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Achieving environmental sustainability through environmentally friendly technologies in OECD countries: The role of financial development

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ABSTRACT

The issue of environmental degradation demands urgent action to mitigate its drastic effects on the economy. To overcome the challenge of climate change, countries around the globe have been devising strategies. Eco-innovation (EI) is a basis to achieve this target because it comprises many technologies and can help to control global warming. Considering the importance of EI, this study examines its impact on environmental performance in OECD countries over the period from 1990 to 2021. Advanced econometric approaches were used, which found that EI is a critical driver of environmental progress and exhibits a negative impact on carbon dioxide (CO_2) emissions, highlighting its role in fostering environmental sustainability. Moreover, financial development (FD), often associated with capital allocation, supports a downward trend in emissions, signifying a synergy between robust financial systems and environmental responsibility. Countries with a well-developed financial infrastructure and a propensity for international trade are poised to reap the benefits from EI, owing to their capacity to readily embrace cutting-edge technological advancements. This study suggests that countries with highly developed finance systems have the ability to amplify the positive impacts of EI on environmental performance.

Contribution/Originality: This study contributes to the existing literature by exploring the impact of eco-innovation on CO_2 emissions in the presence of financial development for OECD countries. This study not only presents novel evidence supporting the development of targeted initiatives to address the issue of CO_2 emissions in this particular location, but it also offers a more comprehensive analysis of the influence of EI on CO_2 emissions in OECD countries. We aim to challenge the notion of uniform country characteristics in terms of financial growth, thereby moving beyond the traditional nexus of EI and environmental sustainability.

1. INTRODUCTION

In an era characterized by growing public awareness and concern regarding climate change and environmental conditions, the pursuit of environmental sustainability has emerged as a paramount global objective. Hence, the issue of environmental degradation demands urgent efforts to mitigate its effects on the economy. EI, a term denoting the advancement and implementation of technology and processes that are ecologically conscious, has emerged as a crucial approach in addressing environmental deterioration and promoting economic sustainability. EI encompasses the advancement and implementation of technology and processes that are environmentally sustainable.

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EI offers the opportunity to assess the compatibility between the objectives of economic development and environmental preservation (Sanni, 2018). Furthermore, EI plays a significant role in mitigating the ecological impact of companies and sectors by effectively minimizing their ecological footprints. This, in turn, alleviates the strain on natural resources and ecosystems. The initiative advocates for the conscientious utilization of energy, minimizes waste generation, and effectively mitigates emissions, hence diminishing the presence of pollutants in the atmosphere and aquatic bodies. EI plays a crucial role in enabling the transition toward the utilization of renewable energy sources, making a substantial contribution to the mitigation of greenhouse gas emissions (Qin et al., 2021; Safi et al., 2021). The implementation of eco-innovative solutions empowers enterprises to make environmentally responsible decisions, thereby influencing customer preferences and fostering the development of a more sustainable market. The potential of EI to support the shift toward a circular economy and promote sustainable business practices brings several benefits, including ecological preservation, economic expansion, and job creation. Furthermore, EI facilitates the preservation of the natural environment. Its importance is undeniable in the global effort to combat climate change, preserve biodiversity, and secure a more environmentally balanced and prosperous world for future generations. Similarly, financial development (FD), characterized by the augmentation of financial services and capital market accessibility, has the potential to both accelerate environmental sustainability and pose challenges to it. The rapid pace of FD can also lead to environmental degradation through increased production, resource consumption, and emissions. In this context, EI emerges as a vital complement to FD (Kirikkaleli, Adebayo, Khan, & Ali, 2021; Li, Zhang, Ali, & Khan, 2020).

