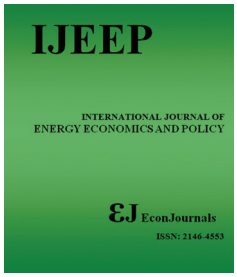

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(2), 953-966.

Geopolitical Risk, Financial Development, and CO_2 Emissions in BRICS: A Dual-Channel Analysis

Walid Trabelsi[1], Chaker Gabsi[2], Eya Chebbi[1], Sami Mensi[1]*

[1]Higher School of Business of Tunis, University of Manouba, Manouba, Tunisia, [2]Higher School of Science and Technology in Hammam Sousse, University of Sousse, Sousse, Tunisia. *Email: sami.mensi@esct.uma.tn

Received: 18 October 2025 **Accepted:** 26 January 2026 **DOI:** https://doi.org/10.32479/ijeep.22809

ABSTRACT

In the face of the global climate emergency, understanding the factors influencing CO_2 emissions has become essential for guiding environmental policies. This paper examines the effect of geopolitical risk and financial development on CO_2 emissions in BRICS countries between 1990 and 2023. To this end, we use Caldara and Iacoviello's GPR index (2022) and three financial indicators (private sector credit, bank credit, domestic credit). The reveals that geopolitical risk and financial development, estimated separately, help to reduce emissions. On the other hand, their interaction has a significant and positive effect, suggesting that financial development exacerbates the environmental impact of geopolitical risk. These results highlight the need to strengthen the supervision of financial flows during periods of instability to avoid an aggravating effect on CO_2 emissions.

Keywords: Geopolitical Risk, Financial Development, CO_2 Emissions, 2SLS, BRICS
JEL Classifications: I31, O13, O43, Q50, Q56

1. INTRODUCTION

Climate degradation, global warming and carbon dioxide (CO_2) emissions are among the most pressing challenges facing the world today (Anser et al., 2021). Nordhaus (2017), through his DICE model, formalized the integration of climate dynamics into economic analysis, providing a benchmark for evaluating the social cost of carbon and guiding sustainable policy design. Awareness of these challenges has intensified during the Conferences of the Parties (COPs), organized by the United Nations Framework Convention on Climate Change (UNFCCC). Despite international commitments, the situation remains alarming: for eighteen consecutive months, the global average temperature recently exceeded the critical threshold of 1.5°C set by the Paris Agreement (Économie Matin, 2025). Against this backdrop, CO_2 emissions take a pivotal position in economic and environmental debates, because of their adverse effects on the environment, public health and macroeconomic stability (Arioli et al., 2020). While many studies have examined the economic, social or political determinants of CO_2 emissions, few have jointly explored the role of geopolitical risk and financial development as these two dimensions seem crucial in understanding current emissions trends. Our study builds on this observation, seeking to determine the separate and joint impact of geopolitical instability and the development of national financial systems on CO_2 emissions.

To assess geopolitical risk, we use the index developed by Caldara and Iacoviello (2022), the Geopolitical Risk Index (GPR), constructed from a textual analysis of press articles dealing with armed conflicts, terrorist threats or diplomatic tensions (Chen et al., 2024). In parallel, we examine the role of financial development, perceived both as a potential lever to support ecological transition, but also as an aggravating factor when it finances carbon-intensive activities (Shoaib et al., 2020). The study focuses on the BRICS countries, which account for a significant share of the world's economy, planetary population and global CO_2 emissions. Their strategic position, marked by strong economic growth and

recurrent geopolitical tensions, makes them a particularly relevant study sample to explore the interactions between finance, political instability and environmental transition.

Bearing on these dimensions, our research problem revolves around the following question: do fluctuations in geopolitical risk and the dynamics of financial development influence CO_2 emissions in the BRICS countries? To answer this, three questions will guide our thinking: does geopolitical risk intensify CO_2 emissions? Does financial development promote their reduction, or contribute to increasing them? Finally, what is the nature of the interaction between these two dimensions, and what are the implications?

In order to provide rigorous answers to these questions, we use an adapted econometric method: the Two Stage Least Squares (2SLS). This method allows us to deal with endogeneity problems, take into account time-dependency effects and the specific features of each country. Recommended by Roodman (2009) for dynamic panel data analysis, this approach offers a robust framework to study lagged adjustment mechanisms and complex causal relationships.

The overall aim of this study is to test the hypotheses put forward and to better understand the complex relationships between finance, geopolitical instability and environmental performance in BRICS economies. Ultimately, this paper aims to contribute to the literature by shedding light on the links between geopolitics, finance and climate, in a context where it is becoming urgent to rethink the sustainable development policies of major emerging economies.

This paper is structured into three complementary sections: the theoretical background of the study, a literature review and an empirical analysis: The first section establishes the foundations of the study by defining the main concepts: CO_2 emissions, geopolitical risk and financial development. It successively explores the determinants of emissions, geopolitical tensions and their interactions with CO_2 emissions, the role of the financial system in CO_2 emissions dynamics, and theoretical models incorporating these dimensions. The second section is devoted to a review of the empirical literature. It presents the main research conducted on the relationships between CO_2 emissions, geopolitical risk and financial development, whether examined jointly or separately. Each section comes with summary tables identifying the methods, variables and results of previous studies. Finally, the third section describes the empirical approach. It begins with a presentation of the variables and a descriptive statistical analysis. It then goes on to check the validity of the econometric specifications by means of multicollinearity tests. The 2SLS estimation method is then detailed, followed by an interpretation of the empirical results, distinguishing between the direct effects of geopolitical risk and financial development on CO_2 emissions, as well as their interaction effects.

2. LITERATURE REVIEW

2.1. The Relationship between Geopolitical Risks and CO_2 Emissions

The relationship between carbon dioxide (CO_2) emissions and geopolitical risks has become central to the climate change debate. Dalby (2013) argues that geopolitical discourses and security concerns are increasingly intertwined with environmental challenges, highlighting how instability and conflict can exacerbate climate degradation. According to Nordhaus (2018), the main cause of climate change lies in greenhouse gas emissions, with carbon dioxide accounting for around 76% of these emissions (Coskuner et al., 2020). These gases trap heat in the atmosphere, leading to global warming (May and Kidder, 2022). To achieve sustainable development and preserve life on the planet, it is crucial to study and understand all the factors that influence and exacerbate these emissions. This includes not only social, economic and political factors, which have been the subject of much research in the literature, but also the impact of geopolitical risks on carbon dioxide emissions (Anser et al., 2021).

Studies on the relationship between CO_2 emissions and geopolitical risks are relatively recent, largely because of the composite Geopolitical Risk Index (GPR). This index covers factors such as war, terrorism and political instability. It provides a better understanding of how geopolitical tensions can influence CO_2 emissions, a crucial issue in the debate on climate change. Some studies have chosen to use terrorism as an indicator of global geopolitical risks. For example, Bildirici and Gokmenoglu (2020) concludes that foreign direct investment (FDI) and acts of terrorism increase CO_2 emissions. The authors use first-generation panel data methods and the panel ARDL approach, over a sample including countries such as Pakistan, Iraq, the Philippines, Nigeria, Thailand, Syria and Yemen. This study highlights the link between geopolitical instability and rising emissions, underlining the importance of security in investment decisions.

Much other research on geopolitical risks relies on militarization as an indicator of political risk. For example, Gokmenoglu et al. (2020) found that militarization, combined with financial development, leads to increased CO_2 emissions in Turkey. These studies point out that high military spending can divert financial resources that could have been invested in more sustainable technologies. Other studies also include political instability as an indicator of geopolitical risk. However, this study will focus mainly on recent research using the new geopolitical risk index developed by Caldara and Iacoviello. This GPR index integrates information on various geopolitical events, such as wars, terrorism and political tensions, offering a more comprehensive and accurate measure of geopolitical risk than the proxies used previously. In addition, the index is based on an analysis of press articles, providing real-time data on geopolitical risks. Its methodology uses a text mining approach to extract relevant information on geopolitical events.

