ORIGINAL ARTICLE

What does the clean energy transition look like for Russian oil exports?

Amin Sokhanvar | Kazi Sohag

Graduate School of Economics and Management, Ural Federal University, Yekaterinburg, Russia

Correspondence
Amin Sokhanvar, Graduate School of Economics and Management, Ural Federal University, Yekaterinburg, Russia. Email: sokhanvar@urfu.ru

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Abstract
The commitment of governments to achieving the goals of the Paris Agreement and the expected decrease in fossil fuel consumption indicate the importance of studying the risks facing the oil exporters and the range of options and responses. This study adopts the Trade Gravity model to examine the effect of clean energy policies on Russian oil exports during the period 1996–2019. Our results based on Cross-Sectional Autoregressive Distributed Lags modeling suggest that Russian oil exports are negatively affected by the energy transitions. This indicates that investing in cleaner energy technologies as a channel toward reducing fossil fuel demand can reduce the oil trade globally. Policies and strategies to retain and support the financial stability of the Russian government under the current scenario are suggested.

KEYWORDS
energy transition, fossil fuels, oil exports, renewable energy, Russia

1 | INTRODUCTION

The coronavirus disease (COVID) crisis in 2020 spurred an unprecedented decline in international oil demand. In 2021, not only were oil markets rebalanced but also an energy crisis prompted a switch to oil that boosted demand by 500 kb/day compared to pre-COVID conditions.\(^1\) Russia is the second largest crude oil producer that has produced above 10 mb/day in 2021.\(^2\) Oil exports contribute to a significant share of the Russian economy. This shows the reliance of this economy on the oil sector.

However, on the demand side, more incentives for governments for low-carbon energy consumption to achieve the goals of the Paris Agreement are expected to cause a downward shift in oil demand in the next decade.\(^3\) For oil exporters that are not interested in leaving resources untapped, it is forcing a hard decision. While societies demand energy services and lower carbon emissions simultaneously, oil companies face the strategic challenge of balancing long-term licenses to operate with short-term returns.\(^4\)

Recently, some macrofiscal stabilization efforts like “fortified capital and liquidity buffer” and “enhanced regulation and supervision in the banking sector” have improved the fiscal position of the Russian economy.\(^2\) However, the Russian ruble depreciation amid the oil price war initiated by Saudi Arabia in March 2020 showed the vulnerability of the Russian economy to oil price shocks.\(^5\) The expansion of the renewable energy sector in oil-importing countries and the global energy transition can be another threat to this economy and harm Russia’s long-term economic prospects. Hence, this study investigates to what extent Russian oil exports are affected by global clean energy policies, and what forms the patterns of international oil trade. This study contributes to this debate where the role of global energy...
transitions remains uncovered, especially in the case of Russia.

In analyzing policy ambitions that lead the energy sector, three boundaries must be considered. First, expanding global economy, growing global population, and rising demand for energy. Second, the critical role that fossil fuels play in today’s economic systems by providing reliable and affordable supplies of energy. Third, international climate targets for reducing energy-related emissions.

This study investigates the impacts of clean energy policies on the international oil trade between Russia and its trade partners between 1996 and 2019. We adopt the gravity model of international trade and use the share of renewable energy in total energy usage in the destinations of Russian oil to represent energy transition policies. The findings could map out the risks facing the Russian oil exports and the range of responses and options.

This research contributes to the literature in different strands. First, although the strategic aspects of fossil fuels are well-documented (e.g., O’Sullivan and Pascaul), there is a great deal of uncertainty about how oil exports can be affected by the global transition to renewable energy. Second, previous analyses have mostly investigated the world average energy trade status (e.g., Najm and Matsumoto). Our analysis of Russian oil exports will be more accurate, addressing the shortcomings of previous studies that have been very general. Third, we use the Cross-Sectional Autoregressive Distributed Lags (CS-ARDL) approach to overcome the spurious regression problem due to the nonstationarity of the series and the issue of cross-sectional dependence (CD) among cross-sectional units. Besides, we consider different control variables that play a critical role in explaining the oil trades between countries.

The rest of this paper is organized as follows: The review of relevant literature is presented in the next section. The data and methodology are explained in Section 3. The results are discussed in Section 4. Finally, the conclusions and policy implications are provided in the last section.

