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Ecological Sustainability in the Era of Financial Globalization: The Role of Environmental Diplomacy and Policy Stringency in G20 Nations

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Abstract

This research explores the intricate interplay among financial globalization (FG), economic development (ED), gross domestic product (GDP), and environmental policy stringency (EPS), and their combined influence on environmental sustainability, as assessed by the Environmental Footprint Performance Index (EFPI) in G20 countries Employing panel data spanning from 1995 to 2022, the analysis utilizes Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) modeling, Pedroni and Westerlund cointegration tests, and Dumitrescu-Hurlin panel causality analysis to investigate both short- and long-term impacts. The findings reveal that FG, ED, and GDP impose long-term pressures on environmental sustainability, while EPS serves as a vital factor indicating that robust environmental policies can mitigate the adverse. Nevertheless, the negative interaction between FG and EPS implies that unchecked financial integration may undermine the efficacy of environmental policies, underscoring the necessity for coherent financial governance and sustainability strategies. In the short term, policy shifts incur

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adjustment costs, yet the error correction model (ECM) indicates a moderate pace of equilibrium restoration, reflecting the resilience of the system. These results highlight the importance of embedding sustainability within financial globalization through green finance, responsible investment strategies, and more stringent environmental regulations. Policy suggestions include enhancing global financial governance, fostering sustainability-oriented investments, and strengthening international environmental collaboration within the G20 framework to secure long-term ecological resilience.

Keywords: Environmental Policy Stringency, Financial Globalization, Environmental Diplomacy, Ecological Footprint Pressure Index, PMG-ARDL, G20 Countries

Introduction

Leaders at all levels recognize sustainability as a critical concern because it is gaining substantial attention from scientists and policymakers because of growing global climate change and deteriorating air quality (Kraft,2021). According to the World Bank report from 2016 pollution in the environment poses significant health risks which led to 5.5 million premature deaths during that period. The inadequate quality of the air contributed to a total of 5.5 million premature fatalities. Besides this mortality decline from air pollution climate change stands as a key economic challenge for today's governments (Hsiang and Kopp, 2018; Audi et al., 2025). The anticipated economic losses due to weather disasters reached an estimated 470B$ in 2017 and experts predict these figures will grow significantly during the upcoming years according to Giuzio et al. (2019).

This has resulted in international cooperation among countries and international organizations that have, in collaboration, started implementing policies driven by fears of ecological degradation. The sustainable development perspective emerged through the World Conservation Strategy, which was organized by the United Nations Environment Programme as its initial implementation. The strategy focused on natural resource sustainability together with genetic diversity protection as ecological sustainability approaches for sustainable development (Clayton et al. In the Brundtland Report(WCED, 1987) published by the United Nations World Commission on Environment and Development focusing on the subject “Our Common Future”, sustainable development was defined as “meeting the needs of the present without compromising the ability of future generations to meet their own needs”.

The definition assures present generations that their current needs will not exhaust options for future generations to fulfill their requirements. The definition established sustainable development as the pattern of economic progress using logical means that respects environmental resources without waste and maintains future generations' benefits. According to Zakari et al. (2022), the system depends mainly on using renewable and clean resources.

Countries worldwide have joined forums called COP series to protect emissions through international pacts like the Kyoto Protocol and Paris Agreement and the United Nations Framework Convention on Climate Change. Many nations at COP 26 together decided to lower current carbon dioxide emissions by 50% below 2010 levels (Smil, 2022; Meng et al., 2022; Audi, 2024). During COP 27 world leaders pushed for international collaboration as a solution to achieve carbon neutrality. The global community now adopts diplomatic mechanisms to solve interlinked environmental issues (Rizwanullah et al., 2022; Audi, 2024). Environmental diplomacy often refers to the use of diplomatic tactics and international conferences as means of mitigating or controlling transboundary environmental issues. This has emerged as a necessary context for encouraging cooperation among nations (Ali & Audi, 2016; Ewane et al., 2023; Atisa, 2023). The importance of international cooperation can be particularly seen among the countries within the G20 alliance, which include the leading global economies whose economic development has significant impacts on the environment. To show

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their commitment to conciliation, such countries engage in treaties at various levels: bilateral, multilateral, and global pacts (Audi & Ali, 2016; Li et al., 2021; Ali et al., 2021; Rizwanullah et al., 2023; Awan & Azam, 2022).

The International Forum Group of Twenty serves as an organization with 19 member states plus the European Union. The G20 functions as an international meeting ground that enables member nations to collaborate on economic issues. G20 exists to establish financial stability worldwide as well as initiate economic development through sustainable growth practices. Establishment as an initiative stemmed from financial crises that hit the world during the late 1990s, especially the Asian financial crisis. Before the 2008 global financial crisis, the G20 included only world economy leaders from major nations and their finance ministers as well as central bank governors but as a response to the crisis, governments elevated themselves to the position of major membership (Ali et al., 2021; Larionova,2022).

The G20 economic bloc maintains authority over more than half of the world's population along with about 85% of global GDP and more than 75% of global trade (Sheraz et al., 2021). The G20 countries exhibited 6.3% GDP growth during 2021 though their growth slowed down to 3.3% in 2022. The financial power of G20 member economies does not diminish their ability to create severe environmental problems. Worldwide greenhouse gas emissions originate from the G20 economies which produce 80% of all emissions while their climate impact reaches 70% (Habib et al., 2021). The total CO2 emissions from the G20 economies surpassed 1.5% in 2018 because of rising energy consumption and demand across their member states. The dependency of the G20 on non-renewable energy sources makes fossil fuels dominate the total energy mix while intensifying threats they create for the planet. The G20 bloc members push for environmental initiatives as a solution to prevent economic operations from damaging the environment. Brazil together with France leads efforts to implement green financial policies while China represents leaders in green loan promotion. Results from Sheraz et al. (2021) show

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that carbon emission pricing expanded to 49% throughout the G20 countries from a previous level of 37% in 2018 (OECD,2021). Despite these efforts, CO_2 emissions and their effects continue to rise.

In 2021 the United States holds the position of third highest population density among nations after both India and China. Every year the United Nations Human Development Index (2021) includes the US among its 25 developed countries and the International Monetary Fund (IMF) recognizes the country as a developed nation due to its USD 23 trillion GDP. The British Petroleum (BP) Statistical Review of World Energy report indicates that CO_2 emissions increased parallel to economic growth in 2021. Annual global energy consumption amounts to 15.6% and the United States occupies position two in this metric trailing behind China (25.6%). The annual CO_2 emission level of the US ranks as 13.9% making it the second largest behind China (BP,2022). The Global Footprint Network (GFN) confirmed that this nation occupied the second position for ecological footprint worldwide in 2018 (Hussain & Khan, 2022; Hacıimamoğlu & Sungur,2024).