In recent years, a noticeable shift has occurred toward reduced greenhouse gases emissions, a phenomenon that can be ascribed to the implementation of more stringent environmental rules and the deceleration of economic activity. After the adoption of the widely recognized Paris Climate Agreement (PCA) in 2015, OECD countries have undertaken measures to maintain environmental sustainability. In pursuit of fostering a more ecologically mindful society, OECD countries have reached a consensus to uphold a global average temperature that remains below the threshold of two degrees Celsius. Nevertheless, the overall development is deemed inadequate, and it is projected that there will be a resurgence in greenhouse gas emissions as a result of the recent upsurge in energy consumption and the corresponding increase in CO_2 emissions (OECD, 2021). Despite the PCA, CO_2 emissions rose by 2.7% in 2018. The primary objective of this study is to examine the influence of financial deepening on the development of EI initiatives within OECD member countries. This enables us to address the intricate issues that we are confronted with.

The study contributes to prevailing research in many ways. First, it examines the impact of EI on CO_2 emissions in OECD member countries. It also examines the underlying mechanism that impacts the association between these two variables, specifically by scrutinizing the role of financial growth. This study not only presents novel evidence supporting the development of targeted initiatives to address the issue of CO_2 emissions in this particular location, but it also offers a more comprehensive analysis of the influence of EI on CO_2 emissions in OECD countries. We aim to challenge the notion of uniform country characteristics in terms of financial growth, thereby moving beyond the traditional nexus of EI and environmental sustainability. The complementary role of FD is investigated to explore the channels that could enhance EI capacity, which could allow for the diffusion and adaptation of environmentally friendly technology. The interconnection of these components is crucial, with significant implications for the long-term sustainability of the ecosystem. Ultimately, the objective of this study is to facilitate the formulation of strategies and policies that can effectively harness the potential advantages of financial deepening, while concurrently mitigating the adverse environmental consequences associated with these phenomena.

2. LITERATURE REVIEW

There is an increasing consensus among scholars and experts that eco-innovation (EI) has the potential to effectively disentangle economic advancement from the degradation of the natural environment. The decoupling

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phenomenon is often seen as a crucial factor in achieving the objective of sustainable development since it enables economic growth to occur independently of any concurrent rise in pollution emissions or natural resource consumption. According to Li et al. (2020), EI encompasses advancements in various domains, such as renewable energy, waste management, sustainable agriculture, and clean technologies, collectively fostering a more sustainable societal framework. Furthermore, the implementation of EI is crucial in addressing worldwide environmental challenges, such as the issue of climate change. Based on the results of recent research, it is possible to achieve substantial reductions in greenhouse gas emissions by means of investigating, advancing, and implementing clean energy technology. For example, the implementation of EI within the energy industry has played a crucial role in facilitating the extensive utilization of solar panels, wind turbines, and energy-efficient architectural designs (Ji et al., 2021; Khan, Ali, Dong, & Li, 2021). One significant finding is that EI often arises from the convergence of regulatory influences, consumer demand for ecologically sustainable products, and the quest for competitive advantage. Sun, Yesilada, Andlib, and Ajaz (2021) and Li et al. (2020) posit that the presence of environmental legislation and standards can serve as a catalyst for businesses to actively participate in EI. Similarly, the inclination of customers toward environmentally friendly products can foster the advancement of sustainable technology. In light of this, enterprises have started to see the potential of EI in enhancing their market competitiveness while concurrently reducing their environmental footprint. EI is widely recognized and commended for its inherent capacity to mitigate the adverse consequences of human activities on the environment. However, it encounters several challenges and impediments in its pursuit of sustainable development. Several researchers, such as Khan, Ali, Umar, Kirikkaleli, and Jiao (2020) and Li et al. (2020), have identified various barriers to EI, which include substantial initial costs, uncertain market demand, and organizational resistance to change. Governments and politicians have the potential to help eliminate these barriers through several means, such as offering incentives, establishing legislative frameworks, and providing financial support for research and development.

