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The Impact of Geopolitical Risk, Economic Complexity, and Good Governance on the Environment, Across Countries with Different Income Levels

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Abstract: Environmental quality is considered one of the most important pillars of sustainable development and plays multiple roles in maintaining balance in human life. However, due to the absence of specific laws and regulations and the lack of clearly defined ownership, the environment is often exploited in an unlimited manner, resulting in environmental degradation and various forms of pollution. Consequently, environmental pollution has become one of the most critical challenges for all countries. Global warming and climate change, driven by extensive human activities, are among the major environmental problems that have generated significant concern in recent decades. Countries across all income groups face environmental challenges. Given the intensification of global environmental pressures and the rise in geopolitical uncertainties, understanding the interaction between the environment and geopolitical risks is of considerable policy importance. Accordingly, this article employs panel data econometric methods to examine the impact of geopolitical risk, economic complexity, and good governance on environmental outcomes across countries with different income levels (lower-middle, upper-middle, and high income) over the period 2002–2024.The findings indicate that geopolitical risk has a positive effect on environmental pollution, leading to higher levels of environmental degradation. In contrast, economic complexity and good governance exert negative effects on environmental pollutants, thereby contributing to pollution reduction. The results also suggest that the relationship between geopolitical risk and environmental degradation depends on countries' income levels. Specifically, elevated geopolitical risk increases environmental pressure in lower(and upper-middle)income countries. This may be attributed to weaker regulatory institutions, reduced investment in clean technologies, and the prioritization of defense and military expenditures over environmental concerns. Conversely, in high-income countries, the effect of geopolitical risk on environmental pollution may be weaker, potentially due to stricter environmental regulations. Based on these findings, environmental policies should be designed in accordance with the level of development and the specific conditions of each group of countries. For lower-middle and upper-middle-income countries, managing geopolitical risks and facilitating a transition toward environmentally compatible economic complexity and good governance are essential. For high-income countries, enforcing environmental laws and sustaining investment in green innovation appear to be vital.

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Introduction

Greenhouse gas emissions from human activities have intensified the warming effect and led to global climate change. A significant percentage of these gases (particularly carbon dioxide) result from the burning of fossil fuels such as coal, oil, and natural gas. Consequently, climate change and global warming have become one of the most critical challenges facing humanity in recent years. This issue affects both developing and advanced economies, with adverse consequences for the current situation and the achievement of sustainable development goals(Dow & Downing, 2016; Nordhaus, 2018; Lin & Xu, 2020; Syed & Bouri, 2022; Jahanger et al., 2022; Gozgor & Paramati, 2022; Arslan et al., 2023).Greenhouse gas emissions are the primary cause of air pollution, and among them, carbon dioxide (CO_2) emissions account for the largest share in terms of volume (over 75% of total emissions). As a result, CO_2 emissions constitute the most important greenhouse gas among all emitted (Coskuner et al., 2020). Accordingly, to achieve the goal of sustainable development, CO_2 emissions must be controlled and monitored, and appropriate policy measures must be taken to reduce them (Sun et al., 2023). Researchers have therefore attempted to investigate and identify the sources of greenhouse gas emissions, particularly CO_2, in different regions and countries worldwide. In this context, the world's highest-carbon-intensity countries and many resource-rich nations have increased their reliance on coal, oil, and natural gas due to the global energy crisis and rising energy prices. As a result, environmental degradation in these countries has been influenced by natural resource use (Bilgili et al., 2023). This issue evokes the Carbon Curse hypothesis, meaning that most resource-rich countries pursue more carbon-intensive growth and development pathways compared to resource-poor countries (Chiroleu-Assouline et al., 2020). However, higher levels of development also lead to a shift toward better technologies, advanced environmental regulations, and structural changes in the economy. Hence, using these advancements, environmental pollution can be reduced (Danish et al., 2019). Various factors have been introduced to explain, reinforce, or weaken the Carbon Curse hypothesis. For example, political instability, conflicts, and weak governance in resource-rich countries can increase the risk of environmental degradation and reduce effective environmental management (Balsalobre-Lorente et al., 2018).