2 | LITERATURE REVIEW

In the last decade, many economies have adopted various measures and policies for reducing emissions via energy transition, however, demand for fossil fuels has recently exceeded pre-COVID-19 highs. Clearly, countries’ dependence on oil and gas cannot be ignored as they remain critical commodities in the international trade market and crucial resources related to a country’s energy security and national strategy at least in the near future.

On the path to sustainable development, the fossil fuels trade enables energy importers to achieve energy balance and use better quality energy. Developing countries depend on fossil energy trade for their energy balance. Another factor that emphasizes this fact is the increase in energy consumption. Some previous studies provided evidence that fossil fuels are irreplaceable with respect to machinery and transportation. A study by Ndlovu and Inglesi-Lotz on BRICS (Brazil, Russia, India, China, South Africa) countries shows that as the gross domestic product (GDP) share of renewable energy consumption is historically low, it has no effect on economic growth. Another study by Jonek-Kowalska states that the reduction in coal consumption is offset by a rise in natural gas consumption because, in the process of the energy transition, the growth of the renewable energy share in the energy balance is very slow.

Understanding the drivers of energy demand and the energy balance in different sectors, including services, agriculture, and manufacturing sectors, is a crucial step in regional energy transitions. Marques et al. used an ARDL technique to study if fossil energies have been substituted by renewables in the electricity generation mix in European countries. Their analysis detects the substitution effect in hydropower and solar power, but not in wind energy. This indicates that the path to reducing external energy dependency and carbon emission (via using renewable sources) is less straightforward than expected.

Despite the expansion of bioenergy consumption in developed economies, a study by Alsaleh and Abdul-Rahim shows that replacing fossil energy with bioenergy through trade is not currently possible for developing countries. It is not economical to generate bioenergy in these countries. Besides, there are many limitations in terms of importing renewable energy.

Different studies focus on rare materials, industrial competition, and stranded assets as geopolitical aspects of the transition toward renewable energy (e.g., Freeman, Konstantelos et al., OECD, Pierri et al.). Additionally, the effect of renewables on interstate energy relations has been explored by Buschle and Westphal. Goldthau et al., Essribano, and Proedrou. The Paris Agreement invited countries to develop low-emission development strategies. Some studies try presenting low greenhouse gas emission strategies for different industrial countries such as Russia (e.g., Fragkos et al.). Currently, these studies confirm that resource endowments and domestic priorities shape the energy sector investment decisions in Russia.

It is believed that expected future reductions in carbon consumption may accelerate climate change, because environmentally friendly policies may threaten energy exporters and motivate them to extract their resources even faster. The Green Paradox, introduced by...
Sinn,\textsuperscript{30} suggests a new approach based not on regulating the demand side but on controlling the supply side of fossil energies. Van der Ploeg and Withagen,\textsuperscript{31} Smulders et al.,\textsuperscript{32} and Rezai and Van Der Ploeg\textsuperscript{33} are the studies that explore the green paradox theoretically. Studies by Najm,\textsuperscript{34} Zhang et al.,\textsuperscript{35} and Lemoine\textsuperscript{36} explore this theory empirically by investigating the relationship between renewable energy expansion and fossil fuel production.

One of the aspects of the green paradox studied in the literature is carbon leakage. National policies of emission reduction in abating countries increase domestic costs of energy and give an opportunity to firms in nonabating countries to broaden their production and expand via international trade.\textsuperscript{37,38} It is conceivable that the gross reduction in emissions achieved by the abating countries is equal to or smaller than the induced increase in emissions in nonabating countries. Hagem and Storrsen\textsuperscript{39} adopt general equilibrium models and prove that applying supply-side environmental policies can improve the long-run welfare gains.

Despite a significant body of theoretical and empirical research exploring fossil fuels when investigating the international political economy of energy, energy geopolitics, and energy security, the literature rarely addresses renewable energy. Most of these studies are focused on the global oil market, unconventional oil, and shale gas (e.g., O'Sullivan\textsuperscript{6} and Pascual\textsuperscript{7}).

While the strategic aspects of fossil fuels are well-documented, there is a great deal of uncertainty about how the oil trade can be affected by the global transition to renewable energy. We study whether the effects will be considerable and require early attention to exploit opportunities and address challenges. Besides, previous analyses have mostly investigated the world average energy trade status. Therefore, our analysis of trade relations between Russia and its trade partners is more accurate, addressing the shortcomings of previous analyses that are very general. To the best of our knowledge, this topic has not been studied in the case of Russia.