Based on research findings, it can be concluded that EI plays a significant role in the implementation of ecologically sustainable practices. Moreover, the examination of how trade affects the long-term sustainability of the environment has garnered considerable scholarly interest in recent years (Khan et al., 2021; Liddle, 2018; Qin et al., 2021). However, there has been a lack of research on the prerequisites necessary for the effective execution of environmentally creative solutions. Only a few studies have examined the prerequisites for the transformation of EI into environmental sustainability (Cheng, Yang, & Sheu, 2014; Rennings, 2000; Varadarajan, 2018; Yin, Rashid, & Al-Shahmi, 2022). Shahbaz, Nasir, and Roubaud (2018) argue that the efficiency of EI needs prerequisites, such as good governance, sound political and economic conditions, environmentally friendly policies, and human capital, because technology alone is useless if proper resources are not available for the transition to renewable energy sources. Levin and Raut (1997) argue that developed human capital can enhance technology benefits through better utilization of resources in production and consumption activities. Hence, human capital development is a significant variable for improving EI. In the literature, good governance, sound political and economic conditions, environmentally friendly policies, and developed human capital have been considered as prerequisites for the transformation of EI into environmental sustainability. Factors such as FD have been ignored in the relationship between EI and environmental sustainability; therefore, this study aims to extend the existing framework of EI and environmental performance by questioning the underlying assumption that countries possess uniform characteristics in terms of centralization and institutional quality.

In summary, the literature on the impact of EI on environmental sustainability highlights its central role in achieving a greener and more sustainable world. EI presents a pathway to address pressing environmental issues, such as climate change and resource depletion, while fostering economic growth and maintaining a high quality of life for present and future generations. Ongoing research in this field continues to make valuable contributions toward the formulation of policies and programs designed to promote sustainable development and mitigate the environmental challenges prevalent in contemporary society.

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The relationship between FD and environmental sustainability has gained significant attention in academic literature (Aluko & Obalade, 2020; Charfeddine & Kahia, 2019; Fakher & Ahmed, 2023; García-Granero, Piedra-Muñoz, & Galdeano-Gómez, 2018; Yang, Jahanger, & Ali, 2021; Zafar, Saud, & Hou, 2019). The impact of monetary structures on the natural environment is complex and can manifest in either positive or negative ways. The research typically emphasizes the crucial role of FD in providing resources for sustainable programs and activities. The facilitation of cash transfer to environmentally responsible investments can be enhanced by the presence of robust financial systems characterized by efficient banking and capital markets. As a result of this development, firms and organizations are now equipped with the required resources to develop and implement environmentally sustainable technologies and practices. Several studies, including Zhang, Rong, and Ji (2019); Fernando and Wah (2017); Cai and Li (2018) and García-Granero et al. (2018), have provided evidence of a positive association between stable financial systems and increased investments in energy-efficient technology and renewable energy sources. These investments, in turn, play a crucial role in mitigating CO_2 emissions. Furthermore, financial institutions are progressively incorporating environmental, social, and governance (ESG) concerns into their lending and investment activities. The aforementioned alteration signifies a growing awareness of the importance of responsible investment practices and sustainability, as highlighted by Cai and Li (2018). Udeagha and Ngepah (2023) argue that the adoption of ecologically responsible practices by firms is encouraged as a means to secure financial support, contributing to the development of a more sustainable market. Nevertheless, it is plausible that the growth of the financial industry may yield adverse consequences for the environment. For example, an overabundance of loans extended to environmentally hazardous enterprises, inadequate regulatory oversight, and speculation in natural resource markets can all contribute to environmental degradation. Saud, Chen, and Haseeb (2020) identified circumstances wherein the prioritization of financial gain may not align with the preservation of the natural environment.

The impact of the financial industry on environmental sustainability is contingent upon various factors, including regulatory frameworks, government policies, and the dedication of financial institutions to ESG principles. Based on extant literature by Charfeddine and Kahia (2019), it is evident that an effectively utilized financial system possesses the capacity to substantially mitigate or decelerate environmental degradation. Conversely, this underscores the significance of establishing governance frameworks and rules that effectively allocate financial resources to environmentally advantageous initiatives while discouraging environmentally detrimental practices. The research highlights the ongoing and evolving nature of the relationship between economic growth and environmental sustainability.