Geopolitical risks (including wars, trade conflicts, and disputes over resources),can slow down green investments and exacerbate dependence on fossil fuels, thereby causing serious disruptions to environmental sustainability and the transition toward increased carbon dioxide emissions. Consequently, recent research has increasingly emphasized the environmental consequences of geopolitical risks and considers geopolitical stability a prerequisite for sustainable development. These studies highlight the relationship between such risks and increased CO_2 emissions, as well as the design of corrective environmental policies(Wang & Zhang, 2024; Hoang et al., 2025; Xu, 2025; Lin & Zhang, 2025).In this regard, economic complexity(driven by productive diversification and knowledge intensity of products),can be an important factor in mitigating environmental damages (caused by geopolitical risks). Innovation and its effect on complex industries provide greater resilience to various shocks, including environmental shocks. Economic complexity, especially when combined with strong environmental policies and good governance, contributes to environmental improvement even under high geopolitical risk conditions. However, some studies warn that economic complexity may also lead to increased pollution due to the expansion of industrial activities and higher energy consumption(Balsalobre-Lorente et al., 2024; Hassanein et al., 2024; Hamrouni et al., 2025).One objective of this paper is to answer the following questions: First, what is the effect of geopolitical risks on the environment of low-, middle-, and high-income countries? Second, what is the effect of economic complexity on the environment of low-, middle-, and high-income countries? Third, does the effect of good governance on the environment differ across low-, middle- and high-income countries? Several innovations of this study can be highlighted. First, the selection and classification of countries in this work is based on different income levels to examine geopolitical risks and environmental sustainability. Second, one role of this work is to fill a gap in the literature, as existing environmental studies have paid less attention to the role of geopolitical risks. Third, this study addresses the link between the economic complexity index, good governance, and environmental developments for the period 2000–2024. By the way, given the climate change conferences held throughout the 21st century and the emphasis on reducing emission levels in various countries, this study can serve as a useful empirical contribution. By examining the impact of economic complexity, geopolitical risk, and good governance on the environment, the results can help adopt appropriate policies to achieve environmentally compatible growth. Based on the material in this introductory section, the subsequent sections will include a literature review, methodology, and a final conclusion.

literature review and Empirical Studies

This section examines the link between three key variables (geopolitical risks, economic complexity, and good governance), and the environment.

Geopolitical Risk and the Environment

Understanding the link between geopolitical and environmental risks in different countries is vital for advancing economic stability, climate resilience, and sustainable development. Geopolitical risk refers to events related to wars, terrorist acts, and tensions between governments that disrupt the normal and peaceful course of international relations (Caldara and Iacoviello, 2022; Abouelenein et al., 2026). One key variable in this regard is energy, which has always been influenced by geopolitical disputes. For example, energy price changes often occur following such disputes due to actual disruptions or fear of energy supply disruptions. Conflicts, tensions, terrorist attacks, military disputes, and the threat of war directly affect energy supply and demand, exposing different countries to geopolitical risk (Aloui et al., 2024; Mandal and Datta, 2024). Geopolitical risk directly increases uncertainty and reduces investment in green energy technologies. It also slows down research and development and limits innovation in renewable energy. These factors force producers to use dirty technologies in production and increase CO_2 emissions. Indirectly, geopolitical risk exacerbates resource curse consequences by creating instability, conflicts, governance problems, and increasing natural resource prices (especially oil). Such issues can lead to overconsumption of natural resources and its adverse effects in terms of higher CO_2 emissions (Chen et al., 2023).

Geopolitical risk affects CO_2 emissions through various mechanisms. One mechanism is the consumption effect: increased geopolitical risk can lead to higher energy consumption and military-related activities, which in turn intensify CO_2 emissions. The second mechanism is the investment effect: geopolitical risk may increase investment in green (renewable) energy and advanced technology projects, which slows down CO_2 emissions. Thus, net effect of geopolitical risk on CO_2 emissions, depends on the balance of these mechanisms (Wang et al. 2022). Several related mechanisms exist too. First, geopolitical risks can disrupt global supply chains, reduce incentives and slow sustainable investment. Consequently, macroeconomic stability weakens, and governments are forced to prioritize short-term development goals over long-term sustainable development objectives. Under these conditions, as macroeconomic stability and economic growth become the focus, carbon emissions tend to intensify and green investment declines. Second, geopolitical risks increase the vulnerability of energy systems and reduce confidence in renewable energy investments; as a result, fossil fuel consumption rises, leading to increased carbon emissions. Third, geopolitical risks also weaken institutional strength and governance quality. Because, the implementation of environmental laws and regulations ,in circumstances as such, either fails or faces fundamental obstacles, thereby exacerbating carbon emissions. Fourth, through the natural resource and energy channel, geopolitical risks have lasting effects on carbon emission levels. In high-income countries, geopolitical instability is often associated with reduced ecological efficiency. In contrast, in resource- and energy-dependent developing economies, geopolitical risks lead to the raw extraction and use of natural resources (Wang et al., 2024a,b; Luo, 2024; Lee et al., 2023).