The use of this index enriches our understanding of the interactions between geopolitical risks and CO_2 emissions, as it enables us to identify how specific events can influence a country's energy choices and, consequently, its greenhouse gas emissions. This index makes it possible to explore not only the direct effects of geopolitical risks on emissions, but also the underlying mechanisms that can exacerbate or mitigate these effects. Among the relevant studies, Anser et al. (2021) examined variables such as geopolitical risks, renewable energy consumption,

GDP, population and non-renewable energy consumption, and their impact on CO_2 emissions. Using second-generation panel methodologies, the authors found that an increase in geopolitical risks leads to an increase in CO_2 emissions. In addition, renewable energy consumption has a negative effect on CO_2 emissions, while increases in GDP and population are associated with higher emissions. Non-renewable energy consumption also intensifies emissions. This study, carried out between 1985 and 2015 on the BRICS countries, is justified by their significant share in global CO_2 emissions and geopolitical tensions, accounting for around 40% of global emissions and highlighting their crucial role in discussions on climate change and environmental sustainability. Focusing on BRICS, Zhao et al. (2021) examined the asymmetrical relationships between geopolitical risks, energy consumption and CO_2 emissions. The results show that geopolitical risks have a positive impact on CO_2 emissions, but this effect varies according to energy consumption level. With high energy consumption, the impact of geopolitical risks on emissions is amplified. Increased consumption of non-renewable energy strongly correlates with higher CO_2 emissions, while the impact of renewable energies seems to mitigate this effect. Unlike the previous study, which adopts a linear approach, this study uses an asymmetric analysis, allowing for a better understanding of the intricate relationships between the variables using an econometric model based on panel analysis techniques. Another study by Syed et al. (2022) examined the relationship between geopolitical risks and CO_2 emissions in the same emerging BRICS countries. The authors found that geopolitical risk (GPR) increases CO_2 emissions at lower quantiles, but reduces them at middle and upper quantiles. This study also incorporates other variables, including economic policy uncertainty (EPU), GDP per capita, non-renewable energy consumption and urbanization. The results show that economic policy uncertainty has a heterogeneous effect on CO_2 emissions, decreasing emissions at lower quantiles, while increasing them at higher quantiles. Furthermore, GDP per capita, non-renewable energy consumption, renewable energy and urbanization also exert heterogeneous impacts on CO_2 emissions, with renewable energy consumption associated with reduced emissions. The results were obtained using second-generation panel methods, including the augmented mean group estimator (AMG) and the common correlated effects mean group estimator (CCEMG), as well as a panel quantile regression model. The fourth study on the BRICS region, by Uddin et al. (2023), simultaneously assessed the impact of geopolitical risk, corruption, governance, foreign direct investment (FDI) and innovation on CO_2 emissions. Using econometric techniques such as CS-ARDL, FMOLS and DOLS, the authors found that increased geopolitical risk and corruption lead to higher CO_2 emissions. They justify this positive effect of geopolitical risk by the fact that it can discourage investment in renewable energy sources, pushing countries to turn more to the more polluting fossil fuels. Furthermore, an unstable geopolitical environment makes countries less attractive to FDI, which can hamper innovation and sustainability initiatives. On the other hand, good governance, as well as innovation and FDI, have a negative effect on CO_2 emissions. The study thus proposes practical recommendations for decision-makers, aimed at reducing CO_2 emissions by improving governance and reducing geopolitical risk. Wang et al. (2022) examined the interaction between geopolitical risk (GPR) and CO_2 emissions in China, a BRICS member. What distinguishes this study from previous research is that it establishes a bidirectional causal relationship between GPR and CO_2 emissions. This means that not only does GPR influence CO_2 emissions, but CO_2 emissions also affect GPR. To analyze these complex relationships, the study uses a VAR (Vector Autoregression) model, which dynamically explores the interactions between the two variables. In addition, GPR is measured using the index developed by Caldara and Iacoviello, capturing geopolitical tensions in press articles. This methodological approach enriches our understanding of the mechanisms underlying the relationship between GPR and CO_2 emissions, while taking into account the specificities of the Chinese context.

In addition to studies on the BRICS, a line of research has examined the relationship between geopolitical risk and CO_2 emissions across developed and developing countries (Ma et al., 2022; and Chen et al., 2024). Ma et al. (2022) focused on eight of the top ten CO_2 emitting countries, divided into two groups: developed countries, namely the USA, Germany, Japan and Saudi Arabia, and developing countries, including China, Russia, India and Indonesia. The analysis period runs from 1990 to 2020. The results show that geopolitical risk (GPR) increases CO_2 emissions in both developed and developing countries, with a greater impact in developed countries in the long term. The study validates the presence of the Environmental Kuznets Curve (EKC) for developing countries and confirms the validity of the pollution refuge hypothesis, indicating that these countries may transfer polluting activities to countries where environmental regulations are less stringent. In addition, energy consumption is identified as a key factor increasing emissions in all countries, both in the short and long term. This study used robust methods, such as the PMG-ARDL model and Westerlund cointegration tests. Likewise, Chen et al. (2024) made several complementary contributions and perspectives to the study of Ma et al. (2022). In their study, the authors explored the impact of geopolitical risk on the inequality of CO_2 emissions in a set of 38 developed and developing economies between 1990 and 2019. The study focused specifically on CO_2 emissions inequality, with emissions inequality measured by the per capita carbon footprint of the richest 10% of the population as the dependent variable. The authors found that geopolitical risk, the capital-labor ratio and GDP per capita increase CO_2 emissions inequality, while globalization has a negative effect on this inequality. Furthermore, cointegration tests revealed a significant long-term relationship between geopolitical risk and inequality in CO_2 emissions, suggesting that these factors are interconnected. Another study exploring the relationship between carbon dioxide (CO_2) emissions and geopolitical risk is that of Chen et al. (2023). The authors examined how geopolitical risk influences CO_2 emissions, focusing on the role of natural resource rents. They use regression models to establish relationships between variables, showing that geopolitical risk has a significant and positive effect on CO_2 emissions. This suggests that geopolitical tensions can lead to an increase in these emissions. Furthermore, natural resource rents exacerbate this effect, highlighting that resource-rich countries could see their emissions increase further under the effect of geopolitical risk. Moreover, Ding et al. (2023)

used regression models to examine the impact of geopolitical risk on CO_2 emissions, focusing specifically on mineral resource extraction in OECD countries. The study shows that geopolitical risk has a significant and positive effect on CO_2 emissions, and that mineral resource extraction intensifies this effect. This suggests that countries heavily dependent on these resources are particularly vulnerable to increases in CO_2 emissions during periods of geopolitical tensions. The choice of the OECD region is justified by the fact that these countries share similar economic and political characteristics, which makes it possible to eliminate some confounding variables. In addition, OECD countries are rich in natural resources and dependent on mineral extraction. Finally, these countries are often at the forefront of environmental policies and commitments to reduce emissions. The latest study to examine the link between carbon dioxide (CO_2) emissions and geopolitical risk is that of Paramati et al. (2025). This study explored the impact of geopolitical risk (GPR) on carbon emissions and public health risks in 17 countries between 1990 and 2018. Using techniques such as generalized quantile regression, the study shows that an increase in GPR leads to a significant rise in CO_2 emissions. This effect is more pronounced in countries where emissions are already high. In addition, the study highlights that GPR, by increasing carbon emissions, exacerbates public health risks, notably through increased air pollution and reduced life expectancy. In line with these results, we propose to test the following hypothesis in the BRICS countries.

H_1: Geopolitical risks stimulate CO_2 emissions in BRICS countries.

2.2. The Relationship between Financial Development and CO_2 Emissions

The relationship between financial development and CO_2 emissions is complex and requires in-depth analysis to better understand its dynamics. Financial liberalization has long been recognized as a driver of economic growth (Bekaert et al., 2005), yet this growth dynamic may indirectly intensify CO_2 emissions when it relies on carbon intensive sectors. It is essential to specify the geographical research background, the economic contexts and the expected changes, while taking into account the interdependent relationships between the variables. These relationships are often causal in nature, and can be unidirectional or bidirectional in their interaction with carbon dioxide emissions. The complexity lies in the diversity of research findings. On the one hand, some studies suggest that financial development contributes to reducing CO_2 emissions (Zhang, 2011; Shahbaz et al., 2013; 2016). These studies explain that financial development plays a crucial role in the transition to more sustainable practices by facilitating access to capital. In line with this perspective, Porter and Van Der Linde (1995) argue that stringent but well designed environmental regulations can stimulate innovation, enhance competitiveness, and ultimately reduce emissions, supporting the idea that finance and policy can jointly foster sustainability. This enables companies to invest in more efficient technologies and production methods, helping to reduce their carbon footprint. A sound financial system can also encourage innovation in renewable energies, improve resource management and strengthen companies' ability to adopt sustainable practices. On the other hand, another line of research shows that financial development can exacerbate climate degradation (Shoaib et al., 2020; Bui, 2020; Khan and Ozturk, 2021). In line with this perspective, Battiston et al. (2017) emphasize that the architecture of financial networks and systemic risk can amplify environmental shocks, suggesting that unchecked financial flows may worsen CO_2 emissions during periods of instability. According to these studies, access to finance sometimes encourages companies to adopt more polluting practices by enabling them to invest in obsolete or inefficient technologies. In addition, financial liberalization and market expansion can encourage the development of unsustainable economic sectors, such as natural resource extraction, associated with environmental damage. This damage is often exacerbated by the absence of strict environmental regulations in some contexts, allowing companies to make profits at the expense of sustainability. Finally, some studies point to a lack of a significant relationship between financial development and CO2 emissions (Omri et al., 2015). The results of Cole et al. (2005) are particularly puzzling. Their study suggests that, on the one hand, financial development can help companies overcome planning constraints and achieve economies of scale in the production process, thereby reducing pollution. On the other hand, it points out that this same development can facilitate the entry of new polluting and inefficient industries, thus posing a threat to a sustainable environment.

