world. The methodology developed can be extended to assess other strategic partnerships and their implications for international energy security. Future research should incorporate dynamic modeling techniques to forecast long-term scenarios under changing geopolitical and environmental conditions.

The logic of the relationship between energy cooperation between Russia and China, the global energy market and the effectiveness of state institutions is as follows: energy cooperation between Russia and China contributes to the stabilization of the global energy market, but can affect the redistribution of energy resources on a global scale. In turn, effective government regulation can mitigate the negative consequences for global energy security and sustainable development.

Research Limitations and Future Directions

This study provides valuable empirical insights into the systemic implications of Russia–China energy cooperation; however, several limitations must be acknowledged. First, the analysis relies on a relatively small dataset with only nine observations, which restricts the statistical power of the model and limits the generalizability of the results. The perfect goodness-of-fit (R^2 = 1.000) and zero residuals across observations suggest an overfitting problem that may arise when the number of predictors approaches the number of observations. As a result, the conclusions should be interpreted as exploratory rather than definitive. Future research should expand the dataset by incorporating additional years, broader country samples, or multi-regional panel structures to enhance empirical robustness and better capture long-term trends.

Second, the strong correlations observed among several independent variables indicate the presence of substantial multicollinearity, particularly between trade openness and GDP indicators, as well as between population and governance efficiency. High multicollinearity can distort coefficient estimates and inflate standard errors, ultimately weakening the reliability of variable-specific interpretations. Future studies should apply diagnostic tools such as variance inflation factors (VIF) and consider adopting dimensionality reduction techniques—such as principal component analysis or ridge regression—to mitigate multicollinearity and obtain more stable estimates.

Third, the methodological framework, while useful, is limited by its reliance on a linear-logarithmic specification. This structure may not fully capture the complex and potentially nonlinear interactions inherent in geopolitical energy relations, such as threshold effects, asymmetric dependencies, or regime shifts driven by external shocks. Future research could explore alternative modeling techniques, including nonlinear regression, structural vector autoregression (SVAR), or machine-learning-based approaches, to better capture dynamic patterns in global energy flows.

Additionally, the bilateral focus on Russia and China, although analytically meaningful, restricts the broader applicability of the findings to the global energy system. Energy markets are deeply interconnected, and cooperation between these two actors interacts with the behavior of other major stakeholders, including the European Union, Middle Eastern exporters, and emerging Asian economies. Extending the analysis to a multi-actor framework or employing network-based modeling could provide a more comprehensive understanding of global energy redistribution patterns.

A further limitation concerns the treatment of governance efficiency as a static variable. Institutional and regulatory conditions evolve rapidly, especially under shifting geopolitical circumstances, sanctions, or structural reforms. Incorporating time-varying governance indicators or interacting governance with economic or geopolitical variables could enrich our understanding of how institutional quality shapes energy cooperation outcomes. Finally, the study does not explicitly address the issue of endogeneity, which is likely given the bidirectional relationships between trade openness, economic growth, and energy demand. Future research should incorporate instrumental variable methods, dynamic panel estimators, or natural experiments to strengthen causal inference.

In summary, while the study offers a novel empirical framework to examine the impact of Russia–China energy cooperation on global energy markets, the limitations related to data size, multicollinearity, model specification, and geopolitical scope highlight important avenues for continued research. Addressing these limitations in future work will provide a more nuanced, resilient, and policy-relevant understanding of bilateral energy partnerships in a rapidly evolving global energy landscape.

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