This research bridges a critical literature gap by exploring the complex relationship between EI and FD in the context of environmental sustainability and offering a holistic perspective that enhances our understanding of how these factors interact and influence the environmental outcomes in OECD countries. It advances the literature by uncovering the potential complementarities and tensions between these variables, ultimately providing valuable insights for policymakers, businesses, and researchers seeking to foster a more sustainable future.

3. DATA

Data was collected for the study variables using a sample of ten emerging economies: Brazil, China, Columbia, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, and Thailand. The sample period runs from 1990 to 2021. Environmental sustainability is used as the dependent variable to represent the level of environmental sustainability in OECD countries. CO_2 emissions are used as a proxy for environmental sustainability. The description, unit, and sources of the variables are given in Table 1.

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Table 1. Variables units and sources.

Variable	Description	Unit	Literature source/s	Data source
$CO2_{i,t}$	Carbon dioxide emissions	Metric tons of CO_2	Shi, Visas, Ul-Haq, Abbas, and Khanum (2022)	OECD (2021) https://stats.oecd.org
$EXP_{i,t}$	Exports	Percentage of GDP	Ul-Haq, Nazeer, and Khanum (2021)	WDI (2021)
$IMP_{i,t}$	Imports	Percentage of GDP		WDI (2021)
$GDP_{i,t}$	Gross domestic product	Constant US$ (2010)	Dou, Ul-Haq, Visas, Aslam, and Khanum (2023)	WDI (2021)
$FD_{i,t}$	Financial deepness	Domestic credit to private sector as a % of GDP	Umar, Ji, Kirikkaleli, and Xu (2020)	
$EI_{i,t}$	Eco-innovation	% of all technologies	Hye, Ul-Haq, Visas, and Rehan (2023) and Sumrin et al. (2021)	OECD (2021) https://stats.oecd.org

3.1. Model Specification

This study also checks the complementarity between eco-innovation and FD in affecting environmental sustainability. The purpose of this study is to examine the potential interaction effects among the factors in order to determine if the collective impact of these variables on CO_2 emissions surpasses the cumulative impact of their individual impacts. A well-developed financial sector, including banks and capital markets, plays a crucial role in allocating resources to various economic activities. In this study, the negative impact of FD on CO_2 emissions implies a shift toward more sustainable investments and eco-friendly projects. Based on theory and prior research, this study formulates hypotheses regarding the relationships between these variables. This study hypothesizes that increased financial deepening is associated with higher environmental sustainability. Furthermore, financial deepening strengthens the association between eco-innovation and financing deepening with CO_2 emissions. Based on these hypotheses, the model specification is given as follows:

$$CO2_{i,t} = \beta 0 + \beta_1 GDP_{i,t} + \beta_1 EXP_{i,t} + \beta_1 IMP_{i,t} + \beta_2 EI_{i,t} + \beta_4 FD_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where, CO_2 stands for carbon dioxide emissions, which represents the level of environmental sustainability, GDP is gross domestic product, EXP and IMP represent exports and imports as a percent of GDP, respectively, EI is eco-innovation, and FD represents the level of financial deepening.

In the next step, we extend model 1 with the interaction term between FD and EI (FD*EI), which captures how the combination of FD and EI influences the level of CO_2 emissions. To check the combined role of financial deepness and EI in affecting environmental sustainability, the model is extended by the interaction term of FD*EI. A positive coefficient suggests that the interaction enhances EI, while a negative coefficient suggests a dampening effect. By including the interaction terms in our model, we can gain a deeper understanding of how financial deepening influences the relationship between EI and CO_2 emissions in OECD countries. The extended model is given as:

$$CO2_{i,t} = \gamma 0 + \gamma_1 GDP_{i,t} + \gamma_2 EXP_{i,t} + \gamma_3 IMP_{i,t} + \gamma_4 EI_{i,t} + \gamma_5 FD_{i,t} + \gamma_6 (FD * EI)_{i,t} + \varepsilon_{i,t} \quad (2)$$

The size and sign of the interaction terms are particularly important for policy implications.