It is crucial to consider geographical and economic contexts in order to understand and define the nature of the relationship between financial development and CO_2 emissions. Grossman and Krueger (1995) introduced the Environmental Kuznets Curve (EKC), suggesting that pollution initially rises with economic growth but eventually declines once income reaches a certain threshold, a framework that remains central to debates on sustainability. In this regard, some studies have adopted a global sample to examine this relationship. For example, Bui (2020) used a sample of 100 countries to obtain comprehensive and more generalizable results. In addition, some studies have adopted a comparative approach between developing and developed countries. These studies have focused on two groups of countries with different economic contexts, such as the D8 and G8 in the study of Shoaib et al. (2020). This study produced significant results thanks to a PMG-panel ARDL estimation, making it possible to analyze long-term and short-term relationships between variables. D-H causality tests also revealed unidirectional relationships towards CO_2 emissions, with the exception of a bidirectional causality between financial development and energy consumption in the G8 panel. Furthermore, it is important to note that most research has focused on the direct relationship between financial development and CO_2 emissions. However, Bui (2020) proposes the concept of transmission channels, focusing on energy demand, economic growth and income inequality. The aim is to examine how financial development can affect CO_2 emissions, taking into account the indirect effects often overlooked by the previous literature. Empirical results indicate a positive direct effect of financial development on environmental degradation, mainly due to an increase in energy demand. Furthermore, the study revealed a trade-off between income inequality and environmental quality: while financial development may reduce inequality, it may also lead to higher CO_2 emissions.

In addition, Khan and Ozturk (2021) examined both the direct and indirect effects of financial development on CO_2 emissions,

focusing specifically on a sample of 88 developing countries observed between 1990 and 2012. For the direct effect, the authors found that financial development had a significant positive impact on CO_2 emissions. For the indirect effect, an improvement in financial development led to an increase in energy consumption. It should also be noted that financial development can reduce income inequality, but this reduction can paradoxically lead to an increase in CO_2 emissions, as countries with higher living standards tend to pollute more. These results were obtained using a two-stage least-squares (2SLS) estimation approach. Lv and Li (2021) showed that financial development has a significant positive impact on CO_2 emissions by increasing energy demand. Beyond the direct and indirect effects of financial development on CO_2 emissions, recent research highlights the importance of climate economy feedbacks. Kikstra et al. (2021) demonstrate that temperature variability and feedback mechanisms significantly alter the social cost of carbon, reinforcing the need to integrate these dynamics into financial and environmental policy assessments. In addition, the authors discuss how income inequality and economic structure influence this relationship.

What sets this study apart is the use of spatial econometric analysis, making it possible to examine not only the overall effects of financial development on CO_2 emissions, but also the variability of these effects across geographical regions. The study also highlights the fact that CO_2 emissions in one country can be influenced by financial development in neighboring countries, underlining the importance of regional interactions.

Habiba and Xinbang (2022) examined the impact of financial development on CO_2 emissions in developed and emerging countries. The authors use a multiple regression model to quantify the relationship between financial development and CO_2 emissions, controlling for various factors such as GDP, energy consumption, income inequality and other macroeconomic variables likely to influence emissions. The results show that the impact of financial development on CO_2 emissions varies according to the level of economic development. In emerging countries, this effect is often more pronounced, which can be attributed to rapid industrialization and greater dependence on polluting energy sources. In addition, Lv and Li (2021) also discussed neighborhood effects. On the other hand, Petrović and Lobanov (2022) used a sample comprising a wide range of countries, both developed and emerging, to compare the effects of financial development on CO_2 emissions in different economic contexts between 1990 and 2020. The study underlines that the impact of financial development on emissions varies according to the level of economic development of countries.

The authors found a significant positive relationship between financial development and CO_2 emissions. They also highlight the role of financial innovation, suggesting that the development of green financial products can mitigate the negative effects on CO_2 emissions. The authors use both fixed and random effects models to estimate this relationship.

Other authors examined the effects of financial development on CO_2 emissions in different economic contexts, using a sample of several countries, both developed and emerging. What distinguishes Raheem and Tiwari (2020) from the previous literature is that it incorporates information and communication technologies (ICT), thus offering a more holistic perspective on the factors influencing emissions and economic growth. The results show that the effects of ICT and financial development on CO_2 emissions vary from country to country, depending on their development level. In developed countries, ICTs can help reduce emissions through more sustainable practices, while in developing countries they can increase energy consumption. Bayar et al. (2020) examined the impact of financial development on CO_2 emissions in 11 European Union countries that have recently completed their economic transition. The authors reveal a significant positive relationship between financial development and CO_2 emissions, suggesting that an increase in financial development correlates with an increase in CO_2 emissions in these post-transition countries. The authors chose to study these countries because of their unique economic context and the specific environmental challenges they face. While transitioning to market economies, these countries offer an interesting perspective on the impact of financial development on CO_2 emissions.

In addressing the importance of the geographical dimension, it is essential to consider the varied economic contexts and expected changes in the influence of financial development on CO_2 emissions. Bearing this in mind, the impacts of Chinese policies on the global energy-growth nexus deserve particular attention, especially with regard to the spillover effects of CO_2 emissions and financial development. Given that China is the world's second largest economic player and leading energy consumer, it is crucial to understand current global dynamics (Marques et al., 2021). The authors adopted an autoregressive distributed lag (ARDL) approach to analyze annual data from 1977 to 2016, focusing on four global regions and a global model. This methodology enables in-depth exploration of the short- and long-term relationships between the variables under study. The results highlight a traditional trade-off between energy consumption and economic growth, both in the short and long term. In addition, CO_2 emissions and financial development in China contribute significantly to an increase in global energy consumption. The observed effects vary from region to region, indicating heterogeneous impacts and underlining the need for a nuanced approach to understanding the implications of Chinese policies on financial development and the environment. In line with these results, we propose to test the following hypothesis in the BRICS countries.

H_2: Financial development reduces CO_2 emissions in BRICS countries.

2.3. The Relationship between Geopolitical Risks and Financial Development

Geopolitical stability is an essential factor in the smooth operation of financial systems. Indeed, geopolitical tensions, such as armed conflicts, economic sanctions or political instability, can disrupt capital flows, weaken investor confidence and curb banking and financial activities (Lu et al., 2020). Numerous empirical studies have highlighted a negative relationship between geopolitical risk and financial development. For example, Lu et al. (2020) examined the impact of geopolitical risks on financial development in emerging markets. Using a sample of 18 countries for the 1985-2018 period, the authors show that an increase in geopolitical

uncertainties leads to a reduction in domestic credit extended to the private sector. This decline in available financing limits access to credit and curbs economic growth. The authors also show that factors such as per capita income and money supply support financial development, while external imbalances have the opposite effect. In a similar vein, Carney et al. (2024) examined the impact of geopolitical risk on the cost of capital in emerging economies. Using a large panel of 55,900 observations from 19 countries between 1987 and 2018, they show that increased geopolitical risk is associated with a significant rise in the cost of equity capital for companies. This rise is explained in particular by a reallocation of investments towards markets perceived as safer, which reduces the availability of capital in the very economies. The observed effect varies according to institutional characteristics and company specificities. Furthermore, Adel and Naili (2024) explored the effect of geopolitical risk on banking performance in 13 emerging economies in the Middle East and Africa over the 2003-2019 period. Using two-stage GMM estimation on a sample of 125 banks, the authors found that Middle Eastern banks are particularly vulnerable to geopolitical risk, with the latter having a significant impact on their profitability and solvency. By contrast, African banks seem less affected, with statistically insignificant results. These findings confirm that geopolitical stability plays a central role in the solidity of the banking sector in developing economies.

Although most studies document a negative effect of geopolitical risk on financial development, some studies suggest that this relationship could be more complex, or even positive in some contexts. Recently, Bashir et al. (2024) highlighted a non-linear relationship between geopolitical risk, financial development and energy transition in industrialized economies. The authors showed that when geopolitical tensions reach certain thresholds, they can prompt governments and financial institutions to adopt more proactive energy transition strategies. This is reflected in increased investment in renewable energies, greater recourse to sustainable financing, and the creation of innovative financial instruments. This process, properly supported by appropriate public policies, can then foster some dimensions of financial development, particularly those linked to green finance and innovation. With these results in mind, we propose to test the following hypothesis in the BRICS countries.

H_3: The relationship between geopolitical risk and financial development is negative.

