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Risks and Prospects for Russian Regional Export Development in the Face of the Global Energy Transition[1]

Abstract. Export development is a priority for the Russian economy, as it plays a crucial role in ensuring sustainable economic growth. In this context, understanding the determinants of regional export development is essential. In their export activities, Russian companies face a range of limiting factors, many of which have been thoroughly examined, with corresponding mitigation strategies incorporated into export plans. However, the role of the global climate agenda and the energy transition in shaping export development remains largely unexplored for Russian regions. The shift of focus to fulfilling environmental goals creates a new type of economic risk for exporters — transitional climate risks, which intensified after February 2022. This study investigates the comprehensive impact of the global energy transition on export flows in Russian regions and identifies region-specific factors that influence how the energy shift affects export levels. The hypothesis is that the global energy transition creates both risks and opportunities for Russian regions, with varying effects depending on the specific components of the energy shift and the socio-economic and environmental characteristics of each region. Using the gravity equation with the Poisson Pseudo-Maximum Likelihood (PPML) technique, the study finds that the impact of the global energy transition on Russian regional exports is multidirectional. First, environmental regulations in partner countries reduce exports from many Russian regions by 0.3 %, though regions with favorable socio-economic conditions for innovation and active regional environmental policies see an increase in exports—by 0.3 % and 0.7 %, respectively. Second, the production of alternative energy in partner countries decreases Russian exports by 0.2 %. Finally, exports from mineral-abundant Russian regions benefit from the global energy transition. These findings contribute to the literature on Russian export promotion and offer valuable policy insights for addressing the challenges and opportunities posed by the global energy transition.

Keywords: export, global energy transition, transitional climate risks, environmental regulation, Russian regions, Gravity Model

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Риски и перспективы развития экспорта регионов России в условиях глобального энергетического перехода

Аннотация. Интенсификация экспорта является приоритетом России, что обусловлено способностью экспортной деятельности обеспечить устойчивый экономический рост. В данном контексте на первый план выходит изучение детерминант развития экспорта. Российские экспортеры сталкиваются с рядом ограничивающих факторов. Большинство рисков исследованы, а меры по их минимизации включены в экспортные стратегии. Для российских регионов остается неизученной роль глобальной климатической повестки и процесса энергетического перехода в развитии экспорта. Намерения стран по достижению экологических целей создают новый тип экономических рисков для экспортеров — переходные климатические риски, которые в значительной мере интенсифицировались после февраля 2022 г. В исследовании рассматривается комплексное влияние глобального энергетического перехода на экспортные потоки российских регионов. Кроме того, цель работы — выявить региональные факторы, определяющие влияние энергетического перехода на объемы экспорта. В исследовании выдвинута гипотеза о том, что глобальный энергетический переход может генерировать как риски, так и возможности для российских регионов, причем эффект может варьироваться в зависимости от выбранного компонента энергетического перехода, а также социально-экономических и экологических характеристик региона. Оценка гравитационного уравнения с помощью метода псевдомаксимального правдоподобия Пуассона (PPML) показывает, что влияние глобального энергетического перехода на экспортные показатели российских регионов носит разнонаправленный характер. Во-первых, экологическое регулирование торговых партнеров создает риски для многих регионов России, сокращая экспорт на 0,3 %, но увеличивает экспорт из регионов с наиболее благоприятными социально-экономическими условиями для инновационной деятельности (на 0,3 %) и активной региональной экологической политикой (на 0,7 %). Во-вторых, производство альтернативных источников энергии в странах-партнерах снижает российский экспорт на 0,2 %. Наконец, в условиях глобального энергетического перехода усиливается экспорт регионов России, богатых полезными ископаемыми. Результаты исследования расширяют существующую литературу по стимулированию российской внешнеэкономической деятельности и способствуют выработке стратегий развития экспорта.

Ключевые слова: экспорт, глобальный энергетический переход, переходные климатические риски, экологическое регулирование, регионы России, гравитационная модель.

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Introduction

Export promotion has become a key priority for the Russian economy, with the national agenda shifting in 2016 from import substitution to enhancing exports, recognizing their role in strengthening the country's position in the international market. An increase in export activities can boost Russia's economic growth by expanding production, productivity, job creation, and attracting foreign funds (Kadochnikov & Fedyunina, 2013; Malca et al., 2019; Islam et al., 2022; Lee & Zhang, 2022; Fedyunina et al., 2023), which necessitates further research on the factors influencing export development in Russian regions.

Russian companies, however, face internal constraints, including high production costs, technological lag, limited product variety, and misalignment with international market demands, as well as external factors like market requirements, trade restrictions, and geopolitical risks (Volchkova, 2013; Glazatova & Daniltsev, 2020). These challenges have been widely studied, and strategies to address them have been integrated into export development frameworks. In sum, to enhance Russia's export capacity and

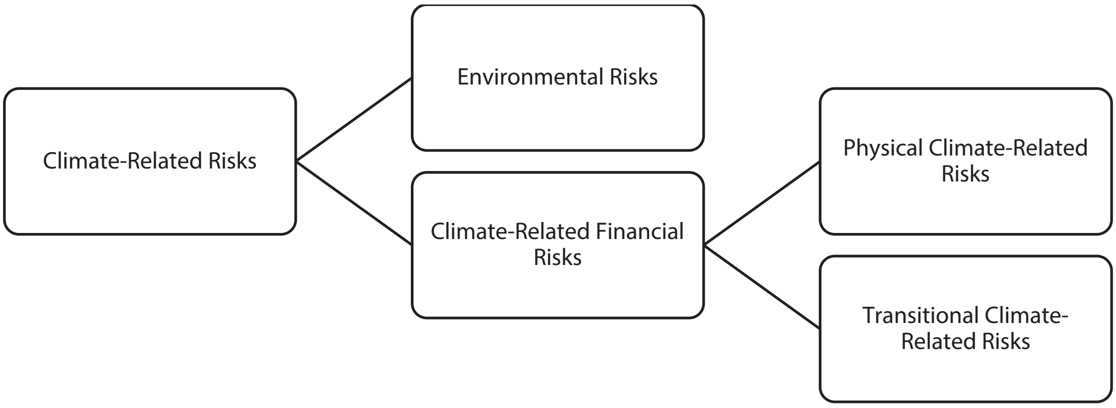

Fig.1 *Classification of Climate-Related Risks*
Sources: Bank of Russia (https://cbr.ru/Content/Document/File/143643/Consultation_Paper_21122022.pdf, accessed: December 2023), TCFD (https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf, accessed: December 2023)

economic growth, it is essential to address both internal and external barriers.

Global climate agenda and energy transition process can also be considered among the international challenges faced by Russian exporters. Countries' intentions to achieve the goals of the Paris Agreement create a new type of economic risk — transitional climate risks[1] (Fig. 1). The main difference between transitional and physical climate risks is that financial losses do not arise from climate change, but from the actions of the public and private sectors aimed at curbing these changes[2]. The drivers of transitional climate risks can be categorized into four groups: (1) regulatory, including national climate policies and environmental regulations; (2) technological, such as the development of low-carbon technologies; (3) behavioral, referring to the preferences of consumers, investors, and counterparties for environmentally-friendly products and companies; and (4) geopolitical, focusing on countries' efforts to secure energy through the development of alternative energy sources in response to growing geopolitical risks[3].