3 | DATA AND METHODOLOGY

3.1 | Variables

A panel data set with annual data between 1996 and 2019 is adopted in this research. The cross-section dimension includes 44 country pairs, including Russia and its oil trade partners. To ensure the robustness of the results, we use three dependent variables including oil export volume, oil export value, and GDP share of oil exports.

The independent variables are defined as follows. The green energy index (Green) is the share of renewable energy in the total energy consumption of the oil importers. This index represents environmental incentives and examines the impact of clean energy transitions on Russian oil exports. A negative relationship between the oil trade and the green index means that renewable energy has been a substitute for oil. However, a positive relationship means oil and renewable energy are complements. This favors the rebound effect and the green paradox.

According to the traditional Trade Gravity model, the GDPs of exporters and importers ($GDP_{exp}$ and $GDP_{imp}$) account for economic scale and are expected to influence trade positively. However, the distance between two trade partners is expected to influence trade negatively.

Oil price is measured as the trade value of oil over the trade volume of oil. Higher prices, according to theory, would have a damaging impact on oil exports because a price surge lowers the demand for imports. Hence, price is expected to have a negative coefficient. Furthermore, as energy consumption is affected by temperature, degree days of oil importers are included in the model as a control variable.

The data on the green energy index and GDP series are gathered from the World Development Indicators.\textsuperscript{1} Oil export data are obtained from the United Nations Comtrade Database.\textsuperscript{2} Distance data were acquired from Mayer and Zignago.\textsuperscript{40} The annual average temperatures adopted from the World Bank's Climate Change Knowledge Portal are used as degree days data.\textsuperscript{3} The descriptive statistics of the variables used in the study are presented in Table 1.

3.2 | Empirical framework

Our model is based on the Trade Gravity model introduced by Pöyhönen.\textsuperscript{41} According to this model, the bilateral trade flows between two countries are positively affected by the economic size of the countries and negatively affected by their distance (Equation 1)

$$Trade_{ij} = \alpha_1 \left( \frac{GDP_{i}^{\alpha_2} GDP_{j}^{\alpha_3}}{Distance_{ij}^{\alpha_4}} \right)$$  \hspace{1cm} (1)$$

where $Trade_{ij}$ is the bilateral volume of trade between trade partners $i$ and $j$, $GDP_{i}$ and $GDP_{j}$ stand for their economic size, and $Distance_{ij}$ is the geographical distance.
between them. \( \alpha_1, \alpha_2, \alpha_3, \) and \( \alpha_4 \) are coefficients. Equation (2) is the logarithmic form of Equation (1)

\[
\ln(\text{Trade}_{ij}) = C + \alpha_2 \ln(\text{GDP}) + \alpha_3 \ln(\text{GDP}) + \alpha_4 \ln(\text{Distance}_{ij}) + \mu_{ij},
\]

where \( C \) is constant and \( \mu_{ij} \) stand for error terms.

The current study investigates the influence of the energy transition on Russian oil exports by using the Trade Gravity model in Equation (2). In selecting control variables (price and temperature), we follow the study by Najm and Matsumoto. As the country pairs in our sample could be connected by financial capital flows and trade relations, the potential CD in our data set must be examined. In analyzing panels, standard regressions cannot overcome the bias due to the existence of CD. Hence, the CD test introduced by Pesaran is applied to test the potential common correlation effects between variables. The null hypothesis of this test is no CD among the country pairs in the sample

\[
CD = \tilde{P} \left( \frac{T(N - 1)}{2} \right)^{1/2},
\]

where \( \tilde{P} \) denotes the degree of pair-wise correlations between cross-sectional residuals obtained from augmented Dickey-Fuller (ADF) regression. The proposed CD test considers the OLS residuals of every single regression in the panel and calculates the mean of pairwise correlation coefficients. This test is robust to the presence of single or multiple structural breaks and unit roots. Besides, this test is applicable to different panel data structures including unit-root dynamic heterogeneous or stationary panels with a large cross-section and short time horizon.

In the case of CD, to avoid spurious regression, the order of integration of the series must be identified by the CIPS (cross-sectional Im, Pesaran, Shin) test, which is a second-generation panel unit-root technique. This approach tests the existence of unit roots in dynamic panels with possible serial correlation and CD. In this panel unit-root test, standard ADF equations are augmented with the first differences of the individual series and averages of lagged levels in the cross-section.