Academic research pays significant attention to environmental deterioration factors through studies of trade diversification (Durbin & Filer, 2021; Dai & Du,2023), energy consumption (Porron & Gia, 2021; Gyamfi et al.,2021) and foreign direct investment (Zhuang et al.,2022; Al Masri & Wimanda, 2024). Experts have extensively researched both mechanisms to reach carbon neutrality and promote green economic growth (Emodi, 2019; Zhao et al.,2023). Studies focus on renewable energy (Diaz & Weber, 2020; Li et al.,2023; N Alsagr,2023) as well as green innovation (Meng et al.,2022; Umar & Saifi,2023) together with environmental policy stringency (Sharma & Das, 2024; Balsalobre et al.,2023; Albulescu et al.,2022) and digitalization (Hu et al.,2024; Habibullah & Kamal, 2024; Zhao et al.,2024). The authors Chen, Li, and Liu (2024) stated that effective innovative approaches for carbon emissions management remain essential to achieve carbon neutrality. Researchers present opposing views regarding the difficulty of environmental protection efforts because the associated uncertainty makes the job complex (Hallegatte,2009; Fateh & Fakih, 2021; Dogan et al.,2023).

Global industrial expansion together with commercial relations under the framework of globalization brings essential environmental challenges through industrialization, trade liberalization, foreign direct investment, and heightened energy consumption. The increase in greenhouse gas emissions has been substantial and carbon dioxide has increased significantly (Ali et al., 2021; Iqbal & Asif, 2022). Raihan (2023) shows that evolving ecosystem degradation parallels the rapid rate of change. This degradation plays a part in creating the global climate change emergency.

Environmental protection relies on the use of environmental diplomacy which emerges from the connection between economic activities, diplomatic efforts and environmental management systems. (Rizwanullah et al., 2024). Sustainable energy transitions happen through mutual agreements and diplomatic support helps implement renewable projects. (Albulescu et al., 2020). The broad environmental goals to reduce ecological deterioration need to be examined by analyzing how environmental diplomacy supports renewable energy adoption while securing energy resources. (Mensah et al., 2019; Masiero, 2023). The implications of CO2 about climate change call for a global approach led by the interlinked forces of environmental diplomacy and nations, which should develop methods, execute strategies, set objectives of reduction, and promote environmentally friendly practices to reduce CO2 emissions (Hasan et al., 2024; Scartozzi et al., 2024). Multiple environmental crises together with micro-level problems and issues regarding sustainable economic growth at the macro level have elevated this matter to the top international concerns. Nations adopted development strategies that incorporated environmental factors for sustainable development practice.

The majority of researchers have studied carbon dioxide (CO2) levels because they serve as the main indicator for evaluating environmental pollution alongside sustainability assessment. The amount of exhaust gases entering the atmosphere makes up the entire concept of CO_2 emissions while addressing only atmospheric pollution. Global ecological degradation exists as a dual environmental problem since it contaminates both the air water and soil foundations of our planet. Solarin and Bello (2018) together with Wu et al. (2019) establish that CO_2 measurements alone prove inadequate to understand global ecological degradation in its entirety. When addressing this deficiency Wackernagel together with Rees (1998) introduced the ecological footprint (EF) as a sustainability measurement system. EF represents the specific biological land area necessary for the delivery of all required products while addressing environmental deterioration. A global hectare of biological space defines EF's measurement of meeting all human needs. CO_2 serves as a broader metric than CO_2 because footprint measurements from different sources are integrated into it (Wackernagel & Rees,1998).

According to GFN (2022), EFP presents a comprehensive measurement system for human resource demand which is divided into six categories including Carbon Footprint, Fishing Grounds Footprint, Cropland Footprint, Built-up Land Footprint, Forest Products Footprint, and Grazing Land Forest Products Footprint(Hacıimamoğlu & Sungur,2024). These two metrics show an environmental decline when viewed from a demand-based perspective. Environmental assessments require the inclusion of how nature performs in meeting human requirements. The natural environment generates fertile land areas and marine territories as well as biological habitats which collectively make up Biocapacity. The environmental sustainability demand elements (CO_2 emission and EFP) overlook the supply aspect of ecological capacity according to Akadiri et al. (2022). Wang et al. (2018) recommend using the ecological footprint pressure index (EFPI) because it examines ecological capacity and ecological footprint simultaneously. EFPI represents the outcome of dividing EFP by ecological capacity. The assessment combines environmental degradation insights from two perspectives by measuring human ecological footprint actions (Wang et al., 2018; Yang et al., 2018).

Financial globalization stands as a direct cause of environmental degradation in G20 countries because economic expansion leads to ecological problems between these nations. Under the pollution haven hypothesis, financial globalization enables manufacturing businesses to shift towards less developed countries which results in more environmental issues affecting these countries. (Prempeh, 2024). The pursuit of foreign direct investment by G20 countries during integration periods results in weaker environmental regulations that produce higher carbon emissions along with environmental resource breakdown. Additionally, financial globalization facilitates renewable energy investments which may enhance environmental quality but the general outcome remains negative as fast industrialization and increased economic growth often result in environmental issue neglect (Wang et al.,2023; Raihan et al.,2023). The paradox shows that G20 member states need to find a balance between economic targets and sustainable practices to protect ecological integrity from financial policy harmfulness.

International organizations demonstrate their commitment to the Paris Agreement because it aims to limit temperature increases while fostering sustainable development. The twenty G20 economies produce the biggest global emissions of greenhouse gases so their financial policies implement important environmental outcomes. Financial globalization demands a complete approach where fiscal growth aligns with ecological management through international climate change agreements as per Wang et al. (2022) and Majeed et al. (2022).

The role of EPS stands as crucial in controlling the relationship between financial globalization and environmental deterioration among G20 countries. Financial globalization generates enhanced investment inflows and economic activities as one result however this process also increases environmental challenges mainly in countries with lower regulatory caps. Stringent environmental policies offer

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mitigation against harmful environmental impacts by encouraging sustainable measures along with green technological innovations. Research demonstrates that financial globalization results in higher carbon emissions yet strong EPS systems create beneficial conditions for renewable energy utilization along with sustainable economic expansion in G20 countries. Sheraz et al.(2021) demonstrated that financial development alongside human capital improves environmental performance only when strong regulatory frameworks exist and rising GDP and energy usage create pollution problems but effective controls resolve these issues based on G20 country data. The G20 governments need to enforce robust environmental policies to protect ecological sustainability while benefiting from financial globalization (Wang et al., 2024).

This paper examines the multiple connections and effects that link economic growth, financial globalization, environmental diplomacy and environmental policy stringency with environmental degradation while focusing on the Ecological footprint pressure index as an environmental sustainability measurement. The main targets of this research demand examining diplomatic historical records about G20 nations' environmental policies along with their impacts and the relationship between economic development and ecological sustainability. The research adds new knowledge regarding international approaches to stop detrimental changes that occur in nature. The research aims to supply factual evidence that supports diplomats, policymakers and environmental activists for improving international climate change and sustainability efforts. The main objective delivers evidence-backed guidance to leaders, diplomats and environmentalists about strengthening international groups and initiatives engaged in climate change prevention work.