Geopolitical risks such as political instability, conflicts, and trade disruptions create policy uncertainty, challenging firms, governments, and investors in planning and implementing long-term strategies to reduce CO_2 emissions. For instance, the Russia–Ukraine war that began in February 2022 demonstrates that this type of risk leads to increased military spending and consequently higher geopolitical risk (due to increased fossil fuel use for military production), resulting in environmental degradation (Anser et al., 2021; Chen et al., 2024). Furthermore, it entails the failure of long-term planning because it forces governments to prioritize immediate political and economic stability over long-term environmental and sustainability goals. This, in turn, generates more CO_2. Finally, geopolitical risk can disrupt the smooth functioning of global trade flows and supply chains, negatively affecting the transfer, implementation, and adoption of environmentally friendly technologies that could ensure CO_2 emission reductions (Chen et al., 2023).In sum, the effect of geopolitical risk on the environment varies depending on the type of risk and different time periods, giving rise to two perspectives. In the first perspective, geopolitical risk can lead to improved environmental performance because it increases investment in renewable and clean energy and reduces dependence on fossil fuels, thereby improving environmental performance. In contrast, the second group argues that geopolitical risk hinders environmental sustainability because it disrupts clean energy supply chains and consequently reduces investment in renewable energy. During geopolitical risk crises, governments prioritize daily and short-term energy security over long-term environmental goals (Dadgar, etal 2025).

Economic Complexity and the Environment

One challenging question in development economics is why some countries are wealthier than others, and economic complexity explains the differences between poor and rich countries. Complex economies are those that absorb large amounts of knowledge to produce a diverse combination of knowledge-intensive products. In contrast, simple economies have less knowledge-intensive products and produce fewer and simpler products. Differences in complexity levels account for differences in economic growth rates, and diversification of commodities. Moreover, the transition of any country's economic development toward a knowledge-based economy is one of the main challenges in achieving economic diversification (Albassam, 2019; Vu, 2019; Sweidan and Elbargathi, 2023; Aloui et al., 2024). Thus, economic complexity reflects countries' national productive capabilities. When a country's production structure is more complex, its productive capabilities are stronger (Stojkoski & Kocarev, 2017; Zhu & Li, 2017, Hausmann et al., 2014). The economic complexity index captures the amount of knowledge and technology used in countries' production and reflects the level of knowledge and technology from production to exports. Today, looking at developed and rapidly developing countries, we observe that they invest heavily in research and development to make their manufactured products more complex. Producing complex products rather than raw materials and basic goods brings these countries to high levels of competitiveness and income (Erkan & Yildirimci, 2015; Canh et al., 2020).

The relationship between economic complexity and environmental degradation is multifaceted and can be positive or negative. Several channels through which economic complexity affects environmental quality are explained here. First, economically complex countries often possess more advanced technologies. This can lead to more sustainable resource use, and lower pollution. More complex economies may invest in cleaner technologies and renewable energy, which can reduce environmental degradation. However, as countries' economic complexity rises, industrial activities (especially in developing countries) often increase, and the knowledge employed and product diversification can lead to higher pollutant levels. Second, higher economic complexity can promote the spread of green technologies that reduce greenhouse gas and other pollutant emissions and increase energy efficiency and environmental sustainability. On the other hand, increased demand for raw materials and energy can lead to environmental degradation through mining, deforestation, and other activities. Third, trade expansion can facilitate the diffusion of green knowledge through trade with economically complex countries, helping to improve environmental standards in less complex economies. Conversely, trade expansion can lead to the relocation of polluting industries from more complex developed economies to less developed economies, causing environmental degradation there (Can & Gozgor, 2017; Gala et al., 2018; Gramkow & Anger-Kraavi, 2018; Mealy & Teytelboym, 2020; Eslamloueyan et al., 2024).