3.2. Analytical Techniques

3.2.1. Diagnostic Tests

Diagnostic tests were performed to check the reliability and robustness of the model. Pesaran's test (Pesaran, 2015) was used to check the cross-sectional dependency (CSD), and the equation is given as:

$$CSD^{NT} = \sqrt{\frac{TN(N-1)}{2}} * \hat{\rho}_N \quad (3)$$

Where $\hat{\rho}_N$ represents the pair-wise correlation coefficient.

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In addition, this study uses the Pesaran and Yamagata (2008) test to check the slope heterogeneity. The test takes CSD into account in the panel data, which is preferable over other heterogeneity tests (Ali & Malik, 2021).

3.2.2. CIPS Unit Root Test

The cross-sectionally augmented IPS (CIPS) unit root test is employed to analyze time series variables and determine the existence of a unit root, indicating the non-stationarity of the data. The idea of stationarity holds significant importance in the field of time series analysis as it guarantees the constancy of the statistical features of a variable over the duration of the inquiry. This renders it an essential process. The CIPS test is a useful choice for analyzing datasets containing non-independent observations due to its explicit consideration of cross-sectional dependence in panel data. The utilization of the CIPS test is deemed appropriate for datasets in which the observations lack independence. The outcome of the CIPS test, which fails to establish the presence of a unit root, provides support for the assertion that the variable under consideration exhibits stationarity. Consequently, the data can be subjected to a suitable differencing approach. The following is an example of an equation that can be written for the CIPS test:

$$\Delta W_{i,t} = \varphi_i + \varphi_i Z_{i,t-1} + \varphi_i \overline{W}_{t-1} + \sum_{l=0}^{p} \varphi_{il} \Delta \overline{W_{t-l}} + \sum_{l=1}^{p} \varphi_{il} \Delta W_{i,t-l} + \mu_{it} \quad (4)$$

The cross-sectional averages are represented by $\overline{W}_{t-1}$ and $\Delta\overline{W_{t-l}}$. The test statistic for the CIPS test is given as:

$$\widetilde{\text{CIPS}} = \text{N}^{-1} \sum_{i=1}^{n} \text{CADF}_i \quad (5)$$

Where CADF represents the cross-sectionally augmented Dickey–Fuller test.

3.2.3. Westerlund Cointegration Test

This study utilizes the Westerlund test to examine the level of cointegration in the panel dataset. The test is suitable for examining potential links among non-stationary variables within the context of panel data analysis. The presence of cointegration suggests the existence of a durable relationship between the variables in question, persisting over an extended period. This relationship serves as a fundamental basis for the application of error correction models and the acquisition of insights into the equilibrium dynamics of the system.

3.2.4. Cross-Sectional Augmented Autoregressive Distributed Lag (CS-ARDL) Model

The CS-ARDL model is a panel data approach that combines autoregressive distributed lag modeling with cross-sectional dependence considerations. This model is particularly useful when analyzing the dynamics between variables over time while accounting for potential cross-sectional interdependencies. The CS-ARDL model accommodates both short-run and long-run effects, making it suitable for investigating the impact of EI and FD on CO_2 emissions across different emerging economies. The inclusion of lagged variables allows for the modeling of dynamic relationships, and the cross-sectional dimension considers potential heterogeneity across countries. The general specification for the CS-ARDL model is written as:

$$CO_2^{i,t} = \delta^o + \sum_{j=1}^{p} \delta^{it} CO_2^{i,t-j} + \sum_{j=0}^{p} \acute{\alpha}_{it} \text{W}_{t-j} + \sum_{j=0}^{3} \ddot{\upsilon}_{it} \bar{Z}_{t-j} + \varepsilon^{it} \quad (6)$$

Where $\bar{Z}_t = (\Delta\overline{CO_2^{i,t}}\ \overline{W}_t')$ contains the cross-section averages, and the explanatory variables are included in $W_{it} = (GDP^{it}, EXP^{it}, IMP^{it}, EI^{it}, FD^{it})$.

