Ekonomi, Politika & Finans Araştırmaları Dergisi, 2025, 10(3): 994-1007
Journal of Research in Economics, Politics & Finance, 2025, 10(3): 994-1007
Araştırma Makalesi / Research Article, https://doi.org/10.30784/epfad.1680590

DOES GEOPOLITICAL RISK RISE CARBON EMISSIONS? EVIDENCE FROM A CS-ARDL MODEL FOR OECD COUNTRIES

Jeopolitik Risk Karbon Emisyonunu Artırır mı? OECD Ülkeleri İçin CS-ARDL Modelinden Kanıtlar

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Keywords:
Geopolitical Risk,
Carbon Emissions,
CS-ARDL.

JEL Codes:
C33, F51, Q56.

Abstract

Geopolitical risk constitutes an escalating global challenge, exerting profound implications for carbon emissions and the stability of ecological systems. This paper investigates the nexus between geopolitical risk and carbon emissions by employing advanced econometric techniques on a balanced panel of 25 OECD member states, incorporating extensive pre-estimation diagnostics and robustness checks to ensure methodological rigor. The empirical evidence demonstrates that elevated geopolitical risk exerts a statistically significant and positive effect on carbon emissions, thereby intensifying environmental degradation. Moreover, population expansion and higher per capita GDP are identified as key drivers of ecological deterioration, while trade openness and financial development emerge as mitigating factors. These results underscore the critical importance of fostering cross-border dialogue and enhancing institutional platforms established by supranational bodies to reduce geopolitical tensions. Coordinated international strategies that address both political stability and environmental sustainability are thus imperative for mitigating the intertwined challenges of global security and climate change.

Anahtar Kelimeler:
Jeopolitik Risk,
Karbon Emisyonları,
CS-ARDL.

Jel Kodları:
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Öz

Jeopolitik risk, karbon emisyonları ve ekolojik sistemlerin istikrarı üzerinde derin etkiler yaratarak giderek büyüyen küresel bir sorun haline gelmiştir. Enerji arz güvenliği, tedarik zincirleri, ticaret akışları ve yatırım kararları üzerindeki olumsuz etkileri, bu risklerin çevresel bozulmayı hızlandırma potansiyelini artırmaktadır. Bu çalışma, metodolojik titizlik sağlamak amacıyla kapsamlı ön testler ve sağlamlık kontrolleri içeren gelişmiş ekonometrik teknikler kullanarak, 25 OECD üyesinden oluşan dengeli bir panel veri seti üzerinde jeopolitik risk ile karbon emisyonları arasındaki ilişkiyi incelemektedir. Ampirik bulgular, artan jeopolitik riskin karbon emisyonları üzerinde istatistiksel olarak anlamlı ve pozitif bir etki yaratarak çevresel bozulmayı şiddetlendirdiğini ortaya koymaktadır. Ayrıca, nüfus artışı ve kişi başına düşen GSYH'nin ekolojik tahribatın başlıca belirleyicileri olduğu; buna karşılık ticari açıklık ve finansal gelişmenin karbon emisyonlarını azaltıcı faktörler olarak öne çıktığı tespit edilmiştir. Bulgular, jeopolitik gerilimlerin azaltılması için sınır ötesi diyalogların teşvik edilmesi ve uluslar üstü kurumlarca oluşturulacak platformların güçlendirilmesinin, küresel güvenlik ve çevresel sürdürülebilirlik açısından kritik önem taşıdığını vurgulamaktadır.

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Received Date (Makale Geliş Tarihi): 20.04.2025 *Accepted Date (Makale Kabul Tarihi): 02.07.2025*

1. Introduction

In the twenty-first century, two formidable global challenges—geopolitical instability and environmental degradation—have converged with growing intensity. The risk posed by geopolitical tensions, including armed conflicts, trade wars, sanctions, and energy insecurity, is increasingly intersecting with the global imperative to curb carbon emissions and climate risk. The interconnected nature of the contemporary world signifies that the repercussions of geopolitical risk transcend national boundaries, exerting influence on global energy markets, investment decisions, technological transitions, and environmental outcomes. In this intricate web of interconnected dynamics, the issue of carbon emissions is not solely determined by economic activities but is also influenced by the uncertainties induced by geopolitical developments. A comprehensive understanding of the link between geopolitical tensions and carbon emissions is crucial for the development and implementation of effective climate policies, energy strategies, and international cooperation frameworks.