Good Governance and the Environment

Governance issues and challenges (including corruption, mismanagement, and weak institutions), hinder the establishment of effective environmental regulations. In contrast, improving a country's governance structure and performance, pursuing economic development and growth, and shifting from traditional to advanced and cleaner technologies can be accompanied by environmental enhancement. Good governance and its components affect the environment. One component of good governance is the rule of law. Where the rule of law exists, the effects of market failures can be minimized. Olson (1996) emphasizes that the quality of institutions and legal systems that can ensure contract enforcement will stimulate high-productivity firm activities among actors. According to Aron (2000), institutions become weak due to factors such as lack of law, weak laws, or poor law enforcement. Therefore, the rule of law also plays a fundamental role in environmental performance. Acemoglu et al. (2005) argue that strict contract enforcement can force firms to accept environmental policies. Another component of good governance is the quality of law and regulations. In countries where transparent rules exist regarding firm activities, companies operate within the legal framework, which can benefit both the environment and economic growth (Safovian et al., 2001; Makdissi & Eodon, 2006).

The component of government effectiveness affects the environment and climate change through inefficient administrative systems and bureaucracy, efficient public services, better management of public resources, and the authority and competence of environmental laws. The focus of the debate on the environmentally destructive role of governments is to identify and acknowledge differences in government function. Governments must play both a developmental role and a protective, caretaking, and responsible role toward the natural environment. Instead of finding solutions to environmental problems, some governments generally exacerbate the problem because they have never accepted responsibility for managing and protecting the environment and natural resources (Bailey & Bryant, 1997; Ghani, 2012; Walker, 2012).

The component of corruption control affects environmental performance in various ways. Corruption in the environmental sector diverts allocated budgets from environmental programs toward embezzlement and bribery. This leads to natural resource damage and environmental pollution through bribery in environmental inspections. On the other hand, corruption contributes to the formulation of environmentally destructive policies and leads to inequitable allocation of environmental resources (Damania, 2003).

