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Trade and the Environment: Do Environmental Provisions in Trade Agreements Enhance Environmental Quality with Green Taxes and Technologies during the Period (2003-2020)? [1]

التجارة والبيئة: هل تعزز الأحكام البيئية في اتفاقيات التجارة جودة البيئة باستخدام الضرائب والتقنيات البيئية؟

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Abstract

Purpose– This study aims to examine the long-run causal relationship between energy intensity (EI), renewable electricity generation (REI), environmental-related technologies (ETEC), environmental-related taxes (ETAX), real gross domestic product per capita (PRGDP), regional trade agreements (RTA), and environmental quality measured by carbon dioxide emissions CO_2 in 17 countries classified as the most reliant on renewable energy and in the meanwhile among the ones with very high human development index.

Design/methodology/approach– After testing cross-sectional dependence in panel data and slope homogeneity, first and second-generation panel unit root tests were conducted to investigate the variable's stationarity. Various first-generation panel cointegration tests are utilized to test for long-term relationships.

The study applies the pooled Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimation techniques to examine the long-term link between variables. Finally, the Dumitrescu-Hurlin causality test tests the causality relationship between variables.

Findings– The results showed that using FMOLS and DOLS, both economic growth and energy intensity significantly positively affect the CO2 emissions in the selected countries. Moreover, renewable electricity generation significantly negatively affects CO2 emissions based on both techniques employed. While FMOLS revealed a significant negative influence of both environmental technologies and joining RTAs on CO2 emissions, DOLS failed to prove any influence of these two variables on CO2 emissions. No significant impact of environmental taxes on carbon emissions has been found.

Practical implications– The transition toward a low-carbon economy is becoming very crucial. Governments in the selected countries should legislate and adopt environmental regulations and policies. Incorporating environmental provisions in RTAs can serve as a platform for international collaboration and coordination in improving global environmental quality.

Originality/value– This study adds to the current literature by concentrating on the nations that heavily rely on renewable energy. Furthermore, the incorporation of environmental provisions in RTAs used a different approach, assigning fair weights to each nation depending on the provisions included in the agreements. Along with investigating the impact of key environmental factors on environmental quality.

Keywords: CO_2 emissions/ Trade Openness / Energy Intensity/Environmental Related Technologies / Environmental Taxation

الملخص

الغرض–تهدف هذه الدراسة إلى استكشاف العلاقة السببية طويلة المدى بين مجموعة من العوامل مثل كثافة الطاقة، توليد الكهرباء المتجددة، التكنولوجيات والضرائب المتعلقة بالبيئة، والناتج المحلي الإجمالي الحقيقي للفرد، واتفاقيات التجارة الإقليمية، وتأثير هذه العوامل على جودة البيئة من خلال قياس انبعاثات ثاني أكسيد الكربون في 17 دولة تعتمد بشكل كبير على الطاقة المتجددة وتتمتع بمؤشر تنمية بشرية مرتفع.

التصميم/المنهجية/النهج – بعد اختبار احتمالية الاعتماد المقطعي في البيانات الجدولية وتجانس المنحدر، تم إجراء اختبارات الجذر للتحقق من ثبات المتغيرات. كما تم استخدام مجموعة متنوعة من اختبارات التكامل المشترك لاختبار العلاقات طويلة المدى. بالإضافة إلى ذلك، تم تطبيق تقنيات تقدير المجمعة FMOLS/DOLS لفحص العلاقة طويلة المدى بين المتغيرات. وأخيرًا، تم استخدام اختبار السببية دوميتريسكو–هورلين لاختبار العلاقة السببية بين المتغيرات.

النتائج – أظهرت النتائج أن استخدام تقنيتي FMOLS وDOLS، يشير إلى أن كلاً من النمو الاقتصادي وكثافة الطاقة يؤثران بشكل إيجابي كبير على انبعاثات ثاني أكسيد الكربون في الدول المختارة. علاوة على ذلك، فإن توليد الكهرباء من مصادر متجددة يؤثر بشكل سلبي كبير على انبعاثات ثاني أكسيد الكربون بناءً على كلا التقنيتين المستخدمتين. في حين كشفت تقنية FMOLS عن تأثير سلبي كبير لكل من التكنولوجيات البيئية والانضمام إلى اتفاقيات التجارة الإقليمية على انبعاثات ثاني أكسيد الكربون، إلا أن تقنية DOLS لم تثبت أي تأثير لهذين المتغيرين على انبعاثات ثاني أكسيد الكربون. ولم يتم العثور على أي تأثير كبير للضرائب البيئية على انبعاثات الكربون.