2.4. The Combined Impact of Geopolitical Risk and Financial Development on CO_2 Emissions

Among the authors exploring the impact of geopolitical risk and financial development on CO_2 emissions, Alsagr and Van Hemmen (2021) stands out in particular. Indeed, these authors examined the interactions between financial development, geopolitical risk and renewable energy consumption in emerging markets, during the 1996-2015 period. This multidimensional approach provides a better understanding of the dynamics at play. Their results, using a two-stage GMM system, reveal that financial development favors investment in renewable energies, which in turn helps to reduce CO_2 emissions by replacing fossil energy sources. However, geopolitical risk creates uncertainty that can discourage these investments in renewable energy infrastructure. Consequently, this would prolong dependence on fossil fuels, leading to increased CO_2 emissions. In addition, geopolitical tensions can disrupt supply chains, negatively affecting the transition to less polluting energy sources.

In another context, Chu et al. (2023) examined the impact of financial development and geopolitical risk on their environmental footprints, measured by indicators such as CO_2 emissions, between 2000 and 2018. What distinguishes these authors is the sample chosen, consisting of 40 high- and middle-income countries, with results varying according to income level. The findings indicate that the impact of financial development on the environmental footprint varies significantly between high- and middle-income countries. In high-income countries, financial development seems to favor more sustainable practices, while in middle- income countries, this impact may be less obvious. Indeed, geopolitical risk also influences this relationship, as increased risk in middle-income countries may dampen investment in green technologies, thereby worsening the environmental footprint. In addition, Saadaoui et al. (2024) analyzed the impact of hydropower generation, financial development, geopolitical risk, income and foreign direct investment (FDI) on CO_2 emissions in Turkey, over the 2000-2020 period. The results indicate that financial development is a key factor positively influencing investment in green technologies. Geopolitical risk, on the other hand, has varying effects on carbon emissions; increased risk can discourage foreign investment, thus undermining efforts to reduce emissions. On the other hand, FDI has a negative effect on emissions, while hydropower generation has a significant impact on reducing carbon emissions in Turkey. This study highlights the importance of renewable energy sources in the fight against climate change, and offers a more comprehensive understanding of the factors influencing carbon emissions by integrating several variables. In addition, Shu et al. (2024) examined the relationships between geopolitical risk, uncertainty, financial development, renewable energy and carbon intensity in 18 countries with high geopolitical risk over the 1985-2021 period. By focusing on these countries, the authors highlight dynamics often overlooked in other studies. Strong empirical evidence reinforces the credibility of the results, which reveal robust cointegration, with variations in the response of carbon intensity to other factors. The results also show that high levels of geopolitical risk are associated with increased carbon intensity, suggesting that uncertainty can dampen investment in renewable energies. Furthermore, financial development is identified as a crucial element in facilitating these investments, although geopolitical risks can disrupt this process. The authors stress the need for long-term strategies to reduce carbon intensity and achieve Sustainable Development Goals (SDGs) 12 and 13. Finally, Hunjra et al. (2024) analyzed how geopolitical risk and financial development influence CO_2 emissions during transition to net-zero emission levels. The authors point out that geopolitical risks create uncertainties that hamper investment in green technologies, thereby jeopardizing efforts to reduce carbon emissions. They also highlight the crucial role of institutional governance and green financing, which can mitigate the negative effects of geopolitical risk by

facilitating a more stable and sustainable energy transition. The results show that strong institutions and an adequate financing framework are essential to overcome the challenges posed by geopolitical risks, enabling countries to progress towards their carbon neutrality goals.

In addition, Adebayo et al. (2023) explored the relationship between geopolitical risk, trade openness, economic growth and carbon emissions in India. The authors highlight how these factors interact and influence climate change in the country. They found that geopolitical risk can hinder economic growth and negatively influence trade openness, which in turn affects carbon emission levels. To this end, the study uses econometric methodology, including cointegration analyses and Granger causality tests, to examine long-term relationships between variables. The authors also apply regression models to quantify the direct and indirect effects of geopolitical risks on CO_2 emissions, while taking into account the specificities of the Indian context.

In conclusion, financial development plays a crucial role in this dynamic by facilitating the investments needed to promote sustainable technologies and reduce carbon emissions. A robust financial sector is essential to support trade openness and economic growth, which directly influence emissions levels. The results indicate that policies to improve governance and promote sustainable trade, while strengthening financial development, can mitigate the negative impacts of geopolitical risk on carbon emissions. In line with these results, we propose to test the following hypothesis in the BRICS countries.

H_4: Financial development moderates the effect of geopolitical risk on CO_2 emissions.

3. METHODOLOGY

3.1. Presentation of the Sample and Variables

Our study examines a sample of five BRICS countries (Brazil, Russia, India, China and South Africa), observed over the 1990-2023 period. The choice of these countries is explained by their growing weight in global CO_2 emissions dynamics. Indeed, the BRICS countries generate around 32% of global gross domestic product (GDP), are home to almost 42% of the world's population and are responsible for around 40% of global CO_2 emissions (Anser et al., 2021; Zhao et al., 2021; Syed et al., 2022). These metrics give our sample particular relevance to study the links between geopolitical risks, financial development and carbon emissions.

As for the variables, they cover three main dimensions: environmental, economic-financial and geopolitical. The dependent variable is total CO_2 emissions, excluding those from land use, land-use change and forestry (LULUCF), to ensure better comparability between countries. Furthermore, our study uses the Geopolitical Risk Index (GPR) developed by Caldara and Iacoviello (2022), which is based on counting press articles containing terms related to geopolitical tensions. This index has the advantage of being objective, standardized and comparable over a long period. To obtain an annual measure of geopolitical risk, we follow the method of Anser et al. (2021), consisting of aggregating monthly data. It is important to point out that the GPR data come directly from the database made available by Caldara and Iacoviello (2022).

For financial development (FD), three main variables were selected: private credit (PC), bank credit (BC) and domestic credit (DC). This methodological choice was inspired from Alsagr and Van Hemmen (2021), who emphasize that financial development is a multidimensional concept and cannot be fully captured by a single indicator. According to their approach, private credit reflects access to financing for the private sector, bank credit measures the efficiency of the banking system via the credit/deposit ratio, while domestic credit captures the total scale of financing granted to the private sector. Thus, the combined use of these three indicators provides a better understanding of the depth, structure and performance of the financial system. Furthermore, the choice to exclude indicators representing stock market financing is explained by the structural nature of the BRICS economies, which are largely oriented towards a banking model. Indeed, as Beck et al. (2000) point out, the financial systems of many emerging countries are marked by a predominance of bank financing at the expense of stock markets, which are often less developed, less liquid and more volatile. Focusing on bank financing therefore better reflects the financial reality of these countries, and ensures empirical consistency in the analysis.

Finally, in order to control for other potential determinants of CO_2 emissions, we include economic and energy variables: GDP growth, change in foreign direct investment (FDI) and the share of renewable energy consumption (REC). The data set for the economic and financial variables is extracted from the World Bank database (World Development Indicators), while data for GPR is taken from the database developed by Caldara and Iacoviello (2022). Table 1 shows the variables and their data sources.

3.2. Descriptive Statistics

Table 2 represents the descriptive statistics of the variables used in our empirical study. CO_2 emissions ($lnCO_2$) are the dependent variable of the study. The geopolitical risk index (GPR) and measures of financial development, namely private credit (lnPC), bank credit (lnBC) and domestic credit (lnDC), are introduced as main independent variables. Control variables include GDP growth (dGDP), net foreign direct investment flows (dIDE100) and renewable energy consumption (REC).

For CO_2 emissions, the mean of the logarithm is 7.08, with a standard deviation of 1.10. The minimum value observed is 5.42 and the maximum value reaches 9.49, reflecting a significant disparity between BRICS countries in terms of emissions. Data on the evolution of CO_2 emissions in BRICS countries shows, an upward trend is observable in recent years, particularly in China and India, reflecting an intensification of industrial activity and increased dependence on fossil fuels in these two countries. The geopolitical risk index has a mean of 3.86 and a high standard deviation of 4.94, indicating significant variability in geopolitical risk between BRICS countries over the 1990-2023 period. This variability is also illustrated in Chart 1 on the evolution of GPR in BRICS countries, presented earlier. It shows that Russia and

Table 1: Variables and their data sources

Abbreviation	Variable	Measure	Unit	Source
CO_2	CO_2 emissions	Total CO_2 emissions, excluding land use, land- use change, and forestry (LULUCF)	Expressed in megatons, Mt CO_2e	World Development Indicators (WDI), World Bank
GPR	Geopolitical risk index	Monthly index based on the frequency of terms related to geopolitical risk	%	Caldara and Iacoviello (2022)
PC	Private credit	Private credit granted by banks and financial institutions, as a percentage of GDP.	% of GDP	WDI, World Bank
BC	Bank credit	Bank credit reported to bank deposits.	%	WDI, World Bank
DC	Domestic credit	Domestic credit to the private sector, as a percentage of GDP	% of GDP	WDI, World Bank
GDP	GDP growth	Annual GDP variation in current dollars (%)	Current dollars (%)	WDI, World Bank
FDI	Foreign Direct Investment	Annual net variation of foreign direct investment	%	WDI, World Bank
REC	Renewable Energy Consumption	Share of renewable energy consumption in total final consumption.	%	WDI, World Bank

Source: Authors from https://www.matteoiacoviello.com/gpr_country.htm

China experience significantly higher levels of geopolitical risk compared to the other countries in the group. Private credit has a mean of 27.13 with a standard deviation of 1.41, while bank credit and domestic credit have respective means of 27.77 and 27.08, along with close standard deviations. These results suggest a degree of homogeneity in the financial development level across BRICS countries, although differences are observable.