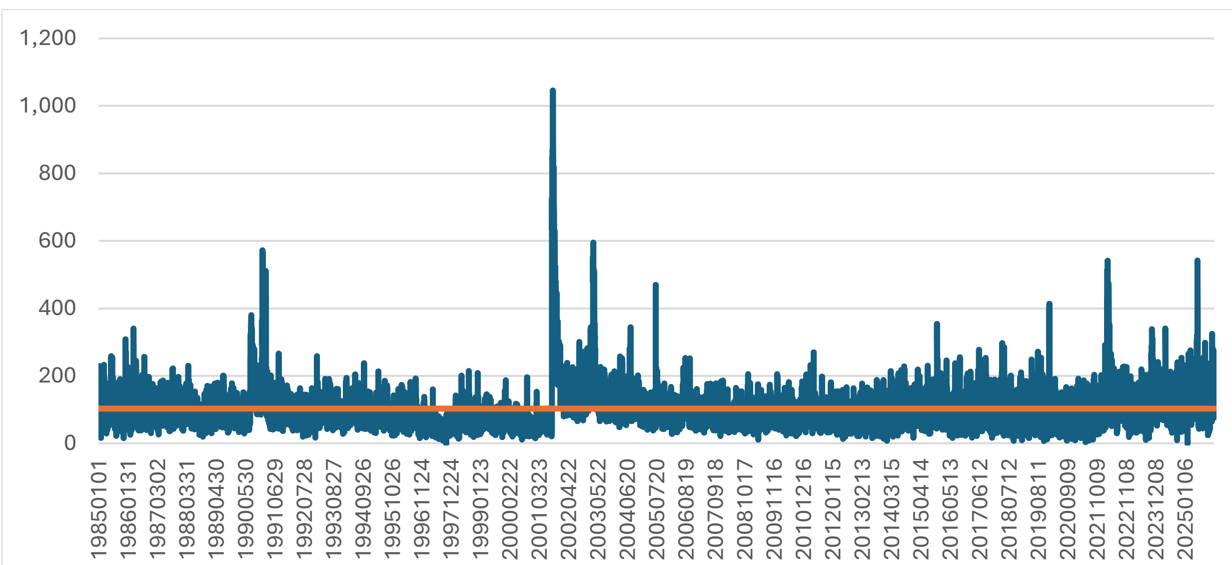
Review of Empirical Studies

Abouelenein et al. (2026), using data from 1990 to 2023 for five countries (South Africa, Tunisia, Egypt, Turkey, and Saudi Arabia), examined the impact of geopolitical risk on environmental quality. Their results showed that geopolitical risks have a negative and significant effect on the environment. Moreover, renewable energy and economic complexity improve environmental quality while moderating the adverse effects of geopolitical risk. Shanyazov et al. (2026) investigated the impact of geopolitical risks and policy uncertainty on CO_2 emissions for G7 countries using data from 1990 to 2022. Their results indicated that geopolitical risk and uncertainties in economic and climate policies have a positive effect on CO_2 emissions. Renewable energy consumption and trade openness have a negative effect on CO_2 emissions. Dagar et al. (2025), using data from 1990 to 2020 for 27 countries, examined the impact of geopolitical risk on environmental sustainability indicators. The results showed a significant relationship between increased geopolitical risk and carbon emissions. Li et al. (2025), investigating the relationship between geopolitical risks and carbon emissions for 41 selected countries, found that geopolitical risks have a positive effect on carbon emissions. Daghbagi et al. (2025), examining the impact of economic complexity and financial development on environmental quality using data from 1999 to 2021 for G20 countries, concluded that the economic complexity index has a positive effect on CO_2 emissions in the long run. Kim (2025), using data from 2001 to 2020 for 52 countries worldwide, investigated the impact of geopolitical risks and global value chains on CO_2 emissions. The results showed that global geopolitical risk affects CO_2 emissions through disruptions in global value chains. Cutcu et al. (2025), in a study examining the impact of geopolitical risk on environmental quality using data from 1997 to 2022 for 17 countries, found that the effect of geopolitical risk on environmental quality was negative. Wang et al. (2024c) examined the impact of natural resource revenues on carbon emissions using data from 1995 to 2021 for 38 selected countries. Their results showed that natural resource revenues, influenced by geopolitical risk and economic complexity, have nonlinear effects on carbon emissions. Balsalobre-Lorente et al. (2024), using data from 1997 to 2018 for G20 countries, examined the impact of economic complexity, geopolitical risk, renewable energy consumption, and economic growth on environmental pollution. The results showed that in the long run, geopolitical risk and policy uncertainty have a positive effect on the environment. Economic growth has a negative effect on the environment. Chen et al. (2024), using data from 1990 to 2019 for 38 developed and developing countries, examined the impact of geopolitical risk on CO_2 emission inequality. Their results showed that geopolitical risk has a positive effect on CO_2 emission inequality. Bergougui et al. (2024) investigated the impact of environmental technologies, economic complexity, and geopolitical risks on carbon emission inequality for 41 countries (including developed and developing countries) using data from 1990 to 2020. Environmental technologies and economic complexity have a negative and significant effect on carbon emission inequality. However, GDP per capita, geopolitical risk, and the share of natural resource revenues in GDP have a positive and significant effect on carbon emission inequality. Luo & Sun (2024), in a study of 27 countries from 1990 to 2020, examined the impact of geopolitical risks on environmental sustainability. Their results indicated that the effect of geopolitical risk on carbon emissions is greater in developing countries than in developed countries. Chen et al. (2023), using data from 1970 to 2021 for 38 selected countries, examined the impact of geopolitical risk and natural resource revenues on CO_2 emissions. The results showed a positive and significant relationship among geopolitical risk, natural resource revenues, and CO_2 emissions. The share of renewable energy has a negative and significant relationship with CO_2 emissions. Arslan et al. (2023) examined the impact of economic complexity, energy consumption, tourism, and economic growth on carbon emissions for 102 countries from 1994 to 2018. Their results showed that economic complexity has a negative effect on carbon emissions in high-income and low-income countries, respectively. Boleti et al. (2021), in a study of 88 developed and developing countries using data from 2002 to 2012, examined the relationship between economic complexity and environmental performance. Their results showed that higher levels of economic complexity led to improved environmental performance. Swart & Brinkmann (2020), using data from 2003 to 2011, examined the relationship between economic complexity and the environment. Their results showed that pollution increases with increasing economic complexity. Lapatinas et al. (2019), in a study of 88 countries using data from 2002 to 2012, concluded that higher complexity leads to an improvement in the environmental performance index. Doğan et al. (2019), using data from 55 countries for the period 1971 to 2014, examined the impact of economic complexity on the environment. Their results showed that economic complexity has significant effects on the environment. Neagu & Teodoru (2019), using data from 1995 to 2016 for EU countries, concluded that there is a significant relationship between the economic complexity index and greenhouse gas emissions. Can & Gozgor (2017), examining the impact of economic complexity on carbon emissions in France, concluded that economic complexity reduces CO_2 and greenhouse gas emissions. Dadgar & Nazari (2017), using data from 2002 to 2014 for Southwest Asian countries, examined the impact of good governance on environmental pollution. Their results showed that the degree of economic openness and the indicators of accountability, regulatory quality, and rule of law (as components of good governance) have a negative and significant effect on pollution. Thus, according to result of this article, the better the governance ,the lower the environmental pollution.