الآثار العلمية/ تشير النتائج العملية إلى أهمية التحول نحو اقتصاد منخفض الكربون، وضرورة أن تتبنى الحكومات سياسات وأنظمة بيئية تشجع على الابتكار في التكنولوجيات البيئية. وتبرز الدراسة أيضًا دور اتفاقيات التجارة الإقليمية كمنصة للتعاون الدولي لتحسين جودة البيئة.

الأصالة/القيمة – تساهم هذه الدراسة في الأدبيات الموجودة من خلال التركيز على البلدان الأكثر اعتمادًا على الطاقة المتجددة. بالإضافة إلى ذلك، يتميز إدراج الأحكام في اتفاقيات التجارة الإقليمية باتباع

أسلوب مختلف، حيث تم إعطاء وزن مختلف لكل بلد بناءً على الأحكام المدرجة. كما تتناول الدراسة تأثير المتغيرات البيئية الهامة على جودة البيئة.

الكلمات المفتاحية: انبعاثات ثاني أكسيد الكربون– الانفتاح التجاري–كثافة الطاقة–التقنيات المتعلقة بالبيئة –الضرائب البيئية.

1. Introduction

Over the last four decades, the world has witnessed a dramatic technological advancement in production and industrial techniques, along with the evolution of the internet and worldwide web, the development of new communication technology, and the use of containerization mode in shipments. These tremendous advancements have been the engine of the globalization process. As globalization implies the removal of barriers and the free flow of goods, services, capital, technology, information, and people across countries, it has facilitated international trade and fostered global production. The world GDP has more than quadrupled in the period between 1990 and 2022. Based on the World Bank, global production has mounted from $22.86 trillion to $100.56 trillion during the same period. This economic growth was accompanied by an average annual increase in the world trade value of 6% during the period from 1995 to 2022, as it increased from $5.18 trillion in 1995 when the WTO was first established to $24.9 trillion in 2022. However, the increase in both world GDP and trade has come at the expense of environmental quality through the increase of greenhouse gas emissions from 33,268,121 kilotons of CO2 emissions in 1990 to 53,786,039 kilo tons in 2022. (2)

Several studies have shown that economic growth, trade, and greenhouse gas emissions are interrelated (Shahbaz et al., 2017, p.230; Leitão and Lorente, 2020,p.11; Wang and Zhang, 2021,p.365). According to the United Nations, climate change is considered the biggest threat confronting human health, as it harms human health through pollution, diseases, and lack of nutrition. Moreover, the United Nations stated that since the 1980s, each decade has been warmer than the previous one, and this is due to the increase in greenhouse gas concentrations. This climate change results in severe natural disasters such as wildfires spreading faster, more frequent destructive storms, droughts with adverse effects on crops, and thus poor nutrition.

(2) EDGAR - The Emissions Database for Global Atmospheric Research (europa.eu)

Based on the New Climate Economy (2018) [(3)], switching to a green, low-carbon economy could directly generate an economic benefit of $26 trillion through 2030 compared with that generated by business-as-usual and create over 65 million new low-carbon jobs which according to the United Nations is three times more than jobs generated from fossil fuels. Moreover, because of the enormous fall in pollution costs, doubling global renewable energy capacity by 2030 could lead to annual global savings ranging between $1.2 and $4.2 trillion. In addition, the New Climate Economy (2018) stated that taxing production emitting carbon along with removing fossil fuel subsidies could generate $2.8 trillion to be reinvested in public priorities.