To estimate our empirical model, we use the CS-ARDL approach introduced by Chudik et al. This approach addresses the potential common correlation bias, serial correlation, and endogeneity problems. Besides, in estimating the long- and short-run relationships, this technique captures the effects of the unobserved common factors. Equation (4) shows the CS-ARDL model used in this study as follows:

\[
\Delta \bar{Y}_{it} = \mu_i + \phi_i (Y_{it-1} - \tilde{X}_{it-1}) + \eta_{it-1} + \xi_{ij} \Delta X_{it-j} + \eta_{ii} \Delta \bar{Y}_{it-1} + \eta_{2i} \Delta \tilde{X}_{i} + \varepsilon_{it},
\]

where \( \Delta \bar{Y}_{it} \) is the dependent variable, \( \Delta Y_{it-j} \) is the dependent variable in the short run, \( \Delta \bar{Y}_{it-1} \) indicates the expected value of the dependent variables in the short run, \( X_{it} \) indicates the matrix of independent variables in the long run, \( \Delta X_{it-j} \) represents the matrix independent variables in the short run, \( \bar{X}_{i} \) represents the expected values of the independent variables in the long run, and \( \Delta \tilde{X}_{i} \) represents the expected values of the independent variables in the short run. \( \tilde{X}_{i} \) stands for the coefficient of independent variables. \( \phi_i \) represents the short-run coefficients of the dependent variables. \( \xi_{ij} \) represents the short-run coefficient of the independent variable. \( \eta_{ii} \) and \( \eta_{2i} \) are the coefficients of mean

### Table 1: Descriptive statistics

|                      | N  | Mean          | Min | Max           |
|----------------------|----|---------------|-----|---------------|
| Export volume (kg)   | 855| 5,437,000,000 | 89  | 70,640,000,000|
| Export value (USD)   | 855| 2,324,000,000 | 1085| 39,980,000,000|
| Export value/GDP     | 855| 0.002         | 0   | 0.021         |
| GDPexp (1000 USD)    | 855| 1,137,000,000 | 195,907,000 | 2,292,000,000 |
| GDPimp (1000 USD)    | 855| 1,192,000,000 | 1,249,061  | 21,430,000,000 |
| Price (USD/kg)       | 855| 0.408         | 0.019| 12.191        |
| Distance (km)        | 855| 3292.38       | 857  | 10169         |
| Green (%)            | 819| 15.206        | 0.33 | 61.11         |
| Degree days (°C)     | 855| 11.019        | −5.38| 28.12         |

Abbreviation: GDP, gross domestic product.
independent and dependent variables in the short run. \( j \) indicates cross-sectional dimension, \( t \) denotes time, and \( \varepsilon_{it} \) is the error term.

4 | RESULTS

Table 2 presents the correlation matrix of the independent variables. As all of the correlation coefficients are less than 50%, there is no multicollinearity problem between the variables.

To identify the best econometric method for estimating the empirical models, a systemic order must be followed. In the first stage, the cross-section dependency of the variables is investigated. The results are reported in Table 3, second column. The null hypothesis of “no CD” is rejected for all variables across the country pairs over the period being studied. The third column shows the average correlations between the cross-sections. The significance of CD statistics in this table indicates CD in all variables. Therefore, in the second step, the second-generation panel unit-root test, which is cross-sectionally unbiased, has to be applied to identify the order of integration of the variables.\(^{44}\) The results reported in Table 3, fourth and fifth columns indicate a mixed order of integration. Ln_GDPexp is \( I(0) \) and the rest of the variables are \( I(1) \). In analyzing panels, standard regressions cannot overcome the bias due to the existence of CD.\(^{42}\) Finally, the presence of both CD and mixed order of integration between our variables imply that the CS-ARDL framework must be applied to the analysis. This framework removes the CD bias jointly in both long-run and short-run estimators.\(^{43}\)

The CS-ARDL estimation results are presented in Table 4. The dependent variables in the first, second, and third columns are oil export volume, oil export value, and the GDP share of the oil export value, respectively. The green energy index and gravity model components are included in all three models.