Export activities, especially in countries supplying environmentally sensitive products, can be vulnerable to the negative impact of transition climate risks. First, international trade is often seen as a contributing factor to environmental problems (LaPlue, 2019; Dardati & Saygili, 2021; Ma & Wang, 2021). Second, limiting the global temperature rise to below 1.5°C cannot be achieved through the environmental policies of individual countries alone. Copeland (1996) and Nordhaus (2015) argue that all nations must be engaged in the environmental agenda through global trade mechanisms. Finally, it is essential to integrate trade mechanisms to achieve carbon neutrality, as countries with more relaxed environmental regulations may gain a competitive edge in the global market (Ederington, & Minier, 2003).

There is ample empirical evidence that transitional climate risks, particularly the stringency of environmental regulations in importing countries, negatively affect export values (Fig. 2). Beers & Ven den Bergh (1997), Xu (2000), Cagatay & Mihci (2006), and Tsurumi et al. (2015) argue that strict environmental regulations increase production and distribution costs for exporters, resulting in a loss of competitiveness.

On the other hand, transitional climate risks can create opportunities for export growth. This perspective is based on the dynamic model of international competitiveness proposed by Porter and Van Der Linde (1995), which suggests that environmental requirements encourage companies to innovate in environmental protection technologies. Studies by Costantini and Mazzanti (2012), Wang et al. (2015), Gong et al. (2020), Xie et al. (2020), He & Huang (2021), Wang et al. (2021), Qiang et al. (2021), Chen et al. (2022), Hamaguchi (2023), and Yu & Zheng (2024) show that this innovation-driven effect boosts export values, diversifies export structures, and enhances product quality. However, the extent of this stimulating effect varies depending on the type of environmental regulation, the stage

[1] Climate risks in changing economic conditions. URL: https://cbr.ru/Content/Document/File/143643/Consultation_Paper_21122022.pdf (In Russ.) (Accessed: December 2023).

[2] Recommendations of the Task Force on Climate-related Financial Disclosures. URL: https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf (Accessed: December 2023).

[3] What is Energy Transition? URL: https://www.spglobal.com/en/research-insights/articles/what-is-energy-transition (Accessed: January 2024); Energy Transitions Indicators. URL: https://www.iea.org/articles/energy-transitions-indicators (Accessed: January 2024); The Global Energy Transition: How the World Sees It. URL: https://energytracker.asia/what-is-energy-transition-an-ultimate-guide/ (Accessed: January 2024).

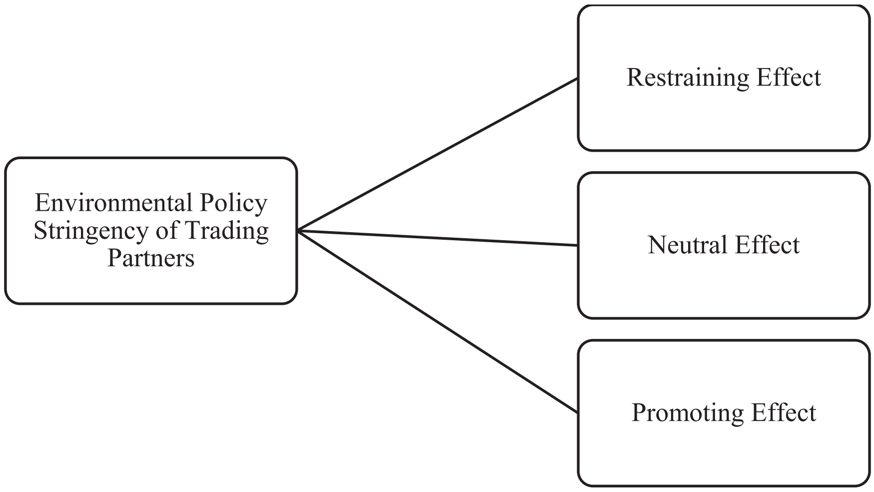

Fig. 2 *Influence of Environmental Policy Stringency on Export Values*
Source: compiled by the author

of innovation and economic development, and government support.

Moreover, since the global energy transition rests heavily on mineral resources such as ferrous and precious metals and rare earth elements, the exports of countries with a specialization in the manufacture of these commodities are increasing significantly (Grandell, et al., 2016; Watari et al., 2019; Lundaev et al., 2023; Liang et al., 2023). Thus, the global energy transition process presents a promising opportunity for the export development of mineral-rich nations (Olawuyi, 2021; Islam et al., 2022; Zhu et al., 2022; Sohag et al., 2023; Islam and Sohag, 2023; Srivastava, 2023).

Evaluating the export prospects of Russian regions under transitional climate risks is a complex task. Russia is one of the largest emitters of pollution, with up to 20 % of the country's emissions arising from the production of export goods. Additionally, countries with strong environmental policies dominate the geographical structure of Russia's CO_2 exports. Meanwhile, Russia's environmental policies are lagging behind, which could lead trading partners to push for more significant efforts from Russia to meet global environmental goals through trade-based environmental regulations (Makarov et al., 2018; Mitrova & Melnikov, 2019; Makarov et al., 2020). In this context, energy-intensive exports from Russian regions, such as metallurgical, chemical, and petrochemical products, may face significant challenges (Martus, 2019). However, according to Porter's Hypothesis, environmental barriers can serve as a strong incentive for innovation, potentially boosting exports and opening access to new markets.

In 2021, Russia was the third-largest exporter of fossil fuels, with a market share of 8.3 %. Over the past two decades, developed countries have made up the largest share of Russia's energy exports. The high dependence of these countries on Russian energy imports has attracted significant attention from policymakers in advanced nations (Fig. 3). Current efforts to reduce reliance on Russian imports are driven by goals to achieve zero emissions, economic pressures, and geopolitical factors (Perdana et al., 2022; Chepeliev et al., 2022; Crowley-Vigneau et al., 2023). The development of the alternative energy sector is seen as a key strategy for decreasing dependence on Russian energy supplies (Krane & Idel, 2021; Cergibozan, 2022). As a result, the global energy transition poses risks for exports from regions specializing in fossil fuel production (Sokhanvar & Sohag, 2022).

While energy exporters face risks, the global energy transition is creating new growth opportunities for mineral producers in Russian regions. Russia remains crucial to the global energy transition, as it is the largest producer of critical minerals such as cobalt, nickel, lithium, iridium, palladium, platinum, zinc, copper, and uranium. Cherepovitsyn & Solovyova (2022), Chupina (2022), Cherepovitsyn et al. (2023), and Dmitrieva et al. (2023) concluded that, given Russia's resource potential in critical minerals, several regions could significantly contribute to global energy transformation trends and boost their exports.