Methodology

The geopolitical risk index was introduced by Caldara & Iacoviello (2022). The index value is expressed as a percentage between 0 and 100, where a larger number indicates higher geopolitical risk. Since geopolitical risk index data are available monthly, to convert them to annual frequency, the arithmetic mean of monthly index values within a given year is used (Chen et al.,2023, Zhao et al.,2024). Geopolitical risk refers to risks related to terrorism, war, militarization, and intra- and inter-country conflicts (Caldara & Iacoviello, 2022). Geopolitical risks are influenced by regional conflicts, political instability, and foreign interventions. The geopolitical risk index from 1985 to 2026 is shown in Figure (1), which covers many events. The most important events up to COVID-19, include: the U.S. bombing of Libya (April 1986); Iraq's invasion of Kuwait (August 1990); the Gulf War (January 1991); the September 11, 2001 terrorist attacks in the United States; the U.S. invasion of Iraq (March 2003); the London bombings(July 2005); the Paris terrorist attacks(November 2015); the Arab Spring (2011–2012); Russia's annexation of Crimea (2014); international sanctions against Iran; and COVID-19 in 2020. Post-COVID events include the Russia–Ukraine war (February 2022, followed by U.S. and European sanctions against Russia); the Hamas attacks on Israel(October 7, 2023); Israel's attack on Gaza (October 2023); the Israel–Iran war (May 2025); the U.S. attack on Venezuela (January 2026); and the U.S. and Israeli attacks on Iran (February and March 2026).

Figure 1: Trend of the Geopolitical Risk Index in the World. 1985-2026



Source: findings of the research(by helping GPR-Index).

These events not only affect the security situation of the countries involved ,but also disrupt the global economy and financial order, which can have significant consequences for international financial stability, resource allocation, and global payment systems (Aloui et al., 2024; Eedogan, 2024; Adams et al., 2020).

Model Specification, Estimation, and Analysis of Results

In the model specification, geopolitical risk, economic complexity, and good governance are considered as key determinants affecting the environment. Selected countries in this study include three groups of different income levels countries: high income, upper middle income and lower middle-income countries. Annual data are used in the 2002-

2024 period. Influential factors on CO2 emission, dependent and independent variables, are indicated in the following's equation:

$$LCO2 = f\left(LGOV, LTRADE, ECI, LGPR\right)$$

where LCO2 is the logarithm of CO2 emission, LGOV is the logarithm of good governance, LTRADE is the logarithm of trade (% of GDP), LECI, the logarithm of economic complexity, and LGPR, the logarithm of a geopolitical risk. The following model is used:

$$LOG(CO2)_{it} = \alpha_0 + \alpha_1 Log\ (GOV)_{it} + \alpha_2 Log(TRADE)_{it} + \alpha_3 \log(ECI)_{it} + \alpha_4 \log(GPR)_{it}$$

Where i, refers to the countries and t indicate the time. In the beginning, the unit root testing is run. The unit root testing of Levin Lin Chu (2002) and, IM, Pesaran and Shin (2003) are used here. The results are shown in table (1). As this table shows, all variables are in stationary status at the level. Unit root tests and Estimation results are presented in Tables 1 and 2 respectively.