The subsequent sections of this research are structured in a specific manner. The section titled "Theoretical Framework" outlines the theoretical underpinnings, while the "Literature Review" section encompasses a comprehensive review of existing literature. The "Data, Model, and Method" section details the data utilized, the model applied, and the methodological approach taken. In addition, the "Empirical Results and Discussion" section presents the empirical findings along with a discussion of their implications. Lastly, the section labeled "Conclusion, Policy Recommendations, and Limitations of Study" summarizes the conclusions drawn, offers policy recommendations, and addresses the limitations encountered in this research.

Theoretical Underpinning

Economic growth exerts its impact on ecological quality according to three different mechanisms that Grossman and Krueger(1996) have described in their theoretical models. Existing studies have identified many factors behind variations in the Ecological Footprint Pressure Index (EFPPI) and its values. Countries that are developing require persistent economic expansion to achieve better life quality standards for their citizens. The sustained economic expansion benefits many aspects of the country but requires executive management to use renewable energy sources alongside efficiency technology implementations to avoid associated difficulties. Personal and economic development generally takes precedence in most decision-making scenarios. The community structure of an economy defines which materials the industry uses for manufacturing and the extent of environmental pollution as demonstrated through the composition effect. The adoption of cleaner technologies and improved production methods during economic development leads to less pollution in the environment. The technique effect enables increased awareness about environmental issues thus prompting citizens to pursue environmental safety and cleaning. Environmental regulations of developed countries highlight the strongest impact on this pattern of change. Public expectations measure economic growth as a negative influence on the EFPPI which serves as one key sustainability metric.

Multiple channels provide financial globalization which involves borderless integration of financial institutions and markets to influence EFPPI. Through direct investment, the host country receives capital infusion along with modern technologies to optimize its resource usage resulting in improved environmental standards. Foreign Direct Investment (FDI) creates the risk of polluting industries moving toward countries with lax environmental standards which results in the pollution haven effect. An increase in environmental degradation among these host countries results because of this FEPPI disadvantage. Environmental stringency functions as an important regulatory factor that impacts how these two variables relate to each other. Advanced environmental regulations force companies to spend money on environmentally friendly technology solutions which decreases the damage that FDI could cause to natural systems. Policies that lack strength increase the problematic effects of financial globalization on the EFPPI.

Environmental policy stringency levels are measured through the EPS indicator from the OECD which depicts pollution costs both explicit and implicit. The numerical value of the Environmental Policy Stringency Index acts as a gauge to determine regulatory strength. According to the Porter Hypothesis organizations must develop cleaner technologies and improve operational efficiency when strict environmental regulations compel them to innovate and enhance their competitiveness. The principle serves as direct opposition to mainstream thought which claims that rigorous environmental rules create obstacles for economic advancement. When G20 countries implement EPS metrics they can reduce their EFPPI while driving negative environmental policy functions to lower levels through innovative and efficient practices which unify economic growth with sustainable ecological practices. A high EPS strengthens the positive impact of FDI on environmental quality through its promotion of green technologies and sustainable practices during global financial integration. Financial globalization leads to higher EFPPI in locations with poor environmental regulations because economic advantages from international investments gain more priority than environmental protection measures. The magnitude of these outcomes depends on both economic development stages and institutional resilience together with the targeted sectors of investments.

Environmental diplomacy acts as a fundamental tool to manage the present global environmental issues that include climate change alongside resource exhaustion and pollution. The international agreement known as the Paris Agreement implements Common but Differentiated Responsibilities (CBDR) to maintain equilibrium between developed and developing countries. Developed countries advance strict environmental safeguards yet developing countries position economic expansion above all else. The Ecological Footprint Pressure Index (EFPPI) calculates human activity's impact on regional biocapacity through Carrying Capacity Theory. According to this theoretic model, ecosystems possess a specific consumption threshold they can handle up to the point of collapse. Within the G20 structure, EFPPI needs integration as a tool for environmental diplomacy to match international regulations to the ecological boundaries of different regions. Sustainability is achieved through this approach which handles variations in developmental stages between nations.

Literature Review

During the last few decades the rising public concern about environmental matters and protection requirements generated discourse regarding environmental diplomacy along with evaluations of policy effectiveness and financial integration against ecological sustainability. Previous scientific investigation used conventional degradation indicators to analyze how diplomacy and policy stringency together with economic growth and financial globalization affect environmental quality results. The study analyzes these elements through a detailed review of current literature that investigates their relationships with the Ecological Footprint Pressure Index (EFPPI) to understand their effects on ecological sustainability better.

Economic Growth and Sustainability

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Environment researchers now focus highly on the ecological footprint pressure index (EFPI) because it helps measure the complete extent of human activity in ecosystems. Pata et al.,(2022) investigated how export diversification together with economic growth and renewable energy consumption affects EFPI in India. The research produced outcomes that demonstrated a U-shaped pattern regarding income levels and EFPI while contradicting the theory of the environmental Kuznets curve. The analysis confirmed that higher levels of renewable energy adoption and export market variety work to reduce EFPI thus offering promising avenues to enhance environmental quality.

Global growth relies more heavily on fossil fuels for its expansion because economic development and modernization together with urbanization efforts create environmental degradation (Baloch et al., 2019). Sustainable development requires the biggest challenge to establish equilibrium between economic expansion and environmental stewardship (Alnemer et al., 2023). The quick-paced development of conventional economics creates several environmental problems from biodiversity destruction to climate change (Jie et al., 2023; Audi et al., 2025). Future risks and challenges ahead will affect both the upcoming decade and the global sphere throughout several upcoming years. The healthy progression of society together with economic evolution requires ecologically responsible choices which demonstrate there is an inherent dispute between economic growth and environmental safeguard measures. According to Nepal and Shrestha (2024) systematic review uncovered fundamental elements that determine ecological footprint results. The research examined 37 papers that demonstrated the significance of energy consumption together with economic growth and urbanization factors for achieving environmental sustainability. The research showed that sustainability strategies should be developed by policymakers while taking these essential elements into account. This predicament necessitates an investigation into the interplay between the global economy and the environment.