This subject is of critical importance given the dual imperative of promoting energy security and achieving net-zero emission targets (Bordoff and O'Sullivan, 2022; Cheng et al., 2025). The task confronting policymakers is to decarbonize economies within a geopolitical landscape characterized by fragmentation and shifting alliances (Gardes-Landolfini et al., 2023; Scheffran, 2023). Geopolitical shocks, such as the Russia-Ukraine war, have exposed the fragility of global energy systems and compelled numerous countries to reevaluate their energy portfolios and strategic reserves (Bricout et al., 2022; Wiertz et al., 2023). The environmental repercussions of these shifts are substantial. Addressing this issue necessitates a multifaceted approach that considers not only the economic channels through which geopolitical risk affects emissions but also the institutional resilience, policy response mechanisms, and technological pathways available to different countries (Bakhsh et al., 2024; Wang et al., 2024). A more nuanced understanding of this interaction can facilitate the development of more robust climate strategies that are resilient to geopolitical turbulence (Maddodi et al., 2024; Mani et al., 2023).

This paper aims to investigate the impact of geopolitical risk on carbon emissions. It makes a crucial contribution to the relevant literature and provides new insights. First, this study uses a cross-sectional autoregressive distributed lag (CS-ARDL) model to handle the cross-sectional dependence, heterogeneous slope coefficients, and mixed order of integration data issues. Second, the stochastic impacts by regression on population, affluence, and technology (STIRPAT) model is extended with trade openness and financial development. These two explanatory regressors contribute to the reliability of the empirical findings. Third, the findings of this research are of significance for a broad range of stakeholders. From a policy perspective, the results can inform the design of climate policies that remain viable under geopolitical stress. Conversely, investors and businesses can leverage the analysis to understand the risks and opportunities associated with green investment during periods of economic turbulence. Furthermore, the findings underscore the necessity for civil society and international organizations to prioritize the cultivation of institutional resilience and multilateralism in their pursuit of environmental objectives. Climate change, by its very nature, poses a global public goods challenge, the resolution of which hinges on cooperation that must demonstrate resilience to geopolitical fragmentation. The ramifications of geopolitical risk within the systemic realm have the potential to broaden the policy discourse and mobilize support for integrative and adaptive strategies.

OECD members are particularly salient and distinctive for the purposes of this analysis. These countries are at the forefront of climate policy innovation, energy transition, and international diplomacy (Qamruzzaman and Karim, 2024). However, they are also subject to considerable geopolitical risks due to their pivotal roles in global trade, energy interdependence, and defense alliances (Bakhsh et al., 2024). Their institutional sophistication, technological prowess, and financial resources empower them to implement comprehensive environmental reforms, but these same attributes may also result in defensive policy shifts in times of uncertainty. Furthermore, as major contributors to global carbon emissions, the manner in which OECD countries navigate the nexus of geopolitical risk and climate action can establish precedents and influence global trajectories. It is therefore imperative to understand the behavioral patterns exhibited by these economies under geopolitical stress to effectively anticipate global emission trends and provide effective guidance for international climate governance.

Methodologically, this paper utilizes state-of-the-art panel analysis techniques. Following the preliminary analysis and diagnostic tests, this paper employs a distinctive panel time-series approach. CS-ARDL model, developed by Chudik and Pesaran (2015), signifies a substantial advancement over the panel regression analysis. The model addresses key limitations and combines heterogeneous slope coefficients, cross-sectional dependence, and mixed order of integration. This approach is particularly well-suited for analyzing macroeconomic variables across countries that may be influenced by common factors, such as global oil prices or international political shocks. The model's flexibility allows for a dynamic lag structure, distinguishing between short-run adjustments and long-run equilibrium relationships. The methodological rigor exhibited by this model serves to enhance the credibility of the findings and provides a reliable basis for policy inference, particularly in settings characterized by strong interdependence and dynamic feedback effects. Empirical findings are checked using the feasible generalized least squares (FGLS) method.