4. RESULTS AND DISCUSSION

Based on the significance of the CSD test results (see Table 2), it can be inferred that a linkage exists among all the variables in model 1 across the various nations included in this research. This implies that a certain level of interdependence or connection exists among the observations made by the countries, potentially resulting from shared variables influencing CO_2 emissions or comparable patterns in environmental sustainability. The results of the P&Y test, presented in Table 3, suggest that both models exhibit varying degrees of slope heterogeneity. This

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phenomenon can be attributed to the influence of several latent confounding factors on CO_2 emissions. The issue of slope heterogeneity arises due to the presence of unobserved common characteristics in CO_2 emissions across various cross-sections. These unobserved qualities have the potential to exhibit a correlation with other variables in the model. The results of the CIPS unit root test, presented in Table 4, show that all the variables except CO_2 emissions and FD are integrated of order one.

Table 2. Cross-sectional dependence test results.

Variable	CO_2	GDP	EI	EXP	IMP	FD
CS statistics	14.26***	12.91***	11.75***	16.12***	14.36***	18.47***

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

Table 3. Slope homogeneity test results.

Slope homogeneity test		
Model	$\tilde{\Delta}$	$\tilde{\Delta}_{Adjusted}$
Model 1	11.86***	10.147***
Model 2	14.37***	12.205***

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

Table 4. CIPS unit root test results.

Variable	I(0)	I(1)	Decision
CO_2	-2.812*	-	I(0)
GDP	-1.084	-3.327***	I(1)
EXP	-0.763	-2.982***	I(1)
IMP	-0.981	-3.001***	I(1)
EI	-0.894	-2.996***	I(1)
FD	-1.287**	-	I(0)

Note: *, ** and *** denote the 10%, 5% and 1% levels of significance, respectively.

The results obtained from the Westerlund technique show that both models exhibit a consistent and enduring relationship between the variables, both in the long run and when in a state of equilibrium (see Table 5). The observation that both models exhibit negative and statistically significant coefficients implies that there exists an annual adjustment of around 40% (in model 1) and 35% (in model 2) to rectify errors in the estimation of CO_2 emissions and its causes. Consequently, the disparity that was present in the immediate period is rectified over an extended duration. The cointegration technique established by Westerlund (2007) offers empirical support for a robust long-term convergence to the equilibrium.

Table 5. Westerlund (2007) cointegration test results.

Model	Gt	Ga	Pt	Pa
Model 1	-3.985***	-17.383**	-21.116***	-12.529***
Model 2	-3.529***	-16.208**	-17.263**	-11.711***

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

Next, we proceed to the estimation of both models. The utilization of the CS-ARDL technique in this study aims to make a valuable contribution toward achieving the specified objective. The results are displayed in Table 6, which show the positive impact of GDP and IMP on CO_2 emissions in both models, indicating that an increase in the GDP and IMP of the country causes an upsurge in CO_2 emissions. However, EXP, EI, and FD negatively influence CO_2 emissions, showing that the CO_2 emissions are reduced with the enhancement of EXP, EI, and FD.

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Table 6. CS-ARDL estimator results (Dependent variable: CO_2).

Variables	Model 1	Model 2
GDP	0.753* [0.069]	0.614* [0.048]
EXP	-0.279** [0.081]	-0.239** [0.071]
IMP	0.216** [0.062]	0.201** [0.062]
EI	-0.194** [0.049]	-0.141** [0.026]
FD	-0.129* [0.048]	-0.095** [0.006]
FD*EI	---	-0.037*** [0.007]

Note: *, ** and *** denote the 10%, 5% and 1% levels of significance, respectively. Standard errors are in parentheses [].

The study's results provide insight into the environmental consequences of global trade by uncovering a significant correlation between trade patterns and trade-adjusted CO_2 emissions. The presence of a negative impact of EXP on the trade-adjusted CO_2 emissions implies that, on average, nations engaged in exporting goods exhibit lower emissions per unit of economic output. This phenomenon may be attributed to the relocation of emission-intensive industrial operations to other nations, or alternatively, it may be attributed to the exportation of relatively cleaner and less carbon-intensive products.