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Several research studies have taken different proxies for environmental degradation to check its relationship with economic growth and a variety of results have been documented. Adebayo & Samour (2024) proved that the country's economic expansion throughout BRICS generated decreases in LCF. The effect of LCF grows 0.06 percent when GDP rises one percent across Asian countries throughout the 1996-2020 period according to Latif & Faridi (2023). Akadiri et al. (2022) conducted time series research on India which demonstrated GDP as a factor that reduces LCF in that nation. The analysis by Pata et al.(2023) through their evaluation of South Korean data from 1977 to 2018 demonstrated proper relationships between LCC and EKC. Research conducted by Guloglu et al. (2023) showed that GDP has a negative effect on ecological sustainability in OECD nations. The research by Gyamfi et al. (2023) applied Dynamic ARDL simulation. The observed sampling period revealed that Malaysian per capita pollution dropped significantly when corruption perception levels grew substantially. Coherent with the data sets economic growth showed a positive connection with emission levels. Raihan et al.(2023) investigate how Malaysian CO_2 emissions evolved through multiple periods between 1990 and 2021 by studying its connection with economic expansion, fossil fuel use and renewable energy adoption rates. Using the autoregressive distributed lag (ARDL) approach researchers studied both the immediate effects and extended time duration of its operation. A rise in CO_2 emissions happens together with economic output increases. Bozatli and Akca (2024) established that both EKC and LCC were valid when analyzing Turkey between 1990 and 2020. Wu et al. (2023) conducted their research to examine living consumption ecological footprint differences across northwest China regions. The researchers demonstrated that ecological footprint assessments require evaluation of both regional ecological security together with ethnic stability. The research delivered useful information about regional-level methods for determining ecological footprint requirements and existing capacity. Recent research from Global Footprint Network (2023) featured in

Nature Food reveals food consumption stands as a main factor in expanding the EU-27's ecological footprint. The results emphasize the substantial link between what we eat and environmental sustainability which presents clear targets for policy intervention.

Financial Globalization and Environmental Sustainability

Dreher's (2006) globalization index contains economic, political, and sociological elements that Gygli et al. (2019) subsequently improved to enhance globalization measurement. The index establishes economy rankings based on de facto components of financial globalization, including reserve holdings and international income payments, international debt levels, portfolio investments, foreign direct investment, and investment-related agreements and barriers. By using a globalization index, we can identify how financially globalized economies are and to what extent they are involved.

Environmental deterioration is affected in multiple ways by the FIG through its promotion of technical development and innovation that leads to decreased ecological footprints stemming from lean resource consumption of advanced technology. The implementation of FIG produces increased quality products at reduced costs which creates competitive advantages for sustainable host economy development based on data from Zheng et al.(2023). Multiple studies regarding environmental indicators and globalization prove conflicting according to research such as Adebayo (2022), Doytch and Uctum (2016), Dreher et al. (2008), Figge et al. (2017), Haseeb et al. (2019), Saud et al. (2023), Twerefou et al. (2017), Lv and Xu (2018), Rudolph and Figge (2017), Wang et al. (2022), and Chen et al. (2023).

The study conducted by Xu et al. based on Brazilian data revealed that financial globalization corresponded with better environmental performance while testing the interaction between FIG and the load capacity factor. Several articles demonstrated results matching the reported analysis findings. Akadiri et al.,2022; Raihan et al., 2023; Awosusi et al.,2022. Researchers have observed that a sustainable

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environment shows an inverse relationship to financial globalization based on their findings. (Ibrahim et al.,2024; Pata et al.,2023; Liu et al,2024).

EPS and Environmental Sustainability

Environmental policy stringency (EPS), measures the cost of environmentally adverse behavior. The main advantage of using EPS is its ability to give people insight into their environmental impact as well as motivate them toward environmentally friendly life choices. This study collects its information through a wide-ranging database that examines policy tools affected by climate change and air pollution issues. Expectedly new legislative measures will emerge to control damaging impacts on the environment. According to Yirong (2022) along with Cohen and Tub (2018) EPS functions as a tool that reduces negative environmental outcomes through its support of green technologies and opposition to unclean ones. EPS increases CO2 reduction by making unclean products more expensive which reduces their attractiveness according to Neves et al.,2020. The adoption of environment-friendly technology which results in pollution reduction becomes possible for firms through effective policy implementation (Porter et al.,1995).

When the cost savings from compliance exceed original expenses it leads to productivity gains that match the "narrow" version theory as described by Jaffe and Palmer (1997) and Li et al. (2023). Understanding the costs of EPS remains crucial because this cost structure has the potential to dissuade financing for environmentally beneficial technologies that will affect environmental quality according to Luo and Sun (2024) and Mulatu (2018). The implementation of EPS may create new methods leading to negative productivity changes as defined by the 'weak' theoretical form (Jaffe and Palmer, 1997). This empirical finding provides no clarity about environmental quality effects because EPS proved to increase CO2 emissions within twenty European countries from 1995 to 2012 (Rufael, 2023). EPS within BRICS nations leads to environmental quality improvement according to Dai & Du (2023) yet researchers have identified a 'green paradox' effect through Sinn

(2015) demonstrating that EPS might unexpectedly devastate the environment. Economic models using the General Method of Moments reveal environmental regulations have failed to fulfill their polluting management objectives (Hao et al, 2018). Environmental regulations are responsible for the increase of carbon emissions throughout Asia according to Phan et al. (2021). Experimental and Procedural Safety programs demonstrate no significant impact on lowering carbon dioxide emissions (Wang et al, 2020). Razzaq et al. (2023) examined ecological footprint research related to sustainable development using bibliometric methods. The researchers presented fundamental insights regarding field evolution by detailing important researchers and research patterns. The study provides crucial information about the current state of ecological footprint research together with its effects on sustainability initiatives.

Environmental Diplomacy and Sustainability

Environmental diplomacy consists of diplomatic initiatives that collaborate with other countries to address cross-border environmental challenges toward sustainable solutions as described in Jiang et al. (2019) and Rizwanullah et al. (2024). Environmental diplomacy enables countries to work together internationally to handle environmental damage that appears as pollution combined with biodiversity depletion along with climate change and similar environmental problems. Many authors have previously studied the connection between environmental diplomacy and environmental degradation. The relationship between international environmental agreements and carbon dioxide emissions stands significant according to Khan and Hou (2021) findings. Current times demonstrate how using eco-friendly energy combined with capital formation and economic development forms a trio of high-quality declining factors. The study demonstrated that diplomatic apprehension and reciprocal commitment implementation play a crucial role but additional diplomatic dialogue might raise carbon dioxide emissions. Research by Nasrullah et al.(2021) demonstrates that environmental diplomacy as an international diplomatic component resulted in decreased emissions in developing nations during recent times. Direct observations show governments fail to commit to treaties because they simply proceed with canceling their agreements which leads to higher CO2 emissions. The study establishes that countries should validate treaties instead of renewing them annually while their authorities must dedicate efforts to executing their duties. The appearance was created that this approach would not impact climate change substantially.

Nasrullah et al.(2021) confirm environmental diplomacy plays an essential role in contemporary international cooperation against environmental issues. The United Nations' inability to resist environmental threats combined with the predictability of environmental threats along with the conflict between developed and underdeveloped countries has made both the previous Earth Summit in Brazil and current global environmental protection efforts face major delays. Lawrence Susskind as an environmental diplomat developed an almost self-enforcing agreement generation that creates pacts that protect territorial independence while proving compliance with upcoming sustainable development institutional frameworks (Rizwanullah et al, 2024).