This article is structured as follows. Following this introduction, Section 2 presents a theoretical framework based on the STIRPAT model. Section 3 discusses the data set, followed by empirical strategy in Section 4. Section 5 presents the empirical findings from the preliminary analysis, diagnostic tests, CS-ARDL analysis, and robustness checks. Section 6 summarizes the empirical findings, the contribution and limitation of the paper, and the way forward.

2. Theoretical Framework

This section presents a theoretical framework based on environmental theory. The foundational model posits that three primary factors, the population, affluence, and technology, influence the environment (Ehrlich and Holdren, 1971). This study aligns with the recommendations put forth by Dietz and Rosa (1994), who expanded the aforementioned model to an STIRPAT model. It provides a flexible framework for analyzing the impacts of anthropogenic activities on the environment.

The fundamental STIRPAT formulation is as follows:

$$I = \theta P^{\beta} A^{\gamma} T^{\rho} \tag{1}$$

where I stands for environmental impact, P denotes population size, A represents affluence, and T is technology. θ denotes the constant term, β, γ, and ρ stand for the elasticity parameters of I with respect to P, A, and T. When Equation (1) is rearranged in accordance with the objective of this study, carbon emissions and gross domestic product per capita can be substituted, respectively, with environmental impact and affluence. Given the established correlation of higher than 0.8 between technology and per capita output, as well as financial development, the technology variable is excluded from the equation to circumvent a multicollinearity issue. Therefore, Equation (1) can be reformulated as follows: $CO_2 = \theta POP^{\beta} GDP^{\gamma}$.

This study extends the STIRPAT model to incorporate geopolitical risk (GPR) as a structural determinant of carbon emissions, recognizing that political instability can disrupt both production patterns and environmental policies. The augmented framework facilitates the examination of how geopolitical shocks interact with traditional drivers to influence emission trajectories. The geopolitical risk exerts its influence on carbon emissions through a variety of pathways. First, geopolitical conflicts may result in energy supply disruptions, which are followed by an escalation in fossil fuel utilization and heightened carbon emissions (Borowski, 2022; Feng et al., 2024; Yasmeen and Shah, 2024). This phenomenon is exemplified by the resurgence of coal use in Europe following the invasion of Ukraine. Second, elevated levels of geopolitical risk have been demonstrated to impede the progress of green finance, consequently precipitating delays in the transition to renewable energy sources and perpetuating the lock-in of carbon intensity (Overland, 2021; Hoffart et al., 2024). This phenomenon is exemplified by the challenges faced by developing countries under sanctions. Third, political instability has been demonstrated to weaken climate governance, leading to enforcement gaps and leakage in emissions (Lamb and Minx, 2020; Asongu and Odhiambo, 2021). Considering the effects mentioned above, the Equation (1) is expanded with the inclusion of geopolitical risk.

$$CO_2 = \theta POP^{\beta} GDP^{\gamma} GPR^{\rho} \tag{2}$$

GPR denotes the geopolitical risk, and ρ is the elasticity of CO_2 with respect to GPR. Therefore, there are some moderating factors. Trade openness may exert a substantial influence on carbon emissions. The degree of trade openness influences the carbon emissions through reshoring or facilitation of clean tech diffusion (Gozgor, 2017; Liang and You, 2023). In addition, financial development may be identified as a pivotal factor influencing carbon emissions. The high financial development contributes the environmental sustainability through sustainable green finance, stable climate policies, effective energy transition frameworks, and robust carbon pricing mechanisms, thereby mitigating the effect of geopolitical risk on carbon emissions. (Zhang, 2011; Hunjra, 2024) Thus, Equation (2) is extended by incorporating the aforementioned moderating factors.

$$CO_2 = \theta POP^{\beta} GDP^{\gamma} GPR^{\rho} TO^{\delta} FD^{\sigma} \tag{3}$$

TO is trade openness, and FD is financial development. δ and σ stand for the elasticity parameters of CO_2 with respect to TO and FD, respectively. It is imperative to consider the dynamic nature and lagged impacts of geopolitical risk on carbon emissions when making adjustments to Equation (3). This process culminates in the formulation of Equation (4).

$$co_{2_{i,t}} = \alpha_{it} + \beta_1 gpr_{i,t} + \beta_2 pop_{i,t} + \beta_3 gdp_{i,t} - \beta_4 to_{i,t} - \beta_5 fd_{i,t} \tag{4}$$

where $\alpha = ln(\theta)$, $i = \{1, 2, \dots, 25\}$ denotes the number of countries, and $t = \{1990, 1991, \dots, 2021\}$ represents time horizon. The lowercase letters indicate the logarithmic expressions. It can be hypothesized that carbon emissions will be negatively affected by trade openness and financial development. Conversely, an increase in population, output per capita, and geopolitical risk will have a positive impact on carbon emissions.