The error correction term is significant and negative in all three models, confirming the long-run relationship between the Russian oil exports and energy transitions,

### Table 2 The correlation matrix

| Variables | (1) | (2) | (3) | (4) | (5) | (6) |
|-----------|-----|-----|-----|-----|-----|-----|
| Ln_GDPexp | 1.00 |     |     |     |     |     |
| Ln_GDPimp | 0.244 | 1.00 | | | | |
| Ln_Distance | 0.109 | 0.480 | 1.00 | | | |
| Ln_Green | 0.156 | −0.132 | −0.253 | 1.00 | | |
| Ln_Price | 0.411 | 0.110 | 0.121 | 0.039 | 1.00 | |
| Ln_DegreeDays | 0.143 | −0.002 | 0.495 | −0.308 | 0.148 | 1.00 |

Abbreviation: GDP, gross domestic product.

### Table 3 Panel unit-root and cross-sectional dependence tests

| Variable | CD | Common correlation | Level | First difference |
|----------|----|--------------------|-------|------------------|
| Ln_ExportVolume | 17.39*** | 0.372 | −1.776 | −2.354*** |
| Ln_ExportValue | 60.16*** | 0.530 | −1.413 | −2.534*** |
| Ln_ExportValue (GDP) | 22.49*** | 0.394 | −1.675 | −3.722*** |
| Ln_GDPexp | 129.79*** | 0.942 | −2.546*** | −2.468*** |
| Ln_GDPimp | 123.17*** | 0.901 | −1.789 | −2.557*** |
| Ln_Green | 48.32*** | 0.724 | −1.319 | −2.172*** |
| Ln_DegreeDays (°C) | 59.01*** | 0.447 | −1.918 | −3.151*** |
| Ln_Price | 100.19*** | 0.830 | −0.830 | −2.187*** |

Abbreviations: CD, cross-sectional dependence statistic; CIPS, cross-sectional Im, Pesaran, Shin.

***One percent significance level.
incorporating the role of oil price and the GDP of Russia and its trade partners through adjusting shocks in the short run. This coefficient indicates a 29.3%, 27.7%, and 27.8% speed of adjustment in the first, second, and third models, respectively. This means that any deviation in the system from long-run equilibrium is corrected by around 30% after 1 year.

Green has a significant negative coefficient in all the models proving the negative effect of the energy transitions on Russian oil exports. This shows that renewable energy has been a substitute for oil in oil-importing countries. Therefore, the Russian oil exports are affected negatively by the energy transition of its oil trade partners. This finding agrees with Marques et al., suggesting that hydropower and solar power have been substituted for fossil energy. This finding also provides evidence against the green paradox.

The negative and significant coefficient of price is not surprising because a higher oil price is associated with lower demand. Therefore, an increase in oil price decreases the oil export volume (first model). However, oil export value and GDP share of oil export value are a function of both price and quantity. When oil prices increase, oil exports decrease. That is why the coefficients of price in the second and third models are smaller than the coefficient of the price in the first model.

Oil exports are positively affected by both the GDP of Russia and the GDP of oil importers. This agrees with the theoretical prediction of the Trade Gravity model. Oil demand might react to short-run economic conditions, while oil trade contracts normally have a long-term nature.

5 | CONCLUSIONS AND POLICY IMPLICATIONS

A fast-moving energy sector and rapid energy transitions would change the game for energy exporters. A key challenge for Russia as one of the world’s leading oil exporters is the potential loss of a key source of revenue essential for the smooth functioning of this economy. The country is currently exposed to long-term challenges related to increased uncertainty about the prospects of oil demand.

This study explores the impacts of energy transitions on the international oil trade between Russia and its trade partners during the period 1996–2019. We adopt a global panel data set in a trade gravity framework and use the share of renewable energy to total energy consumption in the destinations of Russian oil to represent energy transition policies. The analysis used the CS-ARDL technique to capture unobserved heterogeneities within-country pairs and time. To ensure the robustness of the results, three different dependent variables are used in this study to measure the Russian oil export demand.

The findings reveal the risks facing Russian oil exports and the necessity of adaptation strategies.
According to our results, renewable energy has been a substitute for oil in oil-importing countries. This finding is robust across our different models. The Russian oil export value, oil export volume, and the GDP share of oil export value are affected negatively by the energy transition of its oil trade partners. In the other words, global clean energy policies are a threat to Russian oil exports. This finding also provides evidence against the green paradox and carbon leakage theories.