For the control variables, GDP growth has a mean of 7.59%, with a high dispersion around this value, as evidenced by a standard deviation of 14.97%. Foreign direct investment flows have a mean of 61.65 and a very high standard deviation of 296.32, reflecting a high volatility of FDI flows within the studied economies. Finally, renewable energy consumption records a mean of 24.93%, with notable variability, reflecting differences in energy policies and consumption structures among BRICS countries.

These descriptive statistics confirm the presence of significant heterogeneity among the studied countries, both in terms of CO_2 emissions and explanatory factors, which justifies the use of an estimation method suited to panel dynamics, particularly the Arellano-Bond method. This structural and conjunctural diversity among BRICS countries reinforces the relevance of a dynamic econometric approach, allowing for a better understanding of the differentiated impact of geopolitical risk and financial development on CO_2 emissions during the 1990-2023 period.

After presenting the descriptive statistics of the different variables, we will examine the linear relationships between them through a correlation analysis. This step is essential to better understand the dynamics between geopolitical risk, financial development, and CO_2 emissions in BRICS countries over the 1990-2023 period. The correlation matrix allows for identifying initial associations, whether positive or negative, between the variables, and to anticipate potential multicollinearity issues that could affect the econometric results.

This section aims to detect potential collinearity issues using two complementary tools: a correlation analysis, which helps identify linear relationships between variables, and the Variance Inflation Factor (VIF) test, which precisely quantifies the level of redundancy among independent variables.

From Table 3, the correlation matrix gives us several important results. First of all, CO_2 emissions show a strong positive correlation with geopolitical risk (GPR) as well as with various indicators of financial development (lnPC, lnBC, and lnDC). Indeed, the correlation coefficients are above 0.61, indicating a strong correlation between these variables. This relationship suggests that increased geopolitical instability, as well as financial development growth, may be associated with an increase in CO_2 emissions in BRICS countries.

It should be noted, however, that the correlation matrix only measures the bivariate relationship between two variables, without taking into account other factors that may simultaneously influence this relationship. That is why a multivariate econometric analysis is necessary to isolate the specific effects of each variable. Furthermore, renewable energy consumption shows a negative correlation with CO_2 emissions as well as with geopolitical risk. This relationship suggests that an increase in the share of renewable energy in overall energy consumption contributes to reducing CO_2 emissions, and that geopolitical tensions can hinder this transition to less polluting energy sources. Moreover, the various measures of financial development exhibit particularly high correlations among themselves, indicating a strong interdependence between these indicators. This strong correlation can lead to multicollinearity problems in the econometric model, thereby compromising the accuracy of the estimates. It will therefore be necessary to check the effect of each variable on CO_2 emissions independently, in order to avoid the impact of one being artificially attributed to another because of their strong correlation.

4. EMPIRICAL METHODS

4.1. Model

To better isolate the specific direct effect of each financial development indicator on CO_2 emissions, we constructed four distinct models. Each model includes a single measure: private credit, bank credit, domestic credit, or geopolitical risk, as well as control variables (real GDP growth, foreign direct investments, and renewable energy consumption). The objective is to minimize the multicollinearity issues identified in the previous steps. After separately analyzing the impact of geopolitical risk (GPR)

Table 2: Descriptive statistics

Statistic	LNCO2	GPR	LNPRIVATE…	LNBANKCR…	LNDOMEST	LNGDP	FDI	REC	GPR_PRIVATE	GPR_BANK	GPR_DOME…
Mean	7.081052	3.863697	27.13669	27.77302	27.08572	27.55866	2.013891	24.93125	84.77610	87.46970	83.40513
Median	7.211483	2.318591	26.95909	27.75789	26.92566	27.47675	1.743510	18.60000	50.49760	53.35347	50.49759
Maximum	9.492480	44.28464	31.08871	31.80883	30.92163	30.51480	9.660265	53.00000	380.1894	390.9526	379.8901
Minimum	5.424485	0.217541	24.66641	25.59524	24.66727	25.55993	−1.756418	3.200000	5.786561	6.034034	5.780494
Standard deviation	1.109790	4.942156	1.412236	1.412667	1.366259	1.167679	1.586190	17.38440	88.29587	90.90708	86.53835
Skewness	0.478580	3.981744	0.729541	0.877540	0.802732	0.544269	1.002991	0.142174	1.459062	1.421481	1.496799
Kurtosis	2.258539	28.93713	3.427812	3.437480	3.607450	2.854947	5.168710	1.414880	4.457522	4.311696	4.693968
Jarque-Bera	10.38359	5214.408	14.35332	20.17545	17.55630	8.542196	61.09088	17.28973	66.05551	60.45170	70.49396
Probability	0.005562	0.000000	0.000764	0.000042	0.000154	0.013966	0.000000	0.000176	0.000000	0.000000	0.000000
Sum	1203.779	656.8285	4043.367	41110.407	3873.258	4684.973	338.3337	3989.000	12631.64	12945.51	11926.93
Sum Sq. Dev.	208.1460	4127.808	295.1726	293.3575	265.0662	230.4272	420.1716	48052.54	1153832.	1214822.	1063422.
Obs	170	170	149	148	143	170	168	160	149	148	143

Source: Authors' calculation with Stata, 2025. The variables were adjusted either by logarithm (ln) or by first difference (d)

and financial development on CO_2 emissions, we broaden our approach by studying their combined effect. The objective is to examine whether financial development can mitigate or exacerbate the impact of GPR on the environment. To this end, we introduce interaction variables between the GPR and each of the three financial indicators: Domestic Credit, Private Credit, and Bank Credit. This approach allows for a better understanding of how financial stability can influence the relationship between geopolitics and CO_2 emissions in the BRICS countries. The chosen model is thus designed:

$$CO_{2it} = \alpha_0 + \alpha_1 CO_{2it-1} + \beta_1 GPR_{it} + \beta_2 FD_{it} + \beta_3 (GPR_{it} \times FD_{it}) + \gamma_1 GDP_{it} + \gamma_2 FDI_{it} + \gamma_3 REC_{it} + \varepsilon_{it}$$

Where: i denotes the country, t denotes the year, Δ indicates the consideration of dynamics through the lagged variable, and ε_{it} is the error term.

In line with our methodological approach, we opted for a dynamic panel model to account for the temporal nature of our data and the inherent dynamics of our dependent variable (CO_2 emissions), marked by significant inertia. Moreover, due to endogeneity risk that could affect some independent variables, particularly geopolitical risk and financial development, it is necessary to use an appropriate econometric approach. Thus, we chose to adopt the dynamic Two Stage Least Squares (2SLS). This method is particularly well-suited to our study, which aims to determine whether fluctuations in geopolitical risks and financial development dynamics lead to an increase in CO_2 emissions in BRICS countries over the 1990-2023 period. The use of this method allows us to correct biases related to endogeneity, capture the temporal dependence of CO_2 emissions, and better control for unobserved country-specific effects. Moreover, the 2SLS method is well-suited for the analysis of dynamic panel data, particularly by taking into account memory effects and adjustments over time.

To ensure the robustness of our results, we will also conduct post-estimation tests. These tests will allow us to confirm the relevance of the chosen model and ensure the reliability of our estimates. From then on, the use of the 2SLS model ensures us robust econometric results.

5. RESULTS AND DISCUSSION

Table 4 presents the results of the econometric estimations obtained using the 2SLS method for the BRICS countries over the 1990-2023 period. Four distinct models were tested, each introducing a single measure of financial development or geopolitical risk as the main independent variable: model 1 (M1) includes only geopolitical risk (GPR), while models 2, 3, and 4 (M2, M3, M4) respectively incorporate private sector credit (lnPC), bank credit (lnBC), and domestic credit (lnDC).