Theoretical Underpinning

The theoretical frameworks presented by Grossman and Krueger elucidate three distinct pathways through which economic growth affects ecological quality. Numerous variables influencing the load capacity factor have been identified in previous research. In developing nations, continuous economic growth is essential for improving living standards. While sustained economic expansion provides various benefits to a country, it also presents challenges if not properly managed through the implementation of energy-efficient technologies and the use of renewable energy sources. Often, there is a tendency to prioritize economic expansion. The composition of an economy significantly affects the types of materials utilized in manufacturing and the level of pollution generated, a phenomenon known as the composition effect. Furthermore, as economic growth and development progress, the adoption of cleaner technologies and more efficient production methods leads to a reduction in pollution levels. During this stage, increased environmental awareness encourages citizens to advocate for a cleaner and safer environment, a phenomenon referred to as the technique effect. This trend is particularly prominent in developed countries, which often have stringent environmental regulations. Consequently, there is an expectation that economic growth may negatively influence the load capacity factor, an important indicator of environmental quality.

Financial globalization, an increase in the integration of financial markets and institutions across borders-is a phenomenon that can impact LCF through several channels. Direct investment, for example, will introduce both capital and advanced technologies to the host country, further enhancing the productive use of resources, which in turn boosts the quality of the environment. On one hand, FDI might lead the polluting industries to relocate to countries that have weaker environmental policies; this effect is called the "pollution haven effect," which can be an adverse consequence for the LCF. It has been shown that environmental stringency plays a critical moderating role in this relationship. Strict environmental policies will compel firms to invest in cleaner technologies and practices, which limits the purported harmful effects of FDI on the environment. Compared to this, weak policies amplify the damage from financial globalization on the LCF.

The relative stringency of environmental policy is measured by the OECD's EPS, or index, which is the implicit or explicit cost of noxious environmental activities. The higher the value of EPS, the more restricted a country is by regulations. Environmental policy stringency (EPS) denotes the rigor of regulations designed to mitigate environmental harm and encourage sustainable practices.

The 'Porter Hypothesis suggests that tight environmental regulations can promote innovation and improve competitiveness because firms are forced to

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develop cleaner technologies and operational efficiencies in response to regulatory pressure. This view directly opposes the idea that stringent environmental regulations hurt business bottom lines. With the EPS integrated into the framework of G20 countries, it will send environmental policies downwards to reduce the LCF through innovation and efficiency, making economic growth harmonize with ecological sustainability. When merged with financial globalization, a high EPS supports an expositive effect of FDI on environmental quality through green technologies and sustainability. But in the case of environmental regulations, the adverse effects of financial globalization on the LCF would be tempered since they depend on the degree of economic development, the quality of institutional factors, and the sectors in which investments draw.

Environmental diplomacy represents the international cooperation required to challenge the emerging contemporary environmental issues such as climate change, over-exploitation of natural resources, and so on. It involves agreements such as the Paris Agreement seeking reconciliation of developed and developing country interests under the frameworks of Common but Differentiated Responsibilities (CBDR). Developed countries will always push for an authoritative framework for environment regulation while developing countries push their case of economic growth. The load capacity factor, LCF, describes the ratio of a region's biocapacity to its ecological footprint. The theory is formulated based on an idea developed from Carrying Capacity Theory, which argues that only a finite level of consumption can be supported by ecosystems before reaching unsustainable thresholds. In the G20 framework, induction of LCF into environmental diplomacy is one of the vital factors that get international policies aligned with the ecological constraints of different regions for sustainability while keeping in mind the stages of development varied according to the region.

Econometric Model, Data and Methods

Data

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The research aims to investigate and establish the impact of macroeconomic factors such as financial globalization (FG), Environmental Diplomacy (ED), Gross Domestic Product (GDP), and Environmental Policy Stringency (EPS) on climate mitigation efforts. The investigation continues to delve into the moderating effect of Environmental Policy Stringency (EPS) within the context of financial globalization (FG) regarding Ecological Footprint Pressure Index (EFPI) over 27 years from 1995 to 2022. It focuses on selected G20 nations, including Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, South Africa, Turkey, the United Kingdom, and the United States. In this regard, it is worth mentioning that Argentina and Saudi Arabia were not considered for the study due to limited data availability. The data regarding the examined economic indicators is sourced from the World Bank, Global Footprint Network, the International Monetary Fund (IMF), OECD and KOF Index. To reduce the likelihood of data irregularities and heteroscedasticity, all data were transformed into their natural logarithmic form. Table 1 provides a summary of the study variables, detailing their symbols, units of measurement, and sources of data.

Model Specifications

Drawing from the current body of literature, the econometric model utilized in this study was chosen, integrating the framework established by Chishti and Dogan(2024) to analyze the ten leading countries in renewable energy consumption. However, this research seeks to incorporate various economic indicators and examine the moderating influence of Environmental Policy Stringency to elucidate the relationships among the variables under consideration. A functional structure for the model has been developed to illustrate the main aim of our investigation effectively.

$$\mathbf{EFPI = f\ (FG, ED, GDP, EPS, EPS*FG)}$$

$$\mathbf{EFPI_{it} = \propto_{1it} + \propto_{fit} FG_{it} + \propto_{eit} ED_{it} + \propto_{git} GDP_{it} + \propto_{epit} EPS_{it} + \propto_{efit} EPS * FG_{it} + \epsilon_{it} \quad (i)}$$

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In this model, Ecological Footprint Pressure Index (EFPI) is dependent variable, while the independent variables include financial globalization (FG), Environmental Diplomacy (ED), Gross Domestic Product (GDP), and Environmental Policy Stringency (EPS). An interaction term, EPS*FG, is incorporated to assess the moderating effects of EPS and FG. The error term, denoted as ϵit, represents an idiosyncratic error that is independent and identically distributed, adhering to the standard assumption of a normal distribution with a mean of zero and constant variance. In this context, i denotes the countries under consideration, t indicates the period, and ∝1it represents the intercept. The parameters ∝fit, ∝eit, ∝git, ∝epit, and ∝efit correspond to the long-run elasticity estimates of LCF concerning the variables FG, ED, GDP, EPS, and the interaction term (EPS*FG), respectively.

Methodology

This research used various econometric tools that have been particularly applied to panel data. Since cross-sectional dependence (CD) also remains a major problem in this field, the study first started by running tests for CD. After that, unit root tests were performed to examine the stationarity of the variables followed by a cointegration test to see if the series have any long-run relationships with each other. The cross sectional augmented autoregressive distributive lag (CS-ARDL) approach was used to look at the links that exist among the selected variables for the analyzed countries. Finally, the panel heterogeneous causality test was undertaken to check the causal relationships that exist among the variables under analysis.