3. Data

Annual frequency data set compiled for 25 members of the OECD covers the period from 1990 to 2021. The economies in question are as follows: Australia, Belgium, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Hungary, Israel, Italy, Japan, Mexico, Netherlands, Norway, Poland, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Data availability determines the time span and provides sufficient time for a consistent analysis. The data on carbon emissions dates back to 1990. In addition, data on financial development for the period after 2021 is not yet available. The data set is meticulously compiled from World Bank and OECD databases, and Caldara and Iacoviello (2022). Table 1 presents the label, definition, and measurement of the variables.

Table 1. Labels, Definitions, and Measurements of the Variables

Labels	**Definitions**	**Measurements**
CO_2	Carbon dioxide emissions	Million tons
GPR	Geopolitical risk	Share of articles in 10 newspapers
POP	Population	Sum of population
$GDPPC$	Gross domestic product (GDP) per capita	Constant 2015 US$ gross domestic product per capita
TO	Trade openness	Exports and imports of goods and services (% of GDP)
FD	Financial development	Index between 0 and 1 (1=highest)

CO_2 emissions, which encompass the combustion of fossil fuels and industrial processes, are endogenous variables. The primary explanatory variable, geopolitical risk, is measured using a tally of newspapers' articles (For more detailed information, please see https://www.matteoiacoviello.com/gpr.htm).

The study incorporates a set of control variables that are substantiated by both theoretical frameworks and empirical literature. The population count is based on all residents, irrespective of their legal status or citizenship. The population estimates are typically derived from national population censuses. Gross domestic product per capita is calculated by dividing the gross domestic product by the mid-year population. Gross domestic product (GDP) is defined as the sum of the gross value added by all resident producers in the economy. Trade openness of goods and services represents the value of all goods and services provided to and received from the rest of the world. The concept of financial development encompasses indicators that provide insights into the accessibility, depth, and efficiency of financial institutions and markets.

4. Empirical Strategy

Figure 1 illustrates the estimation process in the paper. The initial stage involves the correlation, cross-section dependence (CD), and slope coefficient heterogeneity (SCH) analyses of the data set. Concerning the multicollinearity and endogeneity issues, a correlation matrix is initially constructed. Also, CD and SCH are two pivotal characteristics of the panel data set, which must be tested rigorously. The failure to account for these two features can lead to distorted and unreliable results in panel data analysis (Shu et al., 2023). Pesaran (2021) develops a CD test to ascertain the horizontal cross-sectional dependence degree. As for slope heterogeneity, Pesaran and Yamagata (2008) propose a SCH test, yielding both standard and adjusted test statistics.

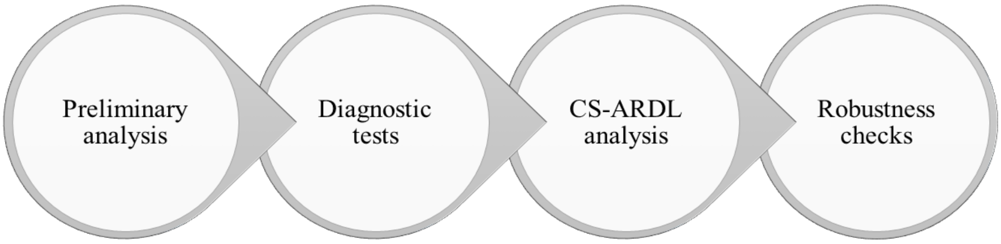

Figure 1. Estimation Process

The second stage of the analysis determines the stationary level of the data and their cointegrated relationship. Pesaran (2007) develops an innovative unit root test to address the issue of cross-sectional dependence. This test adds a cross-sectional means and their first-difference lags to provide a correction to the standard ADF regression. Furthermore, Westerlund (2007) proposes an error correction model (ECM) to determine the long-run relationship among the variables. It assumes that the variables follow a nonstationary process, while each series are cointegrated.