The vulnerability of the Russian economy to the global energy transition has been apparent since the Paris Agreement was signed, due to the significant share of the energy sector in GDP and the high carbon footprint of exports. However, since February 2022, there has been a significant intensification of transitional climate risks for the Russian economy since Western countries are accelerating their plans to limit Russia's carbon-intensive exports and reduce reliance on Russian energy imports. In addition, in the context of the current geopolitical

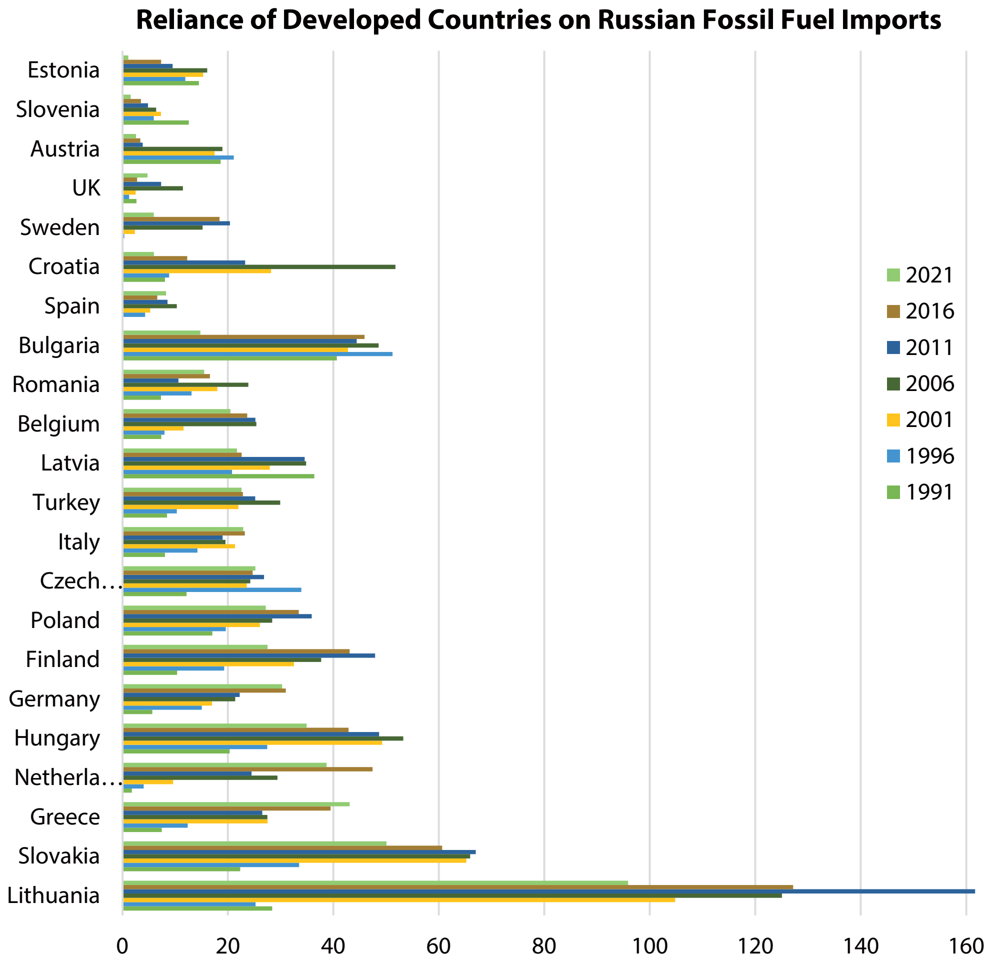

Fig.3. *Reliance on Russian Fossil Fuel Imports in 1991–2021, %*

Resources: Compiled by the author based on the data of the International Energy Agency (IEA) (URL: https://www.iea.org/reports/national-reliance-on-russian-fossil-fuel-imports/which-countries-are-most-reliant-on-russian-energy, accessed December 2023).

crisis, the importance of transitional climate risks for country's exports is emphasized by the fact that redirecting export flows to states that have not joined the imposition of sanctions against Russia will not fully minimize such risks. Firstly, in "friendly" states there is an acceleration of environmental policy and introduction of environmental regulation instruments (for example, China, Kazakhstan, Turkey). Secondly, the execution of export contracts, for example, for the supply of Russian energy, may be hampered by the lack of necessary infrastructure. Thirdly, the markets of "friendly" states are less capacious and their solvency may be affected by the imposition of sanctions by Western countries.

The aim of this investigation is to explore the role of the global energy transition as a factor influencing export development in Russian regions through econometric modeling. Additionally, the study seeks to identify regional characteristics that shape the impact of the global energy shift on export values. To achieve these objectives, the global energy transition process is presented from three perspectives: environmental policy stringency, production of alternative energy, and readiness for the energy transition. Russian regions are categorized into subsamples based on mineral endowment, the socio-economic conditions of innovation activity, and the region's openness to the Green Deal. The investigation hypothesizes that the global energy transition can generate both risks and opportunities for Russian regions, with the effects varying depending on the region's natural resources, innovation potential, and environmental policies.

This study contributes to the existing literature in several ways. The multivariate relationship between the global energy transition and export performance has not been extensively examined for Russian regions. This research examines this relationship using the Extended Gravity Model, estimated with the Poisson Pseudo-Maximum Likelihood (PPML) technique. The analysis is based on data from 84 Russian regions and 204 trading partner countries. Furthermore, while previous studies often generalize findings for Russia's exports, this study focuses on the heterogeneity of the global energy transition's effects on export values by dividing regions into subsamples using a clustering method.

The research is structured as follows. The introduction offers a review of the literature and discusses the current situation, followed by a description of the empirical model and methodology. Finally, the empirical results of the research are presented.

Data and Methodology

The exports dynamics of Russian regions in the context of the global energy transition is examined with regard to the Gravity Model, which enables to explain trade patterns through economic masses of countries, distance, socio-cultural, regulatory, and environmental factors (Yotov et al., 2016).

The Gravity Model is modified as follows (see Table 1 below). Export flows from each Russian region to each importing country are considered as the pair-wise dependent variable. The first group of traditional gravity variables includes GRP and population of Russian regions, GDP and population of trading partner countries, distance, and a binary variable for the common land border between the region and the partner country. The second group of explanatory variables consists of factors determining the export potential of Russian territories. This includes controls for resource endowment, human capital, financial sector development, institutional maturity, infrastructure availability, production capacity, and regional market capacity. The availability of natural resources is represented by the share of the extractive sector in the GRP structure, while other components are integrated using the RAEX investment potential index. Additionally, trade barriers driven by geopolitical tensions are considered.