The current study tries to find relationships both short-term and long-term between the variables of focus. Additionally, it aims to emphasize the moderating effects that exist among these variables. The study further aims to examine causal relations of economic indicators in selected G20 countries over the period from 1995 up to 2022, including Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, South Africa, Turkey, the UK, and the United States. This is now an increasingly interdependent world, facilitated by advances in information and communications technology, digital marketing, and multiple social media platforms. In this regard, the nations are more united than ever. Several factors have thus led to the creation of an atmosphere of interdependence within nations, such as uneven population distribution, income-based classifications of countries, labor shortages and surpluses, demographic aging, and uneven distribution of natural resources. Such collaboration in the form of dealing with climatic changes and other futuristic economic barriers in working toward achieving the United Nations' Sustainable Development Goals by 2030 is largely required, as it is possible for a country's outputs to change the outcomes of the world at large. This interdependence is especially prevalent in G20 countries, which are highly interlinked with one another in their pursuits toward sustainable development. The econometrician has termed this phenomenon as cross-sectional dependence (CSD). In the study, there are four commonly accepted tests to confirm cross-sectional dependence. These include the CD test developed by Pesaran (2007), the BP Lagrange Multiplier (LM) test introduced by Breusch and Pagan (1980), the scaled LM test proposed by Pesaran (2007), and finally, the bias-corrected scaled LM test formulated by Baltagi et al. (2012).

Furthermore, this research incorporates the slope heterogeneity test across the series to assess the presence of heterogeneity. Subsequently, the focus shifted to analyzing the stationary properties of each chosen variable. The stationary process is evaluated through the application of second-generation augmented cross-sectional panel unit root tests, specifically the CIPS and CADF tests introduced by Pesaran et al. (2004). Following the validation of the cross-sectional dependence (CSD) and the stationary characteristics, the next phase involves investigating the cointegration among the variables. To achieve this, the study uses methodologies suggested by Pedroni (2004) and Westerlund (2007) to determine whether there exists a long-term relation among the variables considered in the sample.

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The first author that developed the cointegration test is Pedroni, which would then be applied to check if a process is stationary or not. The Pedroni cointegration test is a residual-based test accounting for short-term dynamics and slope coefficients in the long run and is different between panel members. This test had constituted within-dimension pooled tests and group mean between-dimension tests. Further, it carried individual heterogeneous fixed effects and trend components (Pedroni, 2004). Then on appropriate for situations that arise with the existence of cross-sectional dependence (CSD), the Westerlund panel cointegration test was later on utilized. More recent research uses the cross-sectional methodology within the framework of the ARDL model to try to address issues of cross-sectional dependence (CSD), heterogeneity and to allow the potential mixture of integration orders: I(0) and I(1). The method allows easy estimation of short-run and long-run coefficients., and results come out to be robust as compared to conventional ARDL, fully modified ordinary least squares, and dynamic ordinary least squares methods (Chishti et al,2024). The panel causality test of Dumitrescu and Hurlin (2012) was also conducted to explore the causal relationship between the variables.

Table 1: ***Variables of Study and Their Description***

Variable	Symbol	Measurement	Source
Ecological Footprint Pressure Index	EFPI	Ecological Footprint (Gha person) / Biocapacity (Gha person)	GFN
Financial Globalization	FG	Globalization Index	KOF
Environmental Diplomacy	ED	Cumulative Treaties	IMF
Gross Domestic Product	GDP	Per capita (constant US$ 2015)	World Bank
Environmental Policy Stringency	EPS	Stringency Index	OECD

Results and Discussion

Results

The upper part of Table 2 provides descriptive statistics summarizing key measures for each variable, including mean, standard deviation (SD), and range. GDP has the highest mean at 9.4745, indicating a large economic output, while EPS has the lowest mean at 0.5072. EFPI shows a high variability with an SD of 2.2311, whereas FG has the lowest variability (SD = 0.1162), indicating stability. Skewness values reveal that EFPI is positively skewed (1.1179), meaning more firms have lower EFPI values, while FG and ED are negatively skewed, indicating left-tailed distributions. Kurtosis values suggest that EFPI and FG have sharper peaks, implying more extreme values than a normal distribution.

Table 2: *Descriptive Statistics and Correlation Matrix*

Variables	EFPI	FG	ED	GDP	EPS
Mean	2.8418	4.0852	1.5558	9.4745	0.5072
Median	2.2207	4.1309	1.6094	9.9598	0.6212
Maximum	9.3259	4.2177	4.3694	11.2428	1.0691
Minimum	0.2589	3.7828	0.0000	5.9232	-0.3219
SD	2.2311	0.1162	0.8350	1.2876	0.4557
Skewness	1.1179	-1.1820	-0.8745	-0.8745	-0.5199
Kurtosis	3.5226	3.6294	2.8480	2.8480	1.7875
Correlation Matrix					
EFPI	1				
FG	0.0495	1			
ED	0.1015	-0.2815	1		
GDP	0.2811	0.2930	0.1164	1	
EPS	0.0509	0.9351	-0.3605	0.3352	1

The correlation matrix in the lower part of the table indicates that FG has a strong positive correlation with EPS (0.9351), suggesting financial globalization is closely

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linked to environmental policy stringency. GDP and EPS also show a positive correlation (0.3352), while ED negatively correlates with EPS (-0.3605), implying environmental diplomacy might be associated with lower EPS. EFPI has weak correlations with all other variables, suggesting its impact on financial and economic indicators is minimal.

Table 3: *Cross-sectional dependence test*

Variables	BP LM	PS LM	BCS LM	PCD
EFPI	1402.540*	76.795*	76.480*	9.704*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
FG	3808.647*	222.647*	222.332*	61.708*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ED	431.891*	17.941*	17.626*	16.154*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
GDP	2729.615*	157.261*	156.946*	51.096*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
EPS	3808.00*	222.647*	222.332*	61.708*
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: BP LM: Breusch–Pagan LM test; PS LM: Pesaran Scaled LM; BCS LM: Bias-Corrected Scale;

*PCD: Pesaran CD test; * represents 1% significance level; p- values are in parenthesis*

Hamsal (2015) emphasizes the importance of correlation testing in identifying potential multicollinearity issues that may affect regression analysis, particularly when the correlation coefficient exceeds 0.95. In this analysis, all Pearson correlation coefficients remain below 0.95, suggesting that multicollinearity is not an issue among the independent variables examined in this study.

Cross-Sectional Dependence And Slope Heterogeneity Results

In the context of the present study, the Breusch and Pagan Lagrange Multiplier (LM) test, proposed by Breusch and Pagan (1980), was used in order to remove possible

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difficulties due to vague or unreliable results in testing cross-section dependence (CD). The results presented in Table 3 clearly indicate that the null hypothesis of no CD is rejected at 1%. Hence, the panel data studied presents a grave problem of CD. Following the identification of CD among the variables under investigation, the cross-sectional homogeneity of the slope coefficients was evaluated by using the method of Pesaran and Yamagata (2008). As discussed in Table 4, the study also revealed that the slope of the model in question is heterogeneous rather than homogeneous. As noted by Park et al. (2018), the panel data was aggregated from various cross-sections emanating from diverse institutional frameworks, cultural variances, and the distinct characteristics inherent in each country. Consequently, this increases the likelihood of CD, which may result in biased and spurious findings.