The first model aims to determine the effect of geopolitical risk (GPR) on CO_2 emissions in BRICS countries. The estimation shows that the GPR coefficient is negative and highly significant (−0.0038), which indicates that a 1% increase in geopolitical risk would lead to a decrease of approximately 0.38% in CO_2

Table 3: Correlation matrix

Correlation probability	$LNCO_2$	GPR	LNPRIVATE	LNBANKCR…	LNDOMESTI…	LNGDP	FDI	REC
$LNCO_2$	1.000000							

GPR	0.668588	1.000000						
	0.0000	------						
LNPC	0.698591	0.377637	1.000000					
	0.0000	0.0000	------					
LNBC	0.811726	0.489601	0.945168	1.000000				
	0.0000	0.0000	0.0000	------				
LNDOMESTICCRE	0.714509	0.374320	0.998003	0.949185	1.000000			
	0.0000	0.0000	0.0000	0.0000	------			
LNGDP	0.731474	0.466084	0.904732	0.933409	0.900360	1.000000		
	0.0000	0.0000	0.0000	0.0000	0.0000	------		
FDI	0.334523	0.053740	0.386253	0.460820	0.385123	0.400993	1.000000	
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	------	
REC	−0.331336	−0.512746	−0.255708	−0.200452	−0.267457	−0.076807	−0.007729	1.000000
	0.0001	0.000	0.0021	0.0164	0.0012	0.3619	0.9270	------

Source: Author's calculation with Stata, 2025. The variables were adjusted either by logarithm (ln) or by first difference (d)

emissions. This result contradicts hypothesis H_1, which suggests that geopolitical instability would exacerbate emissions. Furthermore, the lagged variable of CO_2 emissions ($L.lnCO_2$) shows a positive and highly significant coefficient (1.015), highlighting a strong inertia in the dynamics of emissions. This means that past emission levels strongly influence current levels, which confirms the persistence of the phenomenon over time. For the control variables, GDP growth has a positive and significant effect (0.064), which confirms that economic growth in the BRICS remains heavily CO_2-emitting. Foreign direct investment is not significant in this model, suggesting that its impact on emissions remains marginal or indirect in this specific case. Finally, renewable energy consumption shows a negative and very significant effect (−0.472), indicating that an increase in the share of renewable energy consumption effectively contributes to decreasing CO_2 emissions.

In our empirical study, we found that GPR reduces CO_2 emissions, a result that seems contradictory to the conclusions of Anser et al. (2021). However, it is essential to justify that our research period, from 1990 to 2023, aligns with an intensification of geopolitical risks, particularly in Russia, where these risks have reached particularly high levels in recent years.

As Zhao et al. (2021) point out, who conducted an asymmetric analysis, the effect of GPR on CO_2 emissions is negative, especially in countries like Russia, India, and South Africa, while it is positive in China and Brazil. This asymmetry is crucial for understanding our model, as recent geopolitical risks in Russia directly influence our results. Moreover, according to Syed et al. (2022), geopolitical risks increase CO_2 emissions at lower GPR quantiles but can reduce them at middle and high quantiles. This reinforces our observation that, in contexts of increased geopolitical tensions, emissions can indeed decrease. High geopolitical tensions can slow down economic or industrial activity, or cause reallocations of resources that temporarily reduce emissions. In conclusion, although our result may seem contradictory to some studies, it is actually compatible with the authors' observations, given the current geopolitical context. Major events, such as the war in Ukraine, strongly influence the results and demonstrate that in periods of high geopolitical risk, CO_2 emissions can decrease because of economic impacts and adjustments in energy consumption.

The second, third, and fourth models examine the effect of financial development on CO_2 emissions in the BRICS countries. Financial development is measured through three indicators: credit to the private sector (lnPC), bank credit (lnBC), and domestic credit (lnDC). Model 2 introduces credit to the private sector (lnPC) as a measure of financial development to assess its impact on CO_2 emissions in the BRICS countries. The coefficient of the lagged emissions variable L.lnCO2 is positive and highly significant (1.030, significant at 1%), once again confirming the persistence of emission levels over time. For the coefficient of credit to the private sector, it is negative and significant, with a value of −0.011 (at the 1% threshold), indicating that a 1% increase in this credit would lead to a reduction of approximately 1.1% in CO_2 emissions. This result validates hypothesis H_2, according to which financial development contributes to the reduction of CO_2 emissions. For the control variables, GDP growth retains a positive and significant effect (0.120), confirming that economic dynamics in the BRICS are still strongly linked to an increase in emissions. Foreign direct investment (FDI100) is significant but of small magnitude, indicating a potentially marginal effect. Renewable energy consumption shows here a positive but very low effect.

In this model, we evaluate the impact of bank credit on CO_2 emissions. As in the previous models, the lagged variable $L.lnCO_2$ remains highly significant (1.037), confirming the persistent dynamics of emissions. For bank credit, it shows a negative coefficient of −0.018, significant at the 1% threshold. This means that a 1% increase in bank credit is associated with a 1.8% decrease in CO_2 emissions. This estimate also confirms hypothesis H_2, highlighting that financial institutions can play a favorable role in energy transition, particularly by directing credit towards less carbon-intensive investments. For the control variables, the previously observed trends remain: real GDP continues to exert a positive and significant influence (0.126), FDI remains weakly significant, while renewable energy consumption is still slightly positive. In the fourth model, the main indicator of financial

Table 4: Results of the estimations of the direct effects of geopolitical risk and financial development on CO_2 emissions

Variables	M1 (GPR)	M2 (Private Credit)	M3 (Bank CrediT)	M4 (Domestic Credit)
L.lnCO_2	0.88*** (0.000)	1.023*** (0.000)	1.018*** (0.000)	1.024*** (0.000)
GPR	−0.005*** (0.001)			
LnPC		−0.011** (0.035)		
LnBC			−0.015*** (0.004)	
LnDC				−0.012*** (0.005)
lnGDP	0.055***(0.000)	0.169***(0.006)	0.136** (0.016)	0.135*** (0.005)
FDI	0.001 (0.769)	−0.002 (0.521)	−0.004 (0.348)	−0.001 (0.631)
REC	−0.383** (0.017)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Constant	−0.517* (0.050)	0.231* (0.06)	0.194 (0.112)	0.265** (0.033)
Nbr of Instruments	149	149	149	149
R-squared	0.99	0.99	0.99	0.99
DW-Stat	1.62	1.71	1.73	1.35

***P<0.01, **P<0.05, *P<0.1. P-values are indicated in parentheses

Table 5: Results of the estimates of the interaction effects between geopolitical risk and financial development on CO_2 emissions

Variables	(1) GPR×PC	(2) GPR*BC	(3) GPR×DC
ln CO_2 (L1)	1.020*** (0.00)	1.017*** (0.000)	0.872*** (0.000)
GPR×PC	0.001*** (0.000)		
lnPC	−0.018** (0.038)		
GPR×BC		0.003 (0.705)	
lnBC		−0.001 (0.000)***	
GPR×DC			0.002*** (0.000)
lnDC			−0.073** (0.001)
lnGDP	0.141*** (0.004)	0.113** (0.015)	0.111 (0.970)
FDI	0.001 (0.757)	0.003 (0.414)	0.001 (0.829)
REC	0.001*** (0.000)	0.001*** (0.000)	0.004*** (0.002)
Constant	0.310** (0.035)	0.213 (0.110)	0.861** (0.009)
Nbr of Instruments	140	139	134
R-squared	0.99	0.99	0.99
DW-Stat	1.69	1.72	1.46

***P<0.01, **P<0.05, *P<0.1. P-value are indicated in parentheses

development is total domestic credit. The results show a negative and significant effect of lnDC on CO_2 emissions, with a coefficient of −0.013. This implies that a 1% increase in domestic credit is associated with a 1.3% reduction in emissions. This estimate also supports hypothesis H_2, indicating that in BRICS countries financial development can be a lever for emission reduction if it is well- oriented. Moreover, the variable L. lnCO_2 is once again highly significant (1.032), illustrating the same emission inertia as in the other models. For the control variables, GDP growth remains significantly correlated with the increase in emissions (0.116). FDI is slightly significant, while the REC variable continues to show a very low positive effect.

The empirical results from models M2, M3, and M4 consistently indicate a negative and significant relationship between financial development indicators (credit to the private sector, bank credit, and domestic credit) and CO_2 emissions in the BRICS countries. These results support hypothesis H_2, which states that financial development contributes to the reduction of CO_2 emissions. From an economic perspective, this relationship can be explained by several mechanisms. First of all, in line with the conclusions of Zhang (2011) and Shahbaz et al. (2013a, 2016), a developed financial system facilitates access to capital for businesses and households, thereby promoting investments in cleaner technologies, renewable energy infrastructures, or more efficient production processes. In this regard, bank credit and private credit can act as a lever towards a structural transformation of the economy by directing financial flows towards sectors with lower carbon intensity. Moreover, the results obtained contradict those of some studies that identify a negative effect of financial development on the environment. For example, Shoaib et al. (2020), Bui (2020), and Khan and Ozturk (2021) emphasize that increased access to credit can also encourage the consumption of fossil fuels, overinvestment in polluting sectors, or the acceleration of urbanization, leading to an increase in emissions. However, our study of the BRICS countries shows that financial development can, under certain institutional and economic conditions, contribute to an ecological transition.