Given the reliance of the Russian economy on oil revenues, our findings highlight the potential welfare impact of losses in export revenues. As decision-makers in oil-importing countries are designing energy policies to meet carbon-reduction targets, Russian policymakers must monitor the energy structure of Russian oil trading partners. It is worth noting that the war in Ukraine and subsequent economic sanctions against Russian energy exports disrupt global energy markets. It forces European policymakers to shift away from fossil fuels, accelerate the move toward renewable energies, and incentivize efficient home appliances, and better efficiency standards.45 Besides, as rapid inflation persists in 2022, central banks around the world are increasing interest rates and recession is increasingly likely.46 These factors are other risks facing the demand for Russian energy.

Therefore, Russian policymakers have to implement effective policies to increase the resilience of the Russian economy through a better understanding of the long-term risks. Historically, economic diversification has been the core adaptation strategy considered by oil exporters. However, realizing a meaningful fiscal diversification strategy by adopting uncorrelated income streams has remained a challenge. In the current uncertain environment, conservative bet-hedging and diversified bet-hedging are two risk reduction strategies that can improve the long-term adaptability of the Russian economy.

As a major energy exporter in a greening global economy, Russia can better tap its potential for green product exports. Russian export diversification could be improved by environmentally sustainable exports. Previous studies (e.g., IRENA) suggest that Russia can become a competitive exporter of renewable energy equipment. Russia currently exports complex environmental goods such as static converters, air compressors, parts and accessories for optical appliances, measuring equipment, and machines designed for a range of areas of environmental management.2 It is welcome and can be improved.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**ORCID**

Amin Sokhanvar http://orcid.org/0000-0002-3901-9361

**REFERENCES**

1. International Energy Agency. Oil Market Report. 2021.
2. World Bank. Russia Economic Report 45. 2021.
3. IEA. Net Zero by 2050. 2021.
4. IEA. The Oil and Gas Industry in Energy Transitions. 2020.
5. Ma RR, Xiong T, Bao Y. The Russia–Saudi Arabia oil price war during the COVID-19 pandemic. Econ. 2021;102:105517.
6. O’Sullivan M. Windfall. Simon & Schuster; 2017.
7. Pascual C. The New Geopolitics of Energy. Policy Paper. The Center on Global Energy Policy. Columbia University in the City of New York School of International and Public Affairs (SIPA); 2015.
8. Najm S, Matsumoto K. Does renewable energy substitute LNG international trade in the energy transition? Energ. 2020;92:104964.
9. Samargandi N, Sohag K. The interaction of finance and innovation for low carbon economy: evidence from Saudi Arabia. Energy Strateg Rev. 2022;41:100847.
10. Wu Y, Wang P, Liu X, Chen J, Song M. Analysis of regional carbon allocation and carbon trading based on net primary productivity in China. China Econ Rev. 2020;60:101401.
11. Kaygusuz K. Energy for sustainable development: a case of developing countries. Renew Sustain Energy Rev. 2012;16(2):1116–1126.
12. Sohag K, Sokhanvar A, Belyaeva Z, Mirnezami SR. Hydrocarbon prices shocks, fiscal stability and consolidation: evidence from Russian Federation. Resour Policy. 2022;76:102635.
13. Sokhanvar A, Bouri E. Commodity price shocks related to the war in Ukraine and exchange rates of commodity exporters and importers. Borsa Istanbul Review. 2022. doi:10.1016/j.bir.2022.09.001
14. Sbia R, Shahbaz M, Hamdi H. A contribution of foreign direct investment, clean energy, trade openness, carbon emissions and economic growth to energy demand in UAE. Econ Model. 2014;36:191–197.
15. Ndlovu V, Inglesi-Lotz R. The causal relationship between energy and economic growth through research and development (R&D): the case of BRICS and lessons for South Africa. Energy. 2020;199:117428.
16. Jonek-Kowalska I. Transformation of energy balances with dominant coal consumption in European economies and Turkey in the years 1990–2017. Oecon Copernic. 2019;10(4):627–647.
17. McGookin C, Gallachóir BÓ, Byrne E. An innovative approach for estimating energy demand and supply to inform local energy transitions. Energy. 2021;229:120731.
18. Marques AC, Fuinhas JA, Pereira DA. Have fossil fuels been substituted by renewables? An empirical assessment for 10 European countries. Energy Policy. 2018;116:257–265.
19. Alsaleh M, Abdul-Rahim AS. The forecasted accuracy of the bioenergy market in the EU-28 region. J Sustain Sci Manag. 2019;14(4):118–129.
20. Alsaleh M, Abdul-Rahim AS. The economic determinants of bioenergy trade intensity in the EU-28: a co-integration approach. *Sustainability*. 2018;10(2):565.