Table 4: ***Slope heterogeneity test***

	Δ	Δ Adjusted
Model	-5.988*	-7.574*
	(0.000)	(0.000)

*Note: * represents significance level at 1%; p- values are in parenthesis*

Unit Root Results

Table 5 presents the results of second-generation panel unit root tests, specifically the CIPS and CADF tests, to assess the stationarity properties of the variables. The findings indicate a mixture of integration orders, with some variables being stationary at level I(0), while others achieve stationarity only after first differencing I(1). No variables exhibit stationarity at I(2), confirming that all series are at most I(1).

Specifically, FG and ED are stationary at level I(0), implying that they do not contain unit roots. In contrast, EFPI, GDP, and EPS are non-stationary at their levels but become stationary after first differencing, confirming their I(1) nature. This mixed order of integration justifies the application of the CS-ARDL (Cross-Sectionally Augmented Autoregressive Distributed Lag) approach, enabling the estimation of both short-run and long-run relationships among the variables in the study.

Table 5: *Panel unit root test results*

Variables	CIPS		CADF		Order of Integration
	Level	Δ	Level	Δ	
EFPI	-0.64	-6.37*	-1.92	-4.17**	I(1)
FG	-7.07*	---	-3.88**	---	I(0)
ED	-2.08*	---	-3.11***	---	I(0)
GDP	-0.77	-1.77**	-0.05	-4.24***	I(1)
EPS	-2.36	-4.18*	-2.36	-5.38*	I(1)

*Note: *, **, and *** represents 1 %, 5 %, and 10 % levels of significance*

Cointegration Results

The next objective is the estimation of the long-run relations among the variables of interest. Towards that end, we employed a range of cointegration tests, developed by Pedroni (2004) and Westerlund (2007). In the Pedroni tests, the results are reported in Table 6; it is here that six out of eleven statistics gave statistically significant values, thereby confirming a long-run relationship. Additionally, the Westerlund tests have been performed in order to further substantiate these empirical findings that confirm existence of cointegration between the variables. In summary, therefore, both methodologies of testing support the existence of a long term cointegration among the variables.

Long-Run and Short-Run Estimates of CS-ARDL

This table represents the long-run and short-run coefficients estimated using the CS-ARDL (2,2,2,2,2,2) model, with the Ecological Footprint Pressure Index (EFPI) as the dependent variable. From the long-run context, Financial Globalization (FG) has a significant positive effect on EFPI, with a coefficient of 1.2520, indicating that greater financial globalization leads to an increase in ecological footprint pressure.

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Table 6: *Padroni and Westerlund Cointegration tests*

Pedroni				
	Statistic	**p-Value**	**Within Weight**	**p-Value**
Within dimension				
Panel v-Statistic	-3.953	1.0000	-4.019	1.000
Panel rho-Statistic	1.463	0.9282	2.060	0.9803
Panel PP-Statistic	-3.781	0.0001*	-1.691	0.0453**
Panel ADF-Statistic	-8.655	0.0000*	-1.714	0.0433**
Between dimensions				
Group rho-Statistic	2.806	0.997		
Group PP-Statistic	-1.911	0.028**		
Group ADF-Statistic	-2.178	0.014**		
Westerlund				
	19.381	0.0000*		

*Note: * and ** represents 1 % and 5 % levels of significance*

Similarly, Environmental Diplomacy (ED) and Gross Domestic Product (GDP) also exhibit a significant positive impact on EFPI, with coefficients of 0.0249 and 0.5815, respectively, suggesting that higher environmental diplomacy efforts and economic growth contribute to increased ecological footprint.

Table 7: *Long-run and Short-run estimates of CS-ARDL*

Dependent Variable: EFPI		(2,2,2,2,2,2)		
Variable	Coefficient	Std. error	t-stat	p-value
Long-run coefficients				
FG	1.2520	0.2804	4.4637*	0.0000
ED	0.0249	1.2116	5.1477*	0.0000
GDP	0.5815	0.0599	9.7060*	0.0000
EPS	6.2373	1.2116	5.1477*	0.0000
EPS*FG	-1.7000	0.2932	-5.7980*	0.0000
Short-run coefficients				
D(FG)	-1.0848	0.3807	-2.8488**	0.0048
D(ED)	0.0156	0.017	-0.911	0.3632
D(GDP)	0.2981	0.2346	1.2705	0.2052
D(EPS)	-7.2198	3.1757	-2.2738**	0.0239
D(EPS*FG)	1.7298	0.6984	2.4766**	0.0140
ECM(-1)	-0.2181	0.0755	-2.8857**	0.0043
C	-1.5186	0.6149	-2.4695**	0.0143

*Note: * and ** represents 1 % and 5 %, levels of significance*

Environmental Policy Stringency (EPS) shows a strong positive effect on EFPI, with a coefficient of 6.2373, implying that stricter environmental regulations, rather than reducing environmental pressure, may inadvertently increase ecological footprint, potentially due to regulatory inefficiencies or enforcement challenges. However, the interaction term (EPS*FG) is negative (-1.7000), suggesting that financial globalization moderates the adverse effects of policy stringency on ecological footprint.

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In the short run side, FG demonstrates a significant negative effect on EFPI, with a coefficient of -1.0848 (p = 0.0048), indicating that financial globalization initially reduces ecological footprint pressure before contributing to its long-term increase. ED and GDP, however, show insignificant short-term effects on EFPI, with coefficients of 0.0156 (p = 0.3632) and 0.2981 (p = 0.2052), respectively. On the other hand, EPS has a significant negative short-run effect (-7.2198, p = 0.0239), meaning that in the immediate term, stricter environmental policies contribute to reducing ecological footprint pressure. However, the interaction term (EPS*FG) is positive (1.7298, p = 0.0140), indicating that financial globalization may weaken the short-term effectiveness of environmental policies. The error correction term ECM(-1) is negative and significant at -0.2181 (p = 0.0043), confirming the presence of a stable long-term equilibrium relationship. This result suggests that approximately 21.81% of any disequilibrium in EFPI is corrected in each period, indicating a moderate pace of adjustment toward long-run stability.

Causality Results

The findings from the Dumitrescu and Hurlin panel causality analysis indicate the presence of several notable uni-directional and bi-directional causal relationships, as detailed in Table 8. Notably, Financial Globalization (FG) and Ecological Footprint Pressure Index (EFPI) exhibit a strong bidirectional causality, signifying a reciprocal influence between the two variables. While Environmental Diplomacy (ED) does not exert a significant effect on EFPI, the reverse holds true, with EFPI having a considerable impact on ED. Additionally, there is a weak bidirectional causality between GDP and EFPI, suggesting a complex two-way relationship between economic growth and ecological pressure.

Furthermore, Environmental Policy Stringency (EPS) has a strong unidirectional effect on EFPI, indicating that policy stringency significantly impacts ecological footprint pressure, but no lagged reverse effect is observed. Moreover, the interaction between EPS and FG exerts a strong one-way impact on EFPI, implying

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that the combined influence of environmental policies and financial globalization intensifies ecological pressure. These findings highlight the intricate interplay between environmental policies, economic factors, and their implications for climate change mitigation across the selected G20 economies from 1995 to 2022.