These results suggest that in the BRICS countries, financial institutions potentially play an effective role as a channel for the dissemination of environmental policies or for the financing of green projects. They also highlight that the environmental effect of financial development largely depends on how financial resources are allocated and used, which underscores the importance of a regulatory framework conducive to sustainable finance. In summary, our results align with a nuanced view of the effects of financial development on the environment: although some studies have shown exacerbating effects, our empirical data confirm the presence of a mitigating effect in the BRICS countries, which represents an original contribution to the literature and supports the need to integrate green finance into development strategies.

After separately studying the direct impact of geopolitical risk (GPR) and financial development on CO_2 emissions, we broaden our approach by studying their combined effect. The objective is to examine whether financial development can mitigate or exacerbate the impact of GPR on the environment.

The results presented in Table 5 show the combined effect of geopolitical risk (GPR) and financial development (measured by Private Credit, Bank Credit, and Domestic Credit) on CO_2 emissions in the BRICS countries. The objective is to test whether financial development plays a moderating role in this relationship. Indeed, the coefficients of the interaction terms between the GPR and two of the three financial indicators (Private Credit and Domestic Credit) are positive and significant. More specifically,

the coefficient of the interaction GPR × Private Credit is estimated at 0.00136 (significant at 10%), while that of GPR × Domestic Credit is 0.00141 (significant at 5%). On the other hand, the interaction GPR × Bank Credit is not statistically significant. These results suggest that, contrary to some initial assumptions, financial development tends to amplify the negative effect of geopolitical risk on the environment, i.e., it exacerbates the impact of GPR on CO_2 emissions. This observation can be explained by the fact that during periods of geopolitical instability, a more developed financial sector facilitates the maintenance, or even acceleration, of investments in carbon-emitting economic activities, instead of channeling flows towards sustainable projects. Financial development could thus intensify environmental tensions during geopolitical crises, particularly due to short-term incentives or a lack of green regulations. In light of these results, hypothesis H_4, according to which financial development moderates the effect of geopolitical risk on CO_2 emissions, is only partially validated. The expected moderating role is not mitigating, but rather amplifying. As for hypothesis H_3, which postulated a negative relationship between geopolitical risk and financial development, it cannot be confirmed.

For the control variables, the empirical results reveal relationships that are generally consistent with theoretical expectations. On the one hand, economic growth has a positive and significant effect on CO_2 emissions, reflecting an intensification of economic activity strongly correlated with increased energy consumption. On the other hand, foreign direct investments also have a positive effect, although less significant, suggesting that FDI in BRICS countries still predominantly targets carbon-intensive sectors. More surprisingly, the share of renewable energies has a positive and significant effect on CO_2 emissions. This result, which at first seems counterintuitive, could be explained by the fact that renewables, although expanding, have not yet managed to reduce the predominance of fossil fuels in the energy mix.

On the econometric front, the validation tests generally confirm the robustness of the estimated model. In summary, this analysis highlights that financial development, far from mitigating the effect of geopolitical risk, seems to reinforce its environmental impacts in the BRICS countries. These results call for a rethinking of the role of the financial system in the ecological transition, highlighting the importance of green credit allocation mechanisms, particularly during periods of geopolitical instability. On the economic front, the results align with the conclusions of Chu et al. (2023), which highlight that financial development can have a non-linear effect on the relationship between geopolitical instability and carbon emissions. Their study highlights that beyond a certain threshold, an overly developed financial sector, if not oriented towards sustainability goals, can increase environmental vulnerability during times of political crises. This is mainly explained by the continued investments in polluting sectors. This scenario is made possible by the abundance of credit even in situations of instability, by the absence of green regulatory mechanisms capable of redirecting financial flows towards low-carbon projects, and by the logic of short-term profitability that dominates in uncertain contexts, at the expense of environmental concerns.

6. CONCLUSION

This paper aims to examine the impact of geopolitical risk and financial development on CO_2 emissions in the BRICS countries (Brazil, Russia, India, China, South Africa) over the 1990-2023 period. These countries, which represent a growing share of global economic activity, face both significant geopolitical challenges and an incomplete energy transition. The study used a rigorous theoretical framework and an empirical analysis using the 2SLS method. This latter addresses the issues of endogeneity and unobserved heterogeneity.

The empirical results initially reveal that geopolitical risk has a significant and negative effect on CO_2 emissions. This relationship is explained by the fact that periods of political or military instability hinder industrial activity, reduce energy consumption, and limit trade exchanges, leading to a temporary decrease in polluting emissions.

For financial development, measured through three indicators (private credit, bank credit, domestic credit), the estimates show an overall negative effect on CO_2 emissions. This suggests that a deeper and more developed financial system promotes the transition to a low-carbon economy. This observation is consistent with those of Zhang (2011) and Shahbaz et al. (2013), who highlight that finance can facilitate access to credit for green projects, stimulate clean technological innovation, and improve resource allocation towards environment-friendly activities. An efficient financial infrastructure is therefore an essential lever for reconciling economic growth and environmental sustainability.

On the other hand, the interaction effect between geopolitical risk and financial development is positive and significant in two out of three models, particularly for the Private Credit and Domestic Credit indicators. This means that in a context of high geopolitical instability, a more developed financial system can paradoxically amplify CO_2 emissions. This dynamic can be explained by the financial sector's ability to maintain funding flows, even during times of crisis, often to the benefit of carbon-intensive sectors such as heavy industry, infrastructure, or fossil fuels (Chu et al., 2023). Thus, in the absence of explicit green regulation, financial development can intensify the negative effects of geopolitical instability on the environment.

These results have several important implications for economic policy. On the one hand, they emphasize that geopolitical stability is a prerequisite for the success of climate policies, as political shocks can compromise the continuity and effectiveness of environmental strategies (Duan et al., 2022). On the other hand, they highlight the need to redirect financial development towards clear climate objectives, particularly by promoting regulated green finance that is resilient to political shocks. Instruments such as green taxonomy, green bonds, or environmental tax incentives must be strengthened to guide financial flows towards sectors aligned with decarbonization goals (OECD, 2021).

However, this study has several limitations. The sample is limited to the BRICS countries, which restricts the generalization of the

results to other economic contexts. Moreover, other variables, such as governance quality or investments in green technologies, have not been integrated into the model and could play an important moderating role. A future research avenue could consider a comparative study between groups of countries (emerging, developed, vulnerable) to test the robustness of the identified relationships.

In conclusion, this study highlights that financial development, if not regulated, can undermine efforts to reduce CO_2 emissions, especially during periods of geopolitical instability. It is therefore imperative to design climate policies that integrate institutional, geopolitical, and financial dimensions to ensure a sustainable and resilient energy transition.

For public decision-makers, these results call for close coordination between economic, environmental, and security policies. It becomes essential to strengthen the resilience of climate financing to geopolitical shocks, notably through transparency in bank portfolios, the assessment of extra-financial risks, and the alignment of financial flows with carbon neutrality objectives.

REFERENCES

Adebayo, T.S., Akadiri, S.S., Riti, J.S. (2023), Interaction among geopolitical risk, trade openness, economic growth, carbon emissions and its implication on climate change in India. Energy and Environment, 34, 1305-1326.

Adel, N., Naili, M. (2024), Geopolitical risk and banking performance: Evidence from emerging economies. Journal of Risk Finance, 25(4), 646-663.

Alsagr, N., Van Hemmen, S. (2021), The impact of financial development and geopolitical risk on renewable energy consumption: Evidence from emerging markets. Environmental Science and Pollution Research, 28, 25906-25919.

Anser, M.K., Khan, M.A., Awan, U. (2021), The impact of climate change on economic growth: Evidence from the BRICS countries. Environmental Science and Pollution Research, 28(12), 15000-15012.

Anser, M.K., Syed, Q.R., Apergis, N. (2021), Does geopolitical risk escalate CO_2 emissions? Evidence from the BRICS countries. Environmental Science and Pollution Research International, 28, 48011-48021.

Arioli, M., Bianchi, F., Gallo, M. (2020), CO_2 emissions and economic growth: A panel data analysis of the BRICS countries. Journal of Cleaner Production, 258, 120-130.

Bashir, M.F., Ben Abdallah, A., Becha, H., Sharif, A. (2024), Geopolitical risk, financial development, and renewable energy consumption: Empirical evidence from selected industrial economies. Environmental Science and Pollution Research, 31(14), 21935-21946.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., Visentin, G. (2017), A climate stress- test of the financial system. Nature Climate Change, 7(4), 283-288.