As the awareness of green and clean investment and business has increased among countries, governments started to tackle different environmental issues such as climate change, pollution, environmental degradation, and resource depletion (Pegkas, 2015.p.128). Moreover, in the context of economic growth and development, governments started to call for the implementation of green environmental practices such as lowering energy intensity and usage in the production process, depending on more renewable energy sources, imposing environmental taxes, and adopting eco-technology (European Commission, 2019) [(4)].

Regarding international trade, the last 3 decades have witnessed an increase in regional trade agreements (RTAs), many of which include some provisions concerning environmental protection and sustainable development. (WTO,2016) [(5)]. Many studies have investigated the effectiveness of these provisions, but the results obtained were controversial (Abman et al., 2024.p.11).

From the above preview, it can be noticed that as global GDP has grown, so too have the environmental impacts, particularly greenhouse gas emissions that contribute to global warming. This relationship highlights the need for sustainable development strategies that address at the same time how to keep the environment clean. Governments worldwide are increasingly adopting policies aiming at mitigating climate change while still promoting economic growth. Accordingly,

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[(3)] Press Release: Bold Climate Action Could Deliver US$26 Trillion to 2030, Finds Global Commission | New Climate Economy | Commission on the Economy and Climate

[(4)] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/protecting-environment-and-oceans-green-deal_en#:~:text=Preserving%20our%20environment&text=The%20European%20Commission%20adopted%20a,Delivering%20the%20European%20Green%20Deal.

[(5)] https://www.wto.org/

the current study aims to examine the effect of these strategies on environmental quality in terms of different variables such as energy intensity (EI), renewable electricity generation (REI), environmental-related technologies (ETEC), environmental-related taxes (ETAX), real gross domestic product per capita (PRGDP), regional trade agreements (RTA) in 17 countries classified as the most reliant on renewable energy and in the meanwhile among the ones with very high human development index. The methodology used to examine the long-run relationship between the previously mentioned variables and the CO2 emissions will be through applying the pooled Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimation techniques and the Dumitrescu-Hurlin causality test. The study formulated six hypotheses to test whether each of the six variables significantly impacts the emissions of carbon gas in the long run.

Hypothesis 1: Energy intensity (EI) has a significant effect on CO_2 emissions.

Hypothesis 2: Renewable electricity generation (REI) has a significant effect on CO_2 emissions.

Hypothesis 3: Environmental-related technologies (ETEC) have a significant effect on CO_2 emissions.

Hypothesis 4: Environmental-related taxes (ETAX) have a significant effect on CO_2 emissions.

Hypothesis 5: Real gross domestic product per capita (PRGDP) has a significant effect on CO_2 emissions.

Hypothesis 6: Regional trade agreements (RTA) have a significant effect on CO_2 emissions.

The rest of the paper is arranged as follows. A review of the literature is reported in Section 2. Section 3 provides Data and Methodology. Empirical results and discussion are described in Section 4, and, finally, Policy Recommendations and Conclusion are mentioned in Section 5.

2. Literature Review

According to the World Trade Organization 2023 world trade reached $24.9 trillion in 2022, based on trade theories: absolute advantage theory and comparative advantage theory, this high level of foreign trade enhances domestic economic growth. However, it is argued that this increase and growth in production level may lead to lower quality of the environment and higher greenhouse gas emissions. In other words, as this growth takes place more renewable and non-renewable resources are being depleted resulting in the degradation of the environment.

In this section, a thorough literature review is conducted to study the relationship between economic growth, regional trade agreements RTAs with environmental provisions, and environmental quality in terms of greenhouse gas emissions. Moreover, other factors that are found to affect greenhouse gas emissions such as energy intensity, environmental-related technological innovation, and environmental taxes are studied.

2.1 Economic growth and environmental quality

According to Grossman and Krueger (1991, p.36), economic growth may have either a positive or negative effect on the environment, as according to them, economic growth affects the environment through three paths, primarily the scale effect which considers that the increase in production will lead to a higher level of environmental pollution because of the increase in the usage of all factors of production simultaneously. Secondly, the composition effect attributes the pollution of the environment to the composition of output, in other words, whether the resources are directed to producing polluting goods or not. Thirdly, the technique effect explains that economic development is accompanied by higher technological levels and cleaner production techniques, thus, economic growth will result in lower environmental pollution. Grossman and Krueger (1991,p.36) concluded that the previously mentioned three effects interact differently with each other depending on the stage of economic development, as it has an adverse effect in the early stages of development while a positive effect after the economy reaches a certain threshold and they illustrated this relationship by the environmental Kuznets curve (EKC), which they found it to be an inverted U shaped (Sucharita & Steven, 2006, p.27; Rasool et al., 2020,p.904).