A distinctive feature of this analysis is the examination of three aspects related to the possible influence of the global energy transition process on the export values of Russian regions. First, transitional climate risks are captured by the Index of Environmental Policy Stringency of importing nations. The assumption is that a higher index indicates stronger intentions to limit the competitiveness of countries that do not actively pursue environmental policies through environment-related trade barriers. Second, given that the global energy transition involves increased use of alternative energy sources and reduced reliance on fossil fuels, the total renewable energy generation of trading partner countries is integrated into the Gravity Model. This reflects changes in export values of Russian regions resulting from reduced dependence on Russian energy imports. Third, the analysis recognizes that the global energy transition heavily relies on the use of mineral products. Variables SC_{jt}, WC_{jt}, and ETI_{jt} reflect the potential demand of importing counties for mineral products of Russian regions.

The logic of the study is illustrated in Fig. 4. The investigation consists of two key strands. The first focuses on assessing the impact of each component of the global energy transition on the exports of Russian regions, categorized by mineral endowment. The second examines the effect of environmental regulation stringency—one of the components of the global energy transition—on export values in Russian regions. At this stage, the analysis explores the role of regional socio-economic conditions, innovation capacity, and environmental policies in shaping how the environmental requirements of host markets influence the export performance of Russian regions.

Estimating the Gravity Model is complex due to econometric challenges such as zero trade flows, heteroskedasticity, endogeneity, and unobservable factors (Yotov et al., 2016). The Poisson Pseudo-Maximum Likelihood (PPML) method effectively addresses most of these issues. According to Correia et al. (2020), PPML allows for the inclusion of exporter and importer fixed effects, as well as pairwise effects, to control for unobservable factors. This method directly estimates the gravity equation using a Poisson maximum likelihood function (Eq. 1) and accounts for data heteroscedasticity.

$$EV_{ijt} = \exp(\beta_0 + \beta_1 GRP_{it} + \beta_2 GDP_{jt} + \beta_3 P_{it} + \beta_4 P_{jt} + \\ + \beta_5 D_{ij} + \beta_6 B_{ij} + \beta_8 MAB_{it} + \beta_9 IPOT_{it} + \beta_{10} TS_{jt} + \\ + \beta_{11} TCR_{jt} + \pi_i + \chi_j + \sigma_{ij}) + \varepsilon_{ijt} \quad (1)$$

where EV_{ijt} represents export flows from region i to country j, GRP_{it} and GDP_{jt} stand for gross domestic products of exporting region and importing country, P_{it} and P_{jt} signify population of region i and country j, D_{ij} portrays distance between the economic centres of regions and trade-partner, B_{ij} is the dummy variable for common border between region i and country j, MAB_{it} and $IPOT_{it}$ represent the mineral abundance and investment potential of region i, TS_{jt} typify trade sanctions enacted by country j against Russia. TCR_{jt} stands for transitional climate risks, represented by ES_{jt} (environmental policy stringency), RE_{jt} (total renewable energy generation), SC_{jt} (solar energy generation), WS_{jt} (wind energy generation), ETI_{jt} (Energy Transition Index). π_i if fixed effects of region i, χ_j is fixed effects of country j, σ_{ij} is pairwise fixed effects, ε_{ijt} is standard error of the gravity equation.

Results and Discussion

Table 1

Variables and Data Sources

Variable	Definition	Data Source
Dependent variable		
EV_{ijt}	Value of exports from Russian region i to trading partner country *j* at time *t*	Customs services of the Federal Okrugs of Russia (URL: https://customs.gov.ru/structure/regional, accessed December 2023)
Explanatory variables		
GRP_{it}	Gross domestic product of Russian region *i* at time *t*	Rosstat (URL: https://rosstat.gov.ru/folder/210/document/13204/, accessed December 2023)
GDP_{jt}	Gross domestic product of trading partner country *j* at time *t*	UNCTADstat (URL: https://unctadstat.unctad.org/datacentre/dataviewer/US.GDPTotal, accessed December 2023)
P_{it}	Population of Russian region *i* at time *t*	Rosstat (URL: https://rosstat.gov.ru/folder/210/document/13204/, accessed December 2023)
P_{jt}	Population of trading partner country *j* at time *t*	World Development Indicator (URL: https://data.worldbank.org/indicator/SP.POP.TOTL?y, accessed December 2023)
D_{ij}	Geographic distance between economic centers of Russian region *i* and trading partner country *j*	Author's calculations are based on Google maps
B_{ij}	= 1 if Russian region *i* and trading partner country *j* have a common land boarder, = 0 otherwise	Author's calculations are based on Google maps
$IPOT_{it}$	Share of Russian region *i* at time *t* in the all-Russian investment potential	Russian Rating Agency RAEX (URL: https://raex-rr.com/regions/investment_appeal/investment_potential_of_regions/2020/, accessed December 2023)
TS_{jt}	= 1 if trading partner country *j* at time *t* introduced trade sanctions against Russia, = 0 otherwise	The Global Sanctions Data Base (Syropoulos et al., 2023)
ES_{jt}	Environmental policy stringency index of trading partner country *j* at time *t*	OECDstat (URL: https://stats.oecd.org/Index.aspx?DataSetCode=EPS, accessed December 2023)
RE_{jt}	Total renewable energy generation of trading partner country *j* at time *t*	Energy Institute Statistical Review of World Energy (URL: https://ourworldindata.org/grapher/modern-renewable-prod, accessed December 2023)
SC_{jt}	Cumulative installed solar capacity of trading partner country *j* at time *t*	International Renewable Energy Agency (IRENA) (URL: https://ourworldindata.org/grapher/installed-solar-pv-capacity?tab=map, accessed December 2023)
WC_{jt}	Cumulative installed wind capacity of trading partner country *j* at time *t*	International Renewable Energy Agency (IRENA) (URL: https://ourworldindata.org/grapher/cumulative-installed-wind-energy-capacity-gigawatts, accessed December 2023)
ETI_{jt}	Energy Transition Index (ETI) of trading partner country *j* at time *t*	World Economic Forum (WEF) (URL: https://www.weforum.org/publications/fostering-effective-energy-transition-2023/country-deep-dives-a57a63d0d5/, accessed December 2023)
Variables for cluster analysis		
MAB_{it}	Share of the extractive sector in the GRP structure of Russian region *i* at time *t* Groups of Russian regions based on cluster analysis (k-means method): (1) Mineral-scarce regions (the average share of extractive sector in the GRP structure is ranging from 0 to 5 %); (2) Regions with the medium level of natural resource endowment (the average share of extractive sector in the GRP structure is ranging from 6 to 40 %)	Rosstat (URL: https://rosstat.gov.ru/folder/210/document/13204/, accessed October 2023)

Окончание Табл. 1 на след стр.