Table 1: Unit – Root Test

Variable	Group	Levin, Lin & Chu		Im, Pesaran and Shin	
		Statistic(t)	Prob.	Statistic(t)	Prob.
Log(CO2)	High	-38.3	0.0000	-9.13867	0.0000
	Upper Middle	-5.87924	0.0000	-2.48889	0.0064
	Lower Middle	-4.64354	0.0000	-10.5828	0.0000
LOG(GOV)	High	-2.98088	0.0014	-2.78276	0.0027
	Upper Middle	-8.45349	0.0000	-6.02094	0.0000
	Lower Middle	-18.6853	0.0000	-12.0690	0.0000
LOG(TRADE)	High	-6.39011	0.0000	-4.69746	0.0000
	Upper Middle	-4.51413	0.0000	-3.27625	0.0005
	Lower Middle	-6.15087	0.0000	-4.82241	0.0000
LOG(ECI)	High	-3.82884	0.0001	-11.4714	0.0000
	Upper Middle	-3.19165	0.0007	-4.09142	0.0000
	Lower Middle	-1.91200	0.0279	-2.32814	0.0100
LOG(GPR)	High	-10.9049	0.0000	-12.7857	0.0000
	Upper Middle	-10.1771	0.0000	-11.9323	0.0000
	Lower Middle	-9.89033	0.0000	-11.5961	0.0000

Source: the findings of the research

Table (2) indicates the final estimations of all models.

Table 2: Estimation of Models by the Panel GMM EGLS method

Variable	High income countries		Upper middle-income countries		Lower middle-income countries	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.137	-1.60	-0.009	-1.04	0.113*	14.62
LOG(CO2 (-1))	0.993*	489.64	0.995*	3820.1	0.990*	2656.77
LOG(GOV)	-0.081*	-2.96	-0.002***	-1.61	-0.006*	-4.35
LOG(TRADE)	-0.058*	-3.91	-0.007*	-10.80	-0.014*	-12.44
LOG(ECI)	0.269*	3.32	0.031*	6.02	0.005*	4.21
LOG(GPR)	0.070*	3.50	0.007*	5.30	0.006*	3.45

Notes: *, ** and *** denote the statistical significance at the 1%, 5% and 10% levels

Source: the findings of the research

The results showed that the variables of good governance and trade share of GDP have a negative relationship with CO_2 emission levels in all three country groups. That is, with improvements in good governance ,and trade openness, CO_2 emissions decrease. In other words, trade openness facilitates access to international markets. This leads to competition among countries, increases the efficiency of scarce resource use, and encourages the import of clean technologies to reduce CO_2 emissions. The geopolitical risk variable has a positive and significant effect on CO_2 emissions. This variable increases CO_2 emissions by disrupting energy supply chains, hindering the transfer of clean technologies, and shifting government priorities from long-term environmental goals toward short-term energy security. In the long run, the economic complexity can improve the environment. However, it has a positive effect on CO_2 emissions in lower-middle-income countries, and possibly in some high-income countries as well. This may be attributed to industrialization, technological changes, and production diversification, which require energy use (especially from fossil fuels). Consequently, in such circumstances, more CO_2 is generated in practice. However, given that these groups of countries are characterized by energy efficiency, the production of clean technologies (wind turbines, solar panels, etc.), and complex green products (e.g., electric vehicle manufacturing), it is expected that overall, they have lower CO_2 emissions. To investigate this puzzle and re-estimate the model for these two country groups, the interaction term (economic complexity index multiplied by GDP per capita), was used, and the model estimation results are presented in Table 3. According to the results, in countries with higher and above-average per capita GDP, an increase in complexity leads to a reduction in CO_2 emissions, which is consistent with the theory and the realities of these countries. High-income countries have the highest levels of complexity, reflecting their relatively diversified production base and innovative capabilities. High levels of economic complexity significantly increase energy efficiency and consequently reduce emission levels. Moving toward higher levels of economic complexity leads to an overall improvement in environmental performance.