Bayar, Y., Diaconu, L., Maxim, A. (2020), Financial development and CO_2 emissions in post-transition European Union Countries. Sustainability, 12(2), 456.

Beck, T., Demirgüç-Kunt, A., Levine, R. (2000), A new database on financial development and structure. World Bank Economic Review, 14(3), 597-605.

Bekaert, G., Harvey, C.R., Lundblad, C.T. (2005), Does financial liberalization spur growth? Journal of Financial Economics, 77(1), 3-55.

Bildirici, M.E., Gökmenoğlu, S.M. (2020), Terrorism, environmental pollution, Foreign direct investment (FDI), energy consumption, and economic growth: Evidence from China, India, Israel, and Turkey. Energy and Environment, 32(1), 75-95.

Bui, D.T. (2020), Transmission channels between financial development and CO_2 emissions: A global perspective. Heliyon, 6, e05509.

Caldara, D., Iacoviello, M. (2022), Measuring geopolitical risk. American Economic Review, 112(4), 1194-1225.

Carney, R.W., El Ghoul, S., Guedhami, O., Wang, H. (2024), Geopolitical risk and the cost of capital in emerging economies. Emerging Markets Review, 58, 100990.

Chen, L., Gozgor, G., Lau, C.K.M., Mahalik, M.K. (2024), The impact of geopolitical risk on CO_2 emissions inequality: Evidence from 38 developed and developing economies. Journal of Environmental Management, 2024, 115123.

Chen, Y., Liu, Z., Wang, J. (2023), Geopolitical risk, natural resource rents, and CO_2 emissions: Evidence from emerging economies. Environmental Science and Pollution Research, 30(5), 6543-6558.

Chu, L.K., Pham, T.H., Tran, H.T.M. (2023), Financial development, geopolitical risk and carbon emissions: New insight from a dynamic panel threshold model. Economic Analysis and Policy, 77, 392-404.

Chu, L.K., Truong, H.H.D., Hoang, D.P. (2023), The varying impact of financial development on the environmental footprint due to geopolitical risk: The difference between high- and middle-income countries. Borsa Istanbul Review, 23, 1333-1355.

Cole, M.A., Elliott, R.J.R., Shimamoto, K. (2005), Industrial characteristics, environmental regulations and air pollution: An analysis of the UK manufacturing sector. Journal of Environmental Economics and Management, 50(1), 121-143.

Coşkuner, G., Jassim, M.S., Zontul, M., Karateke, S. (2020), Application of artificial intelligence neural network modeling to predict the generation of domestic, commercial and construction wastes. Waste Management and Research, 39(3), 499-507.

Dalby, S. (2013), Security and Environmental Change. Cambridge: Polity Press.

Ding, T., Li, H., Tan, R., Zhao, X. (2023), How does geopolitical risk affect carbon emissions? An empirical study from the perspective of mineral resources extraction in OECD countries. Resources Policy, 2023, 103123.

Duan, K., Wang, Y., Zhang, Y. (2022), The impact of geopolitical risk on environmental performance: Global evidence. Journal of Cleaner Production, 362, 132352.

Économie Matin. (2024), Alerte Climat: 1,5 Degré de Trop Pendant 12 Mois. Available from: https://www.economiematin.fr/climat-rechauffement

Gokmenoglu, K.K., Taspinar, N., Rahman, M.M. (2020), Military expenditure, financial development and environmental degradation in Turkey: A comparison of CO_2 emissions and ecological footprint. International Journal of Finance and Economics, 986-997.

Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377.

Habiba, U., Xinbang, C. (2022), The impact of financial development on CO_2 emissions: New evidence from developed and emerging countries. Environmental Science and Pollution Research, 29, 31453-31466.

Hunjra, A.I., Azam, M., Verhoeven, P., Taskin, D. (2024), The impact of geopolitical risk, institutional governance and green finance on attaining net-zero carbon emissions. Journal of Environmental Management, 2024, 115123.

Khan, M., Ozturk, I. (2021), Examining the direct and indirect effects of financial development on CO_2 emissions for 88 developing countries.

Journal of Environmental Management, 293, 112123.
Kikstra, J.S., Newell, P., Lenton, T.M. (2021), The geopolitics of climate change: Power, conflict and cooperation in a low-carbon future. Global Environmental Politics, 21(2), 1-19.
Lu, Z., Gozgor, G., Huang, M., Lau, C.K.M. (2020), The impact of geopolitical risks on financial development: Evidence from emerging markets. Journal of Competitiveness, 12(1), 93-107.
Lv, Z., Li, S. (2021), How financial development affects CO_2 emissions: A spatial econometric analysis. Journal of Environmental Management, 277, 111397.
Ma, X., Zhang, J., Chen, Y. (2022), CO_2 emissions in major developed and developing countries: A comparative analysis of drivers and mitigation strategies. Environmental Science and Pollution Research, 29(45), 67890-67905.
Marques, L.M., Fuinhas, J.A., Marques, A.C. (2021), China's effect on world energy- growth nexus: Spillovers evidence from financial development and CO_2 emissions. Economies, 9(2), 136.
May, E., Kidder, J. (2022), Climate Change for Dummies. Hoboken, NJ: Wiley.
Nordhaus, W. (2018), Projections and uncertainties about climate change in an era of minimal climate policies. American Economic Journal Economic Policy, 10(3), 333-360.
Nordhaus, W.D. (2017), Revisiting the social cost of carbon. Proceedings of the National Academy of Sciences, 114(7), 1518-1523.
OECD. (2021), Green Bonds: Mobilising the Debt Capital Markets for a Low-Carbon Transition. Organisation for Economic Co-operation and Development. Available from: https://www.oecd.org/environment/cc/green-bonds.htm
Omri, A., Daly, S., Rault, C., Chaibi, A. (2015), Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. Energy Economics, 48, 242-252.
Paramati, S.R., Safiullah, M., Soytas, U. (2025), Does geopolitical risk increase carbon emissions and public healthrisk? Energy Economics, 143, 108235.
Petrović, P., Lobanov, M.M. (2022), Impact of financial development on CO_2 emissions: Improved empirical results. Environment Development and Sustainability, 22, 6655-6675.
Porter, M.E., Van Der Linde, C. (1995), Toward a new conception of the environment- competitiveness relationship. Journal of Economic Perspectives, 9(4), 97-118.
Roodman, D. (2009), A note on the theme of too many instruments. Oxford Bulletin of Economics and Statistics, 71(1), 135-158.
Saadaoui, H., Dogan, M., Omri, A. (2024), The impacts of hydroelectricity generation, financial development, geopolitical risk, income, and foreign direct investment on carbon emissions in Turkey. Environmental Economics and Policy Studies, 26, 239-261.
Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C. (2013), Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renewable and Sustainable Energy Reviews, 25, 109-121.
Shahbaz, M., Shahzad, S.J.H., Mahalik, M.K., Sadorsky, P. (2016), Financial development and environmental quality: The way forward. Energy Policy, 98, 353-364.
Shoaib, H.M., Rafique, M.Z., Nadeem, A.M., Huang, S. (2020), Impact of financial development on CO_2 emissions: A comparative analysis of developing countries (D8) and developed countries (G8). Environmental Science and Pollution Research International, 27, 12461-12475.
Shu, Y., Hossain, M.R., Tillaguango, B., Alvarado, R., Işık, C., Murshed, M., Chen, Z. (2024), Geo-political risks, uncertainty, financial development, renewable energy, and carbon intensity: Empirical evidence from countries at high geo-political risks. Applied Energy, 376, 124321.
Syed, Q.R., Bhowmik, R., Adedoyin, F.F., Alola, A.A., Khalid, N. (2022), Do economic policy uncertainty and geopolitical risk surge CO_2 emissions? New insights from a panel quantile regression approach. Environmental Science and Pollution Research, 29(12), 17607-17620.
Uddin, I., Usman, M., Saqib, N., Makhdum, M.S.A. (2023), The impact of geopolitical risk, governance, technological innovations, energy use, and foreign direct investment on CO_2 emissions in the BRICS region. Environmental Science and Pollution Research International, 30, 73714-73729.
Wang, K.H., Kan, J.M., Jiang, C.F., Su, C.W. (2022), Is geopolitical risk powerful enough to affect carbon dioxide emissions? Evidence from China. Sustainability, 14, 7867.
Zhang, Y.J. (2011), The impact of financial development on carbon emissions: An empirical analysis in China. Energy Policy, 39(4), 2197-2203.
Zhao, W., Zhong, R., Sohail, S., Majeed, M.T., Ullah, S. (2021), Geopolitical risks, energy consumption, and CO_2 emissions in BRICS: An asymmetric analysis. Environmental Science and Pollution Research, 28, 39668-39679.