Окончание Табл. 1

Variable	Definition	Data Source
MAB_{it}	(3) Mineral-abundant regions (the average share of extractive sector in the GRP structure is ranging from 41 to 100 %)	
$SECI_{it}$	Index of socio-economic conditions of innovative activity of Russian region *i* at time *t* Groups of Russian regions based on cluster analysis (k-means method): (1) Regions with a favorable socio-economic environment for innovative development (the average Index is ranging from 0.400 to 1.000) (2) Regions with an average socio-economic environment for innovative development (the average Index is ranging from 0.250 to 0.399) (3) Regions with a unfavorable socio-economic environment for innovative development (the average Index is ranging from 0.000 to 0.249)	Higher School of Economics (URL: https://www.hse.ru/primarydata/rir, accessed January 2024)
$OGDI_{it}$	Index of openness to the Green Deal of Russian region *i* at time *t* Groups of Russian regions based on 2021 Survey: (1) Regions with active environmental policy (≥ 6 Green Deal measures, 1 breakthrough decision, no false solutions) (2) Regions with moderate environmental policy (< 6 Green Deal measures, no breakthrough solutions, 1 false solution) (3) Regions with lagging-behind environmental policy (< 6 Green Deal measures, no breakthrough solutions, 2 false solutions)	Rating of Russian Regions' Openness to the Green Deal (URL: https://esg-library.mgimo.ru/publications/reyting-otkrytosti-regionov-rossii-k-zelyenomu-kursu/, accessed January 2024)
i = 1, ..., 84 (Russian regions) *j* = 1,..., 204 (Trading partners) *t* = 2013, ..., 2021 (Time)		

Source: compiled by the author.

The descriptive statistics (Table 2) show that: (1) distance and trade sanctions negatively impact export indicators, while GRP, population, mineral endowment, and investment potential have a positive effect on export values; (2) environmental controls and renewable energy production in partner countries are negatively associated with exports from Russian regions; and (3) the deployment of clean energy capacity and institutional readiness for the energy transition process positively contribute to the growth of Russian exports.

The association between transitional climate risks and export values of Russian regions is studied utilizing the Gravity Model of international trade assessed by the PPML method. The results for the general subsample of Russian regions are presented in Table 3. The main drivers for the development of Russian regional exports are the following: GRP of the region, GDP of the trading partner, the common land border between the exporting and importing regions, the availability of natural resources and investment potential. Transport costs and the introduction of trade sanctions are negatively related to the export values of Russian regions.

Environmental regulation of trading partner countries is negatively related to the export values of Russian regions, which is consistent with the study by Makarov et al. (2020). This association can be explained by the following: environmental regulation acts as a trade barrier; environmental requirements of importing countries increase the costs of Russian exporters, which negatively affects competitiveness; Russian companies respond ineffectively to environmental requirements.

Table 3 shows that the influence of the alternative energy production in importing countries is adverse as well, indicating the reduced reliance on Russian energy, which is in line with Sokhanvar & Sohag (2022). The results on the influence of SC_{jt}, WC_{jt}, and ETI_{jt} variables are mixed.

Table 3 shows an inverse correlation between the environmental and climate regulation sophistication of importing countries and export flows from Russian regions. However, our literature review suggests that

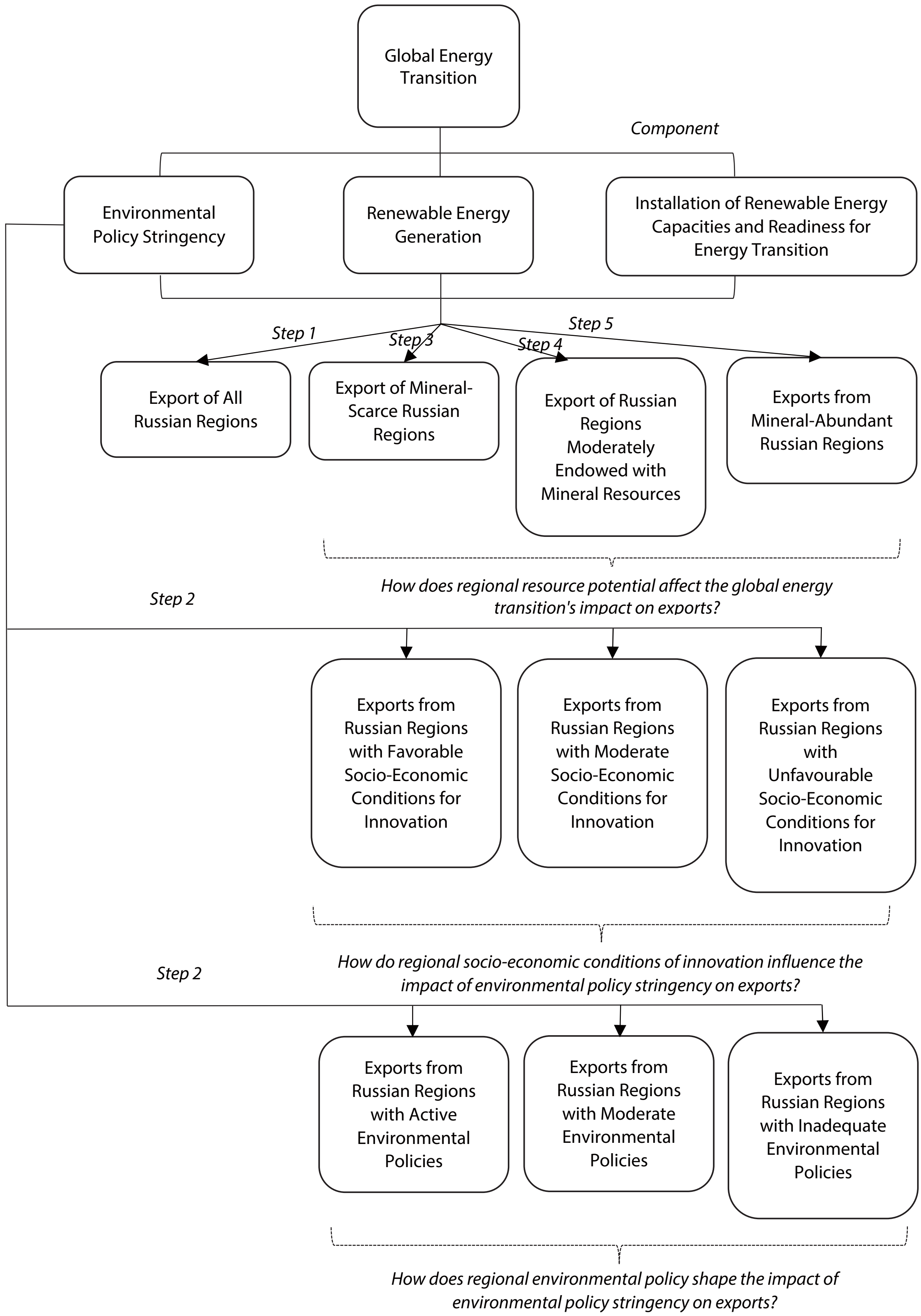

Fig.4. *Methodology*

Notes: The empirical results of the steps are presented in the following tables: Step 1 — Table 3, Step 2 — Table 4, Step 3 — Table 5, Step 4 — Table 6, Step 5 — Table 7.

Source: compiled by the author.