Conversely, the identification of a positive impact of IMP on CO_2 emissions implies that a significant number of the economies under examination can be classified as net importers of CO_2. These nations exhibit a tendency to engage in the importation of goods that require a substantial amount of energy, leading to increased energy consumption and, subsequently, elevated levels of CO_2 emissions. The observed occurrence aligns with the results of prior scholarly investigations, particularly those conducted by Liddle (2018) and Ali, Dogan, Chen, and Khan (2021). These studies emphasize the correlation between trade patterns, IMP that requires substantial energy consumption, and the subsequent rise in CO_2 emissions. The consistent findings underscore the significance of comprehending the consequences of global trade on the environment and the need for policies that incorporate CO_2 emissions that are linked to international commercial operations.

Furthermore, the results of the study demonstrate a negative impact of EI on CO_2 emissions in OECD countries. This implies that EI plays a significant role in mitigating the levels of CO_2 emissions in these nations. This deduction can be made based on the observation that the coefficient of EI has a negative value. Additionally, it is evident that EI possesses the capacity to significantly contribute to mitigating adverse environmental impacts. Within the scope of this article, the term "EI" pertains to the development and use of technologies and practices that are environmentally sustainable. Therefore, fostering innovation can play a crucial role in achieving the objective of mitigating CO_2 emissions.

Moreover, a discernible association can be observed between the augmentation of FD and the reduction of CO_2 emissions within OECD countries. Specifically, the long-term elasticity of FD is -0.129%, as shown in model 1. The findings confirm the significance of robust financial institutions in mitigating the adverse environmental impacts resulting from human activities. The promotion of FD has a crucial role in the reduction of CO_2 emissions since it enhances the accessibility of cash for environmentally sensitive initiatives.

The negative impact of FD on CO_2 emissions in OECD countries represents a counterintuitive yet crucial finding, with significant implications for environmental sustainability. This suggests that these countries are advancing in terms of their financial systems and are working to reduce their CO_2 emissions. There are several key factors contributing to this phenomenon. Enhanced FD often leads to increased investment in sustainable and environmentally responsible projects, as well as the allocation of capital to clean and renewable energy sources.

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Moreover, well-developed financial systems can support the growth of green businesses and eco-innovative technologies.

As financial institutions increasingly incorporate environmental, social, and governance criteria into their lending and investment decisions, they incentivize businesses and projects to have a lower carbon footprint. This not only benefits the environment but also aligns with the changing attitudes of consumers and investors, promoting sustainability as a key driver of economic growth. In this context, the negative relationship between FD and CO_2 emissions is a testament to the potential for financial institutions to drive positive change by channeling resources toward environmentally responsible endeavors and aligning economic progress with environmental responsibility.

The negative coefficient of the interaction term indicates a positive role between EI and FD in affecting environmental performance. Enhancing FD has the potential to bolster the strength of this link. This study suggests that countries with highly developed finance systems can amplify the positive impacts of EI on environmental performance. The adoption and implementation of sustainable procedures by businesses and organizations can be facilitated by an effective financial framework that can provide the necessary resources and funding for environmentally conscious initiatives.

The significance of the finding is that the interactive term demonstrates a negative coefficient, meaning that interactive terms play a key role in reducing CO_2 emissions. This discovery holds considerable implications for the sustainable preservation of the environment in the long run. Based on the aforementioned data, it can be inferred that the collaboration between EI and FD yields a synergistic effect, hence contributing to the mitigation of CO_2 emissions. The functionality of well-developed financial systems is vital in the allocation of funds to green and sustainable initiatives. Furthermore, these platforms offer resources for organizations and projects that prioritize ecologically sustainable practices. Simultaneously, EI encompasses the development and deployment of methodologies and technologies that exhibit reduced adverse effects on the surrounding environment. The negative coefficient of the interaction term implies that the presence of FD enhances the impact of EI in reducing CO_2 emissions by facilitating the provision of essential financial assistance and infrastructure to foster these innovative practices. This finding underscores the crucial role of effective financial systems in channeling resources toward environmentally responsible projects, thus aligning economic development with sustainability. It also demonstrates the potential for public and private sectors to collaborate in driving meaningful reductions in CO_2 emissions, promoting a greener and more environmentally responsible future for OECD countries.