21. Freeman D. China and renewables: the priority of economics over geopolitics. In: Scholten D, ed. *The Geopolitics of Renewables*. Lecture Notes in Energy. Vol 61. Springer; 2018:187-201.

22. Konstantelos I, Pudjianto D, Strbac G, et al. Integrated North Sea grids: the costs, the benefits and their distribution between countries. *Energy Policy*. 2017;101:28-41.

23. OECD. Divestment and Stranded Assets in the Low-carbon Transition: Background Paper for the 32nd Round Table on Sustainable Development, Paris, France, 28 October 2015. OECD; 2015.

24. Piepri E, Binder O, Hemdan NG, Kurrat M. Challenges and opportunities for a European HVDC grid. *Renew Sustain Energy Rev*. 2017;70:427-456.

25. Buschle D, Westphal K. A challenge to governance in the EU: decarbonization and energy security. *Eur Energy Clim J*. 2019;8(3-4):53-64.

26. Goldthau A, Westphal K, Bazilian M, Bradshaw M. How the energy transition will reshape geopolitics. *Nature*. 2019;569(7754):29-31.

27. Escribano G. The geopolitics of renewable and electricity cooperation between Morocco and Spain. *Mediterr Politics*. 2019;24(5):674-681.

28. Proedrou F. *Energy Policy and Security under Climate Change*. Palgrave Macmillan; 2018.

29. Fragkos P, van Soest HL, Schaeffer R, et al. Energy system transitions and low-carbon pathways in Australia, Brazil, Canada, China, EU-28, India, Indonesia, Japan, Republic of Korea, Russia and the United States. *Energy*. 2021;216:119385.

30. Sinn HW. Public policies against global warming: a supply side approach. *Int Tax Publ Fin*. 2008;15(4):360-394.

31. Van der Ploeg F, Withagen C. Is there really a green paradox? *J Environ Econ Manage*. 2012;64(3):342-363.

32. Smulders S, Tsur Y, Zemel A. Announcing climate policy: can a green paradox arise without scarcity? *J Environ Econ Manage*. 2012;64(3):364-376.

33. Rezai A, Van Der Ploeg F. Second-best renewable subsidies to de-carbonize the economy: commitment and the green paradox. *Environ Resour Econ*. 2017;66(3):409-434.

34. Najm S. The green paradox and budgetary institutions. *Energy Policy*. 2019;133:110846.

35. Zhang K, Zhang ZY, Liang QM. An empirical analysis of the green paradox in China: from the perspective of fiscal decentralization. *Energy Policy*. 2017;103:203-211.

36. Lemoine D. Green expectations: current effects of anticipated carbon pricing. *Rev Econ Stat*. 2017;99(3):499-513.

37. Sinn H-W. *The Green Paradox: A Supply-Side Approach to Global Warming*. MIT Press; 2012.

38. Van der Werf E, Di Maria C. Imperfect environmental policy and polluting emissions: the green paradox and beyond. *Int Rev Environ Resour Econ*. 2012;6(2):153-194.

39. Hagem C, Stornesten HB. Supply-versus demand-side policies in the presence of carbon leakage and the green paradox. *Scand J Econ*. 2019;121(1):379-406.

40. Mayer T, Zignago S. General diagnostic tests for cross-sectional dependence in panels. *Empir Econ*. 2021;60(1):39-64.

41. Chudik A, Mohaddes K, Pesaran MH. Long-run effects in large heterogeneous panel data models with cross-sectionally correlated errors. In: GonzÁlez-Rivera G, Carter Hill H, Tae-Hwy L, eds. *Essays in Honor of Aman Ullah*. Vol 36. Emerald Group Publishing Limited; 2016:85-135.

42. Pesaran MH. A simple panel unit root test in the presence of cross-section dependence. *J Appl Econom*. 2007;22(2):265-312.

43. World Bank. *Commodity Markets Outlook: The Impact of the War in Ukraine on Commodity Markets, April 2022*. 2022.

44. OECD. *OECD Economic Outlook, Volume 2022 Issue 1*. 2022.

45. IRENA. *IRENA REMAP 2030: Renewable Energy Prospects for the Russian Federation Working Paper*. 2017:27.

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