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Table 3: Estimation of Models by the Panel GMM EGLS method

Variable	High income countries		Upper middle-income countries	
	Coefficient	t-Statistic	Coefficient	t-Statistic
C	**0.434*****	**1.63**	**0.381***	**60.34**
LOG(CO2 (-1))	**0.997***	**964.84**	**0.997***	**3626.90**
LOG(GOVV)	**-0.0007***	**-7.07**	**-0.009***	**-7.74**
LOG(TRADE)	**-0.039***	**-3.30**	**-0.021***	**-31.69**
LOG(ECII*GDPPER)	**0.165****	**2.39**	**0.158***	**29.35**
LOG(GPR)	**0.058***	**3.00**	**0.010***	**7.98**
LOG(ECII*GDPPER)	**-0.056****	**-2.06**	**-0.052***	**-64.05**

Notes: *, ** and *** denote the statistical significance at the 1%, 5% and 10% levels

Source: the findings of the research

The negative coefficient of the interaction term indicates that the more complex an economy becomes (e.g., manufacturing medical equipment or advanced machinery), the lower the pollution. This is because a wealthy country has the purchasing power to acquire clean technology and renewable energy. Thus, when an economy becomes more complex, the goal shifts from producing smoky, cheap goods to producing clean goods. The positive coefficient of economic complexity and the negative coefficient of the interaction term complement each other. The positive coefficient shows that among high-income countries, those with a more complex economy generate more pollution. However, the negative coefficient of the interaction term shows that with increasing income and complexity, the positive effect of economic complexity diminishes and is moderated. The overall results of the effect of economic complexity on environmental pollution indicate that this variable depends on a country's income level and stage of development. In lower-middle-income countries, due to the nascent stage of the development process, increased product diversification and expansion of industrial activities lead to higher energy consumption (mostly fossil fuels) and consequently higher carbon emissions. In the early stages of development, this effect dominates. However, in the long run, economic complexity can lead to the use of more advanced technologies, improved energy efficiency, and a shift toward cleaner industries, thereby reducing carbon emissions. This is characteristic of high-income and above-average-income countries.

conclusion and Policy Recommendations

On the one hand, environmental quality is considered one of the most important components of sustainable development and plays multiple roles in maintaining balance in human life. On the other hand, geopolitical risks have an influential impact on environmental quality. By analyzing the interaction of geopolitical risk, economic complexity, and good governance on the environment in different countries, this article provides an investigation into this crucial case for 2002–2024.

Analyzing the factors affecting global carbon dioxide emissions is essential, and governments can implement various environmental laws and policies to improve the situation. Therefore, examining the determinants of environmental quality for countries at different income levels is of particular importance. The results of this article, using data from 2002 to 2024 for three groups of countries (high-income, upper-middle-income, and lower-middle-income) showed that good governance and the trade share of GDP have a negative relationship with CO_2 emissions. The geopolitical risk variable has a positive effect on CO_2 emissions. The economic complexity variable has a positive effect on CO_2 emissions; however, for upper-middle-income and high-income countries, part of this positive effect is moderated due to economic conditions and capacities. Based on the results of this article, it is recommended that a policy package be implemented to strengthen sustainable carbon reduction strategies in the field of environmentally polluting abatement technologies. Furthermore, governments can implement a carbon pricing system that provides economic incentives and production efficiency for individuals and firms to reduce carbon emissions and invest in clean technologies. Establishing strong laws, regulations, and legal systems to reduce carbon emissions and improve sustainable development is also essential for different countries. Also, the implementation and expansion of environmental taxes and differentiated tax rates according to targeted activities have a significant effect on carbon reduction. Given the positive effect of economic complexity on carbon emissions in lower-middle-income countries, a reallocation of production factors from traditional economic activities to modern activities is recommended. The development of new methods for reducing pollution and producing cleaner energy (such as solar panels, wind turbines, hydropower, etc.), green technology, and environmental innovation have a strong impact on pollution reduction. Innovations in renewable energy, recycling, wastewater treatment, and environmentally friendly food packaging are also effective in reducing pollution and improving the environment[1].

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[1] - Just for English editing: As English is not our native language, we used OpenAI solely to check our English editing and for no other purpose (Open AI 2025).

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