Table 2

Descriptive Statistics and Correlation Matrix

Var.	EV_{ijt}	GDP_{it}	GDP_{jt}	P_{it}	P_{jt}	D_{ij}	B_{ij}	MAB_{it}	$IPOT_{it}$	TS_{jt}	ES_{jt}	RE_{jt}	SC_{jt}	WC_{jt}	ETI_{jt}
Mean	0.023	0.982	0.038	1.736	0.036	6.943	0.002	10.718	1.203	0.161	2.951	0.032	2.074	3.352	53.853
Std. Dev.	0.364	0.206	1.490	1.764	1.408	3.783	0.051	16.969	1.726	0.368	0.850	0.147	13.607	18.062	9.224
Min	0.000	0.001	0.001	0.001	0.001	0.105	0.000	0.000	0.172	0.000	0.000	0.000	0.000	0.000	33.350
Max	30.926	20.170	22.877	14.393	1.439	18.346	1.000	75.000	15.318	1.000	4.888	2.448	306.972	328.973	78.700
Obs	154 020	154 224	154224	154224	154224	154 224	154224	153819	136272	154224	21504	141 372	140 868	99 372	85680
Correlation matrix															
Var.	EV_{ijt}	GDP_{it}	GDP_{jt}	P_{it}	P_{jt}	D_{ij}	B_{ij}	MAB_{it}	$IPOT_{it}$	TS_{jt}	ES_{jt}	RE_{jt}	SC_{jt}	WC_{jt}	ETI_{jt}
EV_{ijt}	1.000														
GPP_{it}	0.232^b	1.000													
GDP_{jt}	0.098^b	0.008	1.000												
P_{it}	0.191^b	0.812^b	0.000	1.000											
P_{jt}	0.080^b	0.001	0.432^b	0.000	1.000										
D_{ij}	–0.018^b	–0.018^b	–0.030^b	–0.050^b	–0.071^b	1.000									
B_{ij}	0.027^b	0.009^b	0.028^b	–0.004	0.051^b	–0.081^b	1.000								
MAB_{it}	0.001	0.079^b	0.000	–0.154^b	0.000	0.000	–0.011^b	1.000							
$IPOT_{it}$	0.235^b	0.949^b	0.000	0.517^b	0.000	–0.030^b	–0.007^b	–0.067^b	1.000						
TS_{jt}	–0.048^b	–0.009^b	0.000	0.000	–0.048^b	–0.321^b	0.012^b	0.004	0.000	1.000					
ES_{jt}	–0.030^b	0.008	0.009^b	0.000	–0.192^b	–0.053^b	–0.007^b	0.002	0.000	0.451^b	1.000				
RE_{jt}	–0.108^b	0.004	0.762^b	0.000	0.069^b	–0.002^b	0.006^b	0.005	0.000	0.115^b	0.095^b	1.000			
SC_{jt}	0.116^b	0.009^b	0.505^b	0.000	0.060^b	–0.008^b	0.004^b	0.002	0.000	0.097^b	0.090^b	0.799^b	1.000		
WC_{jt}	0.113^b	0.005	0.507^b	0.000	0.071^b	–0.008^b	0.005^b	0.002	0.000	0.050^b	0.051^b	0.876^b	0.926^b	1.000	
ETI_{jt}	0.044^b	0.004	0.195^b	0.000	0.000	–0.005^b	–0.002^b	0.001	0.000	0.547^b	0.654^b	0.654^b	0.107^b	0.098^b	1.000

Notes: Descriptive statistics and correlation matrix are presented for the sample of all Russian regions. *b* – significance at the 5 % level.
Source: Author's calculations are based on Stata 17.

Table 3

Relationship Between Transitional Climate Risks and Exports from Russian Regions

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$lGRP_{it}$	0.802[a] (0.088)	0.677[a] (0.069)	0.672[a] (0.069)	0.680[a] (0.071)	0.674[a] (0.072)
$lGDP_{jt}$	0.848[a] (0.035)	0.804[a] (0.027)	0.785[a] (0.020)	0.755[a] (0.021)	0.772[a] (0.021)
lP_{it}	0.008 (0.070)	0.069 (0.061)	0.050 (0.062)	0.063 (0.062)	0.049 (0.064)
lP_{jt}	–0.138[c] (0.017)	–0.045[c] (0.014)	–0.066[c] (0.014)	–0.046[c] (0.014)	–0.059[c] (0.013)
lD_{ij}	–1.536[a] (0.074)	–1.583[a] (0.042)	–1.559[a] (0.041)	–1.555[a] (0.046)	–1.509[a] (0.046)
$l(1 + B_{ij})$	0.862[a] (0.221)	0.676[a] (0.129)	0.752[a] (0.129)	0.661[a] (0.132)	0.713[a] (0.143)
$lMAB_{it}$	0.315[a] (0.123)	0.268[a] (0.016)	0.263[a] (0.016)	0.270[a] (0.016)	0.271[a] (0.017)
$lIPOT_{it}$	0.362[b] (0.135)	0,491[a] (0.094)	0.508[a] (0.095)	0.490[a] (0.090)	0.505[a] (0.099)
$l(1 + TS_{jt})$	–0.951[a] (0.123)	–0.666[a] (0.089)	–0.731[a] (0.088)	–0.757[a] (0.088)	–0.608[a] (0.099)
lES_{jt}	–0.341[b] (0.099)				
lRE_{jt}		–0.140[a] (0.010)			
lSC_{jt}			0.030[c] (0.010)		
lWC_{jt}				–0.010[c] (0.006)	
$lETI_{jt}$					–0.189 (0.164)
Prob > F	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.580	0.652	0.673	0.640	0.510

Notes: *a* – significance at the 1 % level; *b* – significance at the 5 % level; *c* – significance at the 10 % level; standard clustered regression errors are presented in parentheses; *i* – indicator of Russian regions; *j* – indicator of trading partner countries; *t* – time. Estimation of the gravity equation in Stata 17 using the Pseudo-Maximum Likelihood (PPML) method implies that the dependent variable is reported without logarithms, while the explanatory variables are represented in logarithms. This is why letter *l* before the variable name indicates that it is represented in logarithmic form. Fixed effects of exporting regions, importing countries, pairwise fixed effects are taken into account when estimating empirical models.
Source: Author's calculations are based on Stata 17.

stricter environmental policies can also boost exports for some Russian regions. This positive effect occurs in regions with high innovation potential and active environmental policies (Table 4). First, these regions' well-developed innovation environments enable companies to effectively adapt to environmental regulations. Firms in these areas are better positioned to introduce environmental innovations, technologies, and product improvements. Additionally, their higher productivity allows them to more efficiently internalize environmental costs, confirming the findings of Costantini & Mazzanti (2012). Second, environmental regulations in trading countries have minimal impact on regions with strong environmental initiatives, as local companies' products already meet most environmental standards. Moreover, active regional environmental policies can foster export diversification and the development of new markets, supporting the conclusions of Wang et al. (2022).