Based on the aforementioned facts, it can be inferred that countries with a well-developed financial infrastructure and a propensity for international trade are poised to reap the most benefits from EI, owing to their capacity to readily embrace cutting-edge technological advancements. Consequently, a notable symbiotic association exists between EI and FD in relation to their influence on CO_2 emissions.

Similarly, there is a robust symbiotic association between EI and FD in relation to their influence on CO_2 emissions. The implications of these findings are relevant for policymakers and organizations aiming to promote sustainable development. They emphasize the need for measures that encourage EI, enhance financial systems, and leverage the benefits of FD to drive down CO_2 emissions and achieve environmental goals. Ultimately, these insights provide a roadmap for aligning economic progress with environmental responsibility in the modern global context.

The aforementioned findings shed light on a challenge that policymakers must address in their pursuit of environmental sustainability. While economic progress is essential for improving individuals' quality of life, it is often correlated with a rise in CO_2 emissions.

This highlights the significance of implementing strategies that separate economic growth from environmental damage. Potential solutions that could be employed include investing in greener technologies, promoting energy efficiency, and transitioning to renewable energy sources.

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5. CONCLUSION AND POLICY IMPLICATIONS

In an era characterized by growing public awareness and concern regarding climate change and environmental conditions, the pursuit of environmental sustainability has emerged as a paramount global objective. EI, a term denoting the advancement and implementation of technology and processes that are ecologically conscious, has emerged as a crucial approach in addressing environmental deterioration and promoting economic sustainability. Moreover, the concept of financial deepening, characterized by the augmentation of financial services and capital market accessibility, is closely intertwined with the growth and development of the economy. This study aims to examine the impact of financial deepening on the allocation of financial resources to EI efforts, the accompanying risk profiles, and the overall implications for environmental sustainability within OECD countries. The primary objective of this research is to enhance comprehension regarding the interconnections between financial deepening and EI in affecting environmental performance.

The interconnection of these components is crucial, with significant implications for the long-term sustainability of the ecosystem. Using the CS-ARDL method, it was found that EI is helpful in achieving environmental sustainability.

The results show that the impact of GDP on CO_2 emissions is positive, indicating that an increase in GDP leads to an increase in CO_2 emissions. The variable of EXP is negatively linked to CO_2 emissions, while IMP is positively linked with CO_2 emissions. Moreover, we find that robust financial institutions are important in mitigating the adverse environmental impacts resulting from human activities. The promotion of FD has a crucial role in facilitating the reduction of CO_2 emissions since it enhances the accessibility of cash for environmentally sensitive initiatives. The negative impact of FD on CO_2 emissions represents a counterintuitive yet crucial finding with significant implications for environmental sustainability. This suggests that as these countries advance in terms of their financial systems, they are concurrently working to reduce their CO_2 emissions.

Several countries that are part of the OECD have implemented legislative measures and policies that promote and incentivize EI. These measures can manifest as financial support for research and development, incentives in the form of tax cuts for environmentally sustainable technologies, or adjustments made to emissions objectives to achieve reductions. Furthermore, enterprises and industries situated in nations affiliated with the OECD have exhibited an increased recognition of the importance of matters such as corporate social responsibility, sustainability, and the long-term benefits associated with EI.

In response to the imperative mitigation of their environmental impact, an increasing number of corporations are allocating financial resources to the adoption and implementation of ecologically sustainable practices and technology. OECD countries often serve as global leaders in sustainable practices and EI. Their commitment to reducing CO_2 emissions not only benefits their own environmental goals but also sets an example for other nations to follow. Furthermore, the negative impact of EI on CO_2 emissions doesn't necessarily hinder economic growth. In fact, it can stimulate new economic opportunities and industries related to clean energy, green technology, and sustainable solutions. Moreover, reducing CO_2 emissions through EI contributes to better air and water quality, decreased health risks, and a more stable climate. This results in an improved quality of life for citizens in OECD countries.

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