This paper employs a CS-ARDL model to estimate long- and short-run coefficients. Chudik and Pesaran (2015) develops this approach, which provides enhanced robustness to endogeneity, SCH, CD, non-stationary, and unobserved common factors (Khan et al., 2020). The CS-ARDL specification of Equation (4) is as follows.

$$\begin{aligned}\Delta co_{2_{i,t}} = {} & \xi_i co_{2_{i,t-1}} + \gamma_i \overline{co_2}_{i,t} + \theta_i' Z_{i,t-1} + \rho_i' \bar{Z}_{i,t} + \sum_{j=1}^{p-1} \beta_{ij}\, \Delta co_{2_{i,t-j}} + \sum_{j=0}^{q-1} \delta_{ij}' Z_{i,t-j} \\ & + \sum_{j=1}^{p-1} v_{ij}\, \Delta \overline{co_2}_{i,t-j} + \sum_{j=0}^{q-1} \psi_{ij}' \overline{Z}_{i,t-j} + \alpha_i + \varepsilon_{i,t}\end{aligned} \quad (5)$$

Z represents the set of explanatory variables, i.e., $Z = \{GPR, POP, GDPPC, TO, FD\}$. The overbar stands for the cross-section average. ξ_i represents the group-specific error-correction coefficient, α_i denotes the fixed effects, and $\varepsilon_{i,t}$ stands for the random shocks.

The CS-ARDL model is a reliable empirical strategy. However, the FGLS model provides robustness checks for the empirical findings. Hansen (2007) develops the FGLS approach, which deals with cross-sectional dependence and multicollinearity issues.

5. Empirical Findings

This section uncovers the geopolitical risk and carbon emissions nexus by presenting preliminary analysis, diagnostic tests, CS-ARDL estimation results, and FGLS robustness checks, respectively.

5.1. Preliminary Analysis

This section employs a range of preliminary analyses to determine the characteristics of the data set. Table 2 shows the correlation matrix. The findings of the study demonstrate a positive relationship between carbon emissions and geopolitical risk, population, and gross domestic product per capita, while demonstrating an inverse relationship with both trade openness and financial development. This finding aligns with the a priori information concerning the variables. Furthermore, a robust correlation exists between gross domestic product per capita and financial development. This phenomenon can be attributed to the interactive relationship between economic development and financial development, wherein the former serves as a catalyst for the latter, et vice versa. Consequently, the estimations do not suffer from multicollinearity issues.

Table 2. Correlation Matrix

	$\mathbf{co_2}$	**gpr**	**pop**	**gdppc**	**to**	**fd**
co_2	1					
gpr	0.672	1				
pop	0.894	0.623	1			
$gdppc$	0.082	-0.127	-0.239	1		
to	-0.557	-0.413	-0.625	0.196	1	
fd	-0.300	-0.229	0.045	0.806	0.142	1

Table 3 presents the results of the CS and SCH tests. Pesaran (2021) CD test rejects the null hypothesis, which posits no cross-sectional dependence at the 1 percent significance level. This reveals that 25 OECD economies are interdependent. Moreover, Pesaran and Yamagata (2008) SCH test rejects the null hypothesis at the 1 percent significance level, thereby indicating the heterogeneous slopes.

Table 3. CS and SCH Tests

Cross-sectional Dependence		**Slope Coefficient Heterogeneity**	
Variables	**Statistics**	**Tests**	**Statistics**
co_2	15.78^{***}	Δ	30.729^{***}
gpr	34.37^{***}	Δ^{adj}	34.766^{***}
pop	59.81^{***}		
$gdppc$	89.27^{***}		
to	63.28^{***}		
fd	79.87^{***}		

Note: *** represents a significance level of 1%.

5.2. Diagnostic Tests

Concerning the extant evidence of cross-sectional dependence and heterogeneous slopes, Table 4 presents the unit root test and cointegration test results addressing these issues. Pesaran (2007) unit root test statistics indicate that the majority of the variables, such as geopolitical risk, population, trade openness, and financial development, are found to be stationary at the level, while the remaining variables, i.e., carbon emissions and gross domestic product per capita, are stationary at the first difference. Given that all variables manifest an order of integration of either $I(0)$ or $I(1)$, the CS-ARDL approach emerges as the most viable one. Furthermore, Westerlund's (2007) cointegration test rejects the null hypothesis of no cointegration at the 1 percent level, thereby meaning the presence of a long-run relationship among the variables.