Table 5 presents the results for mineral-scarce regions. It shows that the GRP of the region, GDP of the importing country, and shared borders are the most significant drivers of regional exports, while geographical distance, trade sanctions, and transitional climate risks negatively impact export flows.

Table 6 shows that the impact of the global energy transition on the export revenues of Russian regions with medium mineral resource

Table 4

Relationship Between Environmental Regulation of Trading Partners and Exports of Russian Regions: The Role of Socio-Economic Conditions, Innovation Activity, and Regional Environmental Initiatives

Variable	The role of innovative potential			The role of regional environmental initiatives		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
$lGRP_{it}$	1.143[a] (0.307)	1.396[a] (0.101)	3.222[a] (0.190)	1.393[a] (0.168)	0.752[a] (0.154)	0.842[a] (0.210)
$lGDP_{jt}$	1.066[a] (0.077)	1.112[a] (0.080)	0.959[a] (0.258)	1.581[a] (0.162)	0.914[a] (0.075)	0.657[a] (0.066)
lP_{it}	0.121 (0.207)	–0.882[a] (0.118)	–1.108[a] (0.186)	0.406[c] (0.162)	–0.536[a] (0.128)	–0.168 (0.145)
lP_{jt}	0.057 (0.058)	0.166[a] (0.058)	–0.021 (0.122)	–0.056 (0.087)	0.115 (0.075)	–0.002 (0.045)
lD_{ij}	–1.467[a] (0.173)	–1.881[a] (0.077)	–0.793[a] (0.187)	–2.415[a] (0.133)	–1.129[a] (0.103)	–1.560[a] (0.130)
$l(1 + B_{ij})$	0.956[a] (0.211)	0.649[a] (0.178)	0.910[a] (0.248)	0.933[a] (0.187)	0.198 (0.081)	0.671[a] (0.123)
$lMAB_{it}$	0.209[a] (0.060)	0.278[a] (0.030)	0.404[a] (0.067)	0.311[a] (0.072)	0.224[a] (0.042)	0.221[a] (0.031)
$lIPOT_{it}$	0.347[b] (0.026)	0.486[a] (0.123)	–1.058 (0.629)	1.223[b] (0.358)	0.961[a] (0.143)	0.315 (0.207)
$l(1 + TS_{jt})$	–0.604[c] (0.281)	–0.757[a] (0.242)	–1.934[c] (0.789)	–1.065[a] (0.302)	–0.623[c] (0.302)	–1.056 (0.245)
lES_{jt}	0.307[a] (0.120)	–1.004[a] (0.194)	–0.321 (0.371)	0.765[a] (0.352)	0.028[c] (0.016)	–0.634[a] (0.190)
$Prob > F$	0.000	0.000	0.000	0.00	0.000	0.000
$Pseudo\ R^2$	0.640	0.581	0.529	0.601	0.612	0.590

Notes: *a* – significance at the 1 % level; *b* – significance at the 5 % level; *c* – significance at the 10 % level; standard clustered regression errors are presented in parentheses; *i* – indicator of Russian regions; *j* – indicator of trading partner countries; *t* – time. Fixed effects of exporting regions, importing countries, pairwise fixed effects are taken into account when estimating empirical models.

Source: Author's calculations are based on Stata 17.

Table 5

Relationship Between Transitional Climate Risks and Exports of Mineral-Scarce Russian Regions

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$lGRP_{it}$	1.761[a] (0.143)	1.420[a] (0.095)	1.562[a] (0.099)	1.479[a] (0.099)	1.464[a] (0.102)
$lGRP_{jt}$	0.901[a] (0.038)	0.674[a] (0.026)	0.729[a] (0.021)	0.707[a] (0.020)	0.703[a] (0.021)
lP_{it}	–0.804[a] (0.141)	–0.550[a] (0.093)	–0.606[a] (0.093)	–0.600[a] (0.096)	–0.602[a] (0.100)
lP_{jt}	–0.120[a] (0.019)	0.016 (0.014)	–0.023 (0.016)	0.033[c] (0.017)	–0.016 (0.013)
lD_{ij}	–1.380[a] (0.055)	–1.416[a] (0.032)	–1.437[a] (0.032)	–1.464[a] (0.033)	–1.353[a] (0.035)
$l(1 + B_{ij})$	1.025[a] (0.204)	1.099[a] (0.127)	1.129[a] (0.127)	1.035[a] (0.124)	1.021[a] (0.131)
$lMAB_{it}$	0.230[a] (0.030)	0.202[a] (0.020)	0.193[a] (0.020)	0.199[a] (0.021)	0.219[a] (0.022)
$lIPOT_{it}$	0.030 (0.146)	0.161 (0.100)	0.031 (0.107)	0.134 (0.104)	0.162 (0.108)
$l(1 + TS_{jt})$	–1.149[a] (0.132)	–1.016[a] (0.093)	–1.023[a] (0.091)	–1.067[a] (0.089)	–0.811[a] (0.099)
lES_{jt}	–0.582[a] (0.108)				

Окончание Табл. 5 на след. стр.

Окончание Табл. 5

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
lRS_{jt}		–0.018 (0.012)			
lSC_{jt}			–0.040[c] (0.011)		
lWC_{jt}				–0.058[a] (0.008)	
$lETI_{jt}$					–0.883[a] (0.179)
Prob > F	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.520	0.580	0.610	0.590	0.550

Notes: *a* – significance at the 1 % level; *b* – significance at the 5 % level; *c* – significance at the 10 % level; standard clustered regression errors are presented in parentheses; *i* – indicator of Russian regions; *j* – indicator of trading partner countries; *t* – time. Fixed effects of exporting regions, importing countries, pairwise fixed effects are taken into account when estimating empirical models.
Source: Author's calculations based on Stata 17.

Table 6

Relationship Between Transitional Climate Risks and Exports of Russian Regions with Medium Mineral Resources

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$lGRP_{it}$	0.700[a] (0.099)	0.639a (0.108)	0.701[a] (0.112)	0.636[a] (0.104)	0.526[a] (0.119)
$lGDP_{jt}$	0.666[a] (0.036)	0.721[a] (0.031)	0.669[a] (0.025)	0.647[a] (0.023)	0.696[a] (0.023)
lP_{it}	0.428[c] (0.254)	1.098[a] (0.219)	1.129[a] (0.215)	1.165[a] (0.222)	1.053[a] (0.224)
lP_{jt}	–0.094[a] (0.019)	–0.036[c] (0.017)	–0.066[a] (0.018)	–0.045[c] (0.018)	–0.043[c] (0.015)
lD_{ij}	–1.373[a] (0.110)	–1.616[a] (0.059)	–1.545[a] (0.065)	–1.479[a] (0.066)	–1.542[a] (0.067)
$l(1 + B_{ij})$	1.378[a] (0.289)	0.695[a] (0.211)	0.786[a] (0.213)	0.822[a] (0.210)	0.808[a] (0.232)
$lMAB_{it}$	1.189[a] (0.193)	1.208[a] (0.160)	1.225[a] (0.159)	1.185[a] (0.162)	1.112[a] (0.160)
$lIPOT_{it}$	1.323[a] (0.321)	1.138[a] (0.256)	1.264[a] (0.265)	1.172[a] (0.265)	1.141[a] (0.269)
$l(1 + TS_{jt})$	–0.477[a] (0.145)	–0.204[a] (0.059)	–0.460[a] (0.107)	–0.490[a] (0.108)	–0.412[a] (0.099)
lES_{jt}	–0.261[c] (0.101)				
lRE_{jt}		–0.017 (0.016)			
lSC_{jt}			0.061[a] (0.014)		
lWC_{jt}				0.028[a] (0.009)	
$lETI_{jt}$					0.077 (0.259)
Prob > F	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.520	0.610	0.630	0.599	0.584