Table 8: ***Dumitrescu and Hurlin panel causality results***

Null Hypothesis	W-stat	Zbar-stat	p-value	Causality
FG → EFPI	5.9124	6.2124	5.e-10*	
EFPI → FG	3.3403	1.8961	0.0579***	Bi-directional
ED → EFPI	2.9426	1.1649	0.2440	
EFPI → ED	5.7708	5.8078	6.e-09*	Uni-directional
GDP → EFPI	3.3144	1.8525	0.0639***	
EFPI → GDP	3.2317	1.7126	0.0868***	Bi-directional
EPS → EFPI	9.8499	12.8205	0.0000*	
LCF→EPS	2.5566	0.5808	0.5613	Uni-directional
EPS*FG→ EFPI	10.1076	13.2528	0.0000*	
EFPI →EPS*FG	2.7016	0.8241	0.4098	Uni-directional

*Note: * and *** represents 1 % and 10 % levels of significance*

Discussion

The study results identify complex links between financial globalization (FG), environmental policies (EPS), economic growth (GDP) and environmental performance (EFPI). Research data verifies that all these elements form a connected network that affects ecological sustainability through combined direct and indirect effects. The long-term effects of financial globalization and economic development on EFPI exist nevertheless their positive and negative consequences cannot be determined easily. Financial globalization (FG) along with economic development (ED) applies force on ecological resources which results in environmental degradation. Global economic integration initially puts pressure on natural resources because of which environmental concerns about reckless financial expansion emerge.

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Strong environmental policies offset the negative outcomes of financial globalization by ensuring responsible resource management as globalization succeeds in becoming an instrument for sustainability.

Financial and environmental reforms cause temporary adjustment costs during the short-run period. Financial globalization and economic growth produce initial detrimental effects on EFPI because fast financial integration and economic growth yield temporary environmental stress. The existence of an essential error correction mechanism (ECM) shows that environmental policies properly enforced lead to quick corrections against the negative effects of financial globalization. Excellent environmental governance plays a crucial role because it enables stable ecological performance following short-term environmental disturbances due to financial liberalization.

This essential conclusion from the cause-effect study reveals that environmental laws serve as the main force behind EFPI which proves that proper regulatory systems control environmental outcomes for extended periods. Financial openness creates a two-way relationship with EFPI because environmental progress helps establish financial policies for green investments and sustainable economic practices. The relationship between GDP and EFPI operates in both directions because economic development supports environmental investments yet uncontrolled growth creates increased environmental damage. Research findings support wider understanding that economic expansion needs to free itself from negative environmental impacts to achieve sustainable ecological outcomes.

Conclusion

The Environmental Footprint Performance Index (EFPI) model clarifies the key factors affecting Financial Globalization (FG), Economic Development (ED), Gross Domestic Product (GDP), and Environmental Policy Stringency (EPS) in relation to environmental sustainability. Long-term studies indicate that FG, ED, and GDP positively impact EFPI, suggesting that both economic and financial liberalization can improve environmental outcomes, especially when backed by strong governance frameworks. In contrast, the negative correlation between FG and EPS suggests potential inefficiencies that may arise when financial integration occurs without adequate environmental regulations. This underscores the need for comprehensive policies that align financial globalization with stringent environmental governance to tackle potential ecological issues.

The error correction model (ECM) reveals a significant adjustment speed of -0.2181, indicating that approximately 21.81% of deviations from equilibrium are corrected within a certain timeframe. This reflects a moderate rate of convergence, where environmental performance gradually stabilizes after short-term fluctuations or policy adjustments. The findings confirm that EFPI is resilient to external shocks, such as financial crises or regulatory changes, with the system slowly returning to equilibrium. The estimated adjustment period suggests that environmental governance strategies are effective in restoring balance, provided that proactive policy initiatives are implemented.

These results emphasize the crucial role of environmental policies in balancing financial globalization, economic growth, and environmental sustainability. The short-term positive relationship between FG and EPS indicates that well-designed regulations can effectively alleviate the pressures associated with globalization. However, the findings from the long-term analysis underscore the necessity for ongoing policy reinforcement to safeguard ecological integrity amidst financial expansion. In summary, the research underscores the critical importance of harmonizing economic and financial strategies with environmental policies to facilitate sustainable resource management, thereby ensuring that economic advancement and globalization align with enduring environmental goals.

Policy Implications

The results of this analysis highlight the necessity for a coherent integration of financial globalization, economic development, and environmental sustainability.

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Although financial globalization and economic growth can exert considerable strain on ecological resources, the implementation of stringent environmental policies can alleviate these detrimental impacts, thereby allowing globalization to function as a mechanism for sustainable resource management. The observed negative long-term relationship between GDP and the Environmental Footprint Performance Index (EFPI) emphasizes the critical need to decouple economic advancement from environmental harm through the promotion of green finance, circular economy initiatives, and transitions to clean energy. Moreover, the findings from the error correction model indicate a relatively rapid adjustment process, suggesting that well-designed regulatory measures can enhance environmental performance even in the face of short-term disturbances. This underscores the importance of proactive and flexible policies that can reconcile economic growth with ecological conservation, facilitating a resilient shift towards sustainability.

Consequently, policymakers should capitalize on financial globalization as a catalyst for green investments by enacting sustainability-oriented financial policies, ESG-focused capital distribution, and rigorous compliance mechanisms that align economic and environmental objectives. The beneficial relationship between financial globalization and environmental policy stringency indicates that effectively enforced environmental regulations can mitigate the adverse effects of global capital movements, thereby aligning financial liberalization with ecological integrity. Additionally, governments ought to prioritize the enhancement of institutional governance, the fortification of environmental diplomacy, and the promotion of international collaboration within the G20 framework to avert regulatory arbitrage and establish unified global sustainability standards. By integrating robust environmental policies into financial and economic frameworks, countries can attain a balanced coexistence between globalization and ecological stewardship. Integrating strong environmental policies within financial and economic frameworks enables countries to attain a sustainable equilibrium between globalization, economic growth, and enduring ecological stability.

Limitations and Suggestions for Future Research

This research is limited by variations in data quality among different countries, a narrow emphasis on G20 nations, and the omission of nonlinear dynamics or external disturbances such as economic downturns or geopolitical tensions. Furthermore, the focus on macroeconomic indicators fails to fully account for microeconomic elements, such as the sustainability initiatives at the firm level and technological advancements, which also play a significant role in shaping environmental outcomes.

Future investigations should aim to examine nonlinear interactions through sophisticated econometric methodologies, broaden the analysis to include developing nations and perform sector-specific evaluations to uncover the environmental consequences unique to various industries. Incorporating assessments of climate risks, metrics for biodiversity loss, and real-time simulations of policy impacts would improve the accuracy of predictions, thereby assisting policymakers in formulating adaptive and proactive sustainability frameworks.

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