Table 4. Unit Root and Cointegration Tests

	Unit Root		Cointegration		
Variables	**I(0)**	**I(1)**	**Tests**	**Value**	**Z-Value**
co_2	-1.989	-5.388***	G_t	-3.102***	−2.287
gpr	-3.320***	-	G_a	-8.478***	4.386
pop	-2.208**	-	P_t	-13.662**	−1.430
$gdppc$	-1.778	-4.255***	P_a	-9.225	1.931
to	-2.194**	-			
fd	-2.574***	-			

Note: *** and ** denote the significance levels of 1% and 5%, respectively. $\boldsymbol{G_t}$ and $\boldsymbol{G_a}$ are group statistics, while $\boldsymbol{P_t}$ and $\boldsymbol{P_a}$ are panel statistics.

5.3. CS-ARDL Analysis

This paper employs a CS-ARDL model to shed light on the impact of geopolitical risk on carbon emissions in both long- and short-term. Table 5 illustrates the CS-ARDL estimation results.

Table 5. CS-ARDL Estimation Results

	Long-run			Short-run	
Variables	**Coefficient**	**Std. Err.**	**Tests**	**Coefficient**	**Std. Err.**
gpr	0.022***	0.008	Δgpr	0.021***	0.008
pop	0.113	0.712	Δpop	4.249**	2.243
$gdppc$	0.015	0.176	$\Delta gdppc$	0.877***	0.295
to	-0.141**	0.070	Δto	-0.197**	0.083
fd	-0.153***	0.054	Δfd	-0.096	0.065
			ecm	-0.443***	0.041
F-stat	1.30***				
CD test	2.61***				

Note: *** and ** represent the significance levels of 1% and 5%, respectively.

Geopolitical risk, trade openness, and financial development exert a statistically significant influence on carbon emissions in the long run. Rather, geopolitical risk, population, output per capita, and trade openness have a statistically significant impact on carbon emissions in the short term. The signs of the coefficients align with the a priori information and correlation matrix in Table 2. Specifically, a 1 percent rise in geopolitical risk is associated with a 0.2

percent increase in carbon emissions over time, under the condition that all other variables remain constant. The error correction coefficient (ecm) is negative and significant for the estimation in the long run. This coefficient indicates that the estimated model adjusts to short-run disequilibrium by approximately 44 percent in the subsequent period.

As geopolitical risk escalates, it precipitates an augmentation in carbon emissions through energy supply disruptions, hindering the transition to renewable energy sources and the absence of sustainable climate governance (Anser et al., 2021; Borozan, 2024). A review of the extant literature on the relationship between geopolitical risk and carbon emissions reveals findings that are consistent with those of the present study. Despite the varied methodologies employed in relevant studies to measure the impact of geopolitical risk on carbon emissions, a consensus has emerged that it does, in fact, increase carbon emissions (Wang et al., 2022; Ding et al., 2023; Paramati et al., 2024).

Concurrently, population growth is a contributing factor to environmental degradation, and vice versa (Maja and Ayano, 2021; Bashir et al., 2023). An increase in output per capita, an indicator of prosperity, triggers a rise in carbon emissions due to increased production capacity and more complex logistics routes (Mukhtarov et al., 2022; Li and Wang, 2023). While these estimates align with the STIRPAT model and Environmental Kuznets Curve (EKC) theory, it is crucial to note that both population and output per capita exert a statistically significant influence on carbon emissions, albeit only in the short term. In contrast, trade openness has been demonstrated to foster environmental sustainability by enhancing wealth and disseminating clean technology (Chen et al., 2022; Wang et al., 2024). Finally, the depth and efficiency of financial institutions and markets provide more green finance instruments to accelerate the transition to green transformation (Gu et al., 2021; Fu et al., 2023). The findings reveal that the impact of all control variables on carbon emissions is consistent with the relevant literature.