Notes: *a* – significance at the 1 % level; *b* – significance at the 5 % level; *c* – significance at the 10 % level; standard clustered regression errors are presented in parentheses; *i* – indicator of Russian regions; *j* – indicator of trading partner countries; *t* – time. Fixed effects of exporting regions, importing countries, pairwise fixed effects are taken into account when estimating empirical models.
Source: Author's calculations are based on Stata 17.

Table 7

Relationship Between Transitional Climate Risks and Exports of Mineral-Abundant Russian Regions

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$lGRP_{it}$	1.350[a] (0.328)	1.345[a] (0.291)	1.455[a] (0.276)	1.352[a] (0.293)	1.361[a] (0.294)
$lGDP_{jt}$	0.928[a] (0.067)	1.220[a] (0.059)	0.919[a] (0.059)	0.986[a] (0.046)	0.979[a] (0.045)
lP_{it}	0.647[a] (0.125)	0.571[a] (0.109)	0.545[a] (0.111)	0.568[a] (0.108)	0.593[a] (0.111)
lP_{jt}	–0.204[a] (0.030)	–0.193[a] (0.030)	–0.235[a] (0.028)	–0.194[a] (0.027)	–0.153[a] (0.030)
lD_{ij}	–2.733[a] (0.151)	–2.732[a] (0.093)	–2.576[a] (0.108)	–2.599[a] (0.110)	–2.611[a] (0.105)
$l(1 + B_{ij})$	0.798[a] (0.199)	0.604[a] (0.243)	0.806[a] (0.311)	0.760[a] (0.102)	0.812[a] (0.230)
$lMAB_{it}$	5.739[a] (0.526)	4.942[a] (0.420)	5.001[a] (0.443)	5.147[a] (0.449)	5.135[a] (0.448)
$lIPOT_{it}$	1.315[a] (0.468)	1.596[a] (0.424)	1.719[a] (0.407)	1.407[a] (0.430)	1.414[a] (0.434)
$l(1 + TS_{jt})$	–0.934[a] (0.261)	–0.595[a] (0.232)	–0.688[a] (0.220)	–0.705[a] (0.230)	–0.984[a] (0.263)
lES_{jt}	–0.427 (0.277)				
lRE_{jt}		–0.143[a] (0.027)			
lSC_{jt}			0.145[a] (0.044)		
lWC_{jt}				0.155[a] (0.016)	
$lETI_{jt}$					1.809[a] (0.527)
$Prob > F$	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.500	0.645	0.589	0.572	0.525

Notes: *a* – significance at the 1 % level; *b* – significance at the 5 % level; *c* – significance at the 10 % level; standard clustered regression errors are presented in parentheses; *i* – indicator of Russian regions; *j* – indicator of trading partner countries; *t* – time. Fixed effects of exporting regions, importing countries, pairwise fixed effects are taken into account when estimating empirical models.

Source: Author's calculations are based on Stata 17.

endowment is mixed: stricter environmental policies have a negative effect, while the installation of renewable energy capacities in importing countries boosts exports.

Table 7 shows that the energy transition presents more export growth opportunities than risks for Russian regions with a dominant extractive sector. The readiness of partner countries for the energy transition and the expansion of renewable energy drive demand for Russian exports, which aligns with the findings of Islam et al. (2022).

Conclusion

Export is a priority for Russian economic development, driving sustainable growth, industrial advancement, job creation, productivity increases, foreign exchange earnings, and global competitiveness. Currently, the government is shifting focus from import substitution to export development.

Russian exporters face constraints such as high production costs, technological gaps, and quality mismatches with international demand. In the context of the global climate agenda, they also encounter transitional climate risks driven by regulatory and geopolitical factors. On the one hand, Russia's heavy reliance on the energy sector and high carbon emissions make its economy vulnerable to the global energy transition. On the other hand, countries rich in mineral resources, like Russia, may see increased exports due to the rising demand for raw materials (e.g., rare earth elements, non-ferrous metals) needed for alternative energy technologies. Furthermore, stricter environmental regulations are pushing companies to adopt green technologies, boosting competitiveness.

This study empirically analyzes the impact of the global energy transition on regional exports in Russia using the Extended Gravity Model, while also identifying regional factors that influence how the energy shift affects export values. While more sophisticated environmental policies in importing countries generally reduce export flows, regions with strong innovation environments and active environmental policies experience a positive impact. Additionally, countries transitioning to low-carbon development by expanding alternative energy sources decrease their reliance on Russian energy imports, which helps stabilize regions dependent on energy exports. At the same time, Russia's mineral-rich regions benefit most from the global energy shift, supplying essential minerals for alternative energy and electric vehicle production..

The study confirms the hypothesis that the global energy transition presents both risks and opportunities for Russian regional exports. To mitigate risks and capitalize on opportunities, tailored to different regional groups, it is recommended to give attention to fostering a favourable innovation environment to harness the stimulating effect of environmental regulations. Policies should focus on introducing new technologies, updating infrastructure, and developing regional educational potential (Fedyunina & Radosevic, 2022; Yang et al., 2023). Additionally, improving national and regional environmental policies is crucial, which includes prioritizing the environmental agenda through information tools, setting clear environmental goals, and choosing appropriate regulation mechanisms, especially in the context of transitional climate risks. Efficient regions should lead in reducing pollution, while less efficient regions can pay to offset their environmental impact, contributing to the national budget (Chu, 2024). These measures are particularly relevant for regions exporting environmentally sensitive products like fertilizers and metals.

For regions specializing in energy exports, strategies to minimize risks related to the growth of alternative energy in importing countries should focus on diversifying energy sources, restructuring state subsidies, and improving energy efficiency.

Mineral-abundant regions can best capitalize on the global energy transition by focusing on the extraction of rare earth elements and non-ferrous metals. Maintaining the competitiveness of the metallurgical sector through fiscal and monetary policies, along with upgrading technological infrastructure, is also essential.

This study offers several advantages, including its multi-perspective approach to the global energy transition and its consideration of regional differences in the analysis of export impacts. However, it relies on customs data that may not fully capture export values, suggesting that future research should incorporate data from the Federal State Statistics Service. Additionally, the study does not cover the 2022–2023 period, when transitional climate risks intensified due to geopolitical factors.

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