5.4. Robustness Checks

CS-ARDL analysis has provided statistically significant and consistent results. Furthermore, the estimations of the aforementioned model are verified using the FGLS approach. Table 6 presents the findings of the robustness checks. The sign of the coefficients for all explanatory variables supports the results of the CS-ARDL model in Table 5. In contrast, gross domestic product per capita and population have a significant impact on carbon emissions even in the long run. Furthermore, Table 6 underscores the direct impact of geopolitical risk on carbon emissions. Specifically, an increase of 1 percent in geopolitical risk leads to a 3 percent rise in carbon emissions, which aligns with CS-ARDL estimation results.

Table 6. FGLS Estimation Results

Variables	**Coefficient**	**Std. Err.**
gpr	0.003^{***}	0.001
pop	1.013^{***}	0.027
$gdppc$	0.580^{***}	0.019
to	-0.002^{***}	0.009
fd	-0.045^{**}	0.010
Wald test	1934.95^{***}	

Note: *** and ** represent the significance levels of 1% and 5%, respectively.

6. Concluding Remarks

This study examines the geopolitical risk and carbon emissions nexus, offering insights into the population, economic, and financial drivers of carbon emissions. More specifically, this paper focuses on how geopolitical risk influences carbon emissions both long- and short-term. In line with the relevant literature, geopolitical risk, population, gross domestic product per capita, trade openness, and financial development are selected as explanatory regressors to explain carbon emissions. Methodologically, advanced panel data techniques are employed for 25 OECD economies over the period 1990-2021.

Empirical findings reveal that geopolitical risk, population, and gross domestic product per capita have a positive impact on carbon emissions. Conversely, trade openness and financial development have been demonstrated to exert a negative effect. A heightened state of geopolitical risk has been demonstrated to precipitate energy supply disruptions, in turn, result in an escalation in fossil fuel utilization and elevated carbon emissions. Furthermore, elevated geopolitical risk dissuades the adoption of green finance, consequently precipitating delays in the transition to renewable energy sources. Concurrently, population growth has been demonstrated to positively impact carbon emissions, primarily through its effect on energy demand. Economic development engenders an expansion in production and energy demand, consequently leading to the importation of goods, services, and energy. This phenomenon, in turn, exerts a deleterious effect on environmental sustainability. Conversely, a rise in trade openness contributes to a reduction in carbon emissions, as global value chains facilitate reshoring and enable the diffusion of clean technology. Furthermore, enhanced financial development, through sustainable green finance, reduces carbon emissions, thereby enabling the implementation of stable climate policies, effective energy transition frameworks, and robust carbon pricing mechanisms.

This study suggests several potential policy recommendations. Primarily, there is an urgent need to amplify initiatives aimed at mitigating geopolitical risks. It is imperative to enhance inter-country dialogues or to fortify the communication between nations by establishing various platforms by supranational institutions. Secondly, educational initiatives targeting the populace should be implemented, with the objective of fostering individuals who demonstrate sensitivity to carbon emissions and respect for the environment. Thirdly, it is crucial to incentivize sectoral breakthroughs in economic development that prioritize environmental sustainability and reduce carbon emissions. The promotion of global trade openness and the diffusion of green technology through inter-country agreements are also crucial. Finally, the role of financial development, particularly green financial instruments, cannot be overstated in the effort to reduce carbon emissions. It is imperative to acknowledge the heterogeneity of OECD member countries in terms of culture, economy, finance, and society. The policy recommendations delineated herein ought to be interpreted in light of the heterogeneity characteristic of countries. For example, it is evident that emerging economies have a long way to go to catch up in terms of educational advancement, economic growth, and financial development. Consequently, the aforementioned policy recommendations are expected to have a more pronounced impact in these economies than in advanced economies.

As is the case with the majority of studies of this nature, this study is not without its limitations. The data set under consideration encompasses only 25 OECD countries from 1990 to 2021. The panel analysis identifies the key drivers of carbon emissions in different countries using a single equation, without considering the cultural and institutional heterogeneity across countries. Consequently, it is imperative to undertake more comprehensive analyses in the future, with more reliable and larger data sets. Furthermore, this study employs a macro-level analysis covering OECD countries. As an alternative approach, a micro-level analysis encompassing the sectors and firms in one or multiple countries will yield valuable insights.

Declaration of Research and Publication Ethics

This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement

I am a single author of this paper. My contribution is 100%.

Declaration of Researcher's Conflict of Interest

There is no potential conflict of interest in this study.

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