Many studies have confirmed the existence of the EKC hypothesis (Ssali et al. 2019,p.11256; Bah et al. 2019,p.625; Gulistan et al. 2020,p13487; Ssekibaala et al., 2022,p.305 and Xi & Zhai, 2022,p.546), while other studies have confirmed the EKC hypothesis in developed countries only but not in developing countries (Lau et al., 2018,p.240 and Prakash & Sethi, 2022,p.137). Meanwhile, some other studies have found a positive impact of economic growth on CO_2 emissions in the environment and thus environmental pollution and degradation. (He & Richard 2010, p.1092; Munir & Ameer, 2020, p. 229 and Osadume & University, 2021, p.19.)

However, some other studies have concluded a negative relationship between economic growth and environmental pollution and degradation, stating that higher levels of GDP improve the quality of the environment. (Roy, 2023, p.157)

A unique study by Alshubiri & Elheddad, (2019, p.176) has found an N-shaped relationship between economic growth and CO2 emissions as according to them economic growth produces more CO2 emissions at the early stages of economic development than after reaching a threshold level of GDP, CO2 emissions start to decrease, afterwards, this economic growth will cause an environmental degradation.

2.2 Energy Intensity and Environmental Quality

Since carbon emissions frequently accompany the use of energy, many studies attempted to examine the effect of energy intensity on carbon emissions. Energy intensity reflects the total effectiveness of energy usage and can indicate the extent of a country's reliance on energy economically. However, these studies have not reached a consensus, as some studies concluded a positive relationship between energy intensity and carbon emissions (Shokoohi et al., 2022, p. 9; Xue et al., 2022, p.22; Chen et al., 2023, p. 9; Kouakou & Soro, 2023, p. 12; Pang et al., 2023, p. 10;) while the results of some other studies indicated that increasing energy intensity negatively impacts GHG emissions. (Wang & Zhao, 2015, p. 194; Wang et al,2021, p. 366; Danish et al., 2020, p. 1462; Nasir et al.,2021, p. 11)

2.3 Environmental Taxes and Environmental Quality

Another substantial field of research that is currently receiving increased attention from academic researchers, politicians, and practitioners is the issue of environmental taxes and their consequences on the environment. The premise behind the application of an environmental tax is to internalize the negative externalities initially proposed in the ground-breaking paper on environmental taxes by Pigou, 2017, p. 618. According to the 'double-dividend hypothesis,' rising taxes on polluting activities might bring two types of rewards. The first is an improvement in the environment in the form of reducing pollution, while the second is an increase in economic efficiency due to using environmental tax revenues to lower other taxes that skew labor supply and saving decisions, such as income taxes.

Concerning the impact of environmental taxes on the environment, findings indicated that they help reduce carbon emissions (Bashir et al., 2021, p.

1275; Ghazouani, et al., 2021, p.22765; Dogan et al., 2022, p. 653; Farooq et al.,2023, p.6247).

However, in the context of the effect of environmental taxes on economic growth and the economy, there was a debate in academic research over their effect. Some studies indicated that they could have a detrimental impact on economic growth. (Siriwardana et al. 2011,p .1461; Tu et al., 2022, p. 13).

On the other hand, other studies showed that environmental taxation policies can increase economic growth through the usage of the generated tax revenues and cutting off other taxes such as labor tax. (Carbone et al., 2013, p. 26; Parry et al., 2015, p. 88)

Another study by Hassan et al., (2019) p.81, stated that the nature of the link between environmentally related taxes and economic growth can be influenced by the initial level of a nation's economic growth. They indicated that environmental tax in nations with low GDP per capita will impair economic growth while this condition may be reversed in nations with a high level of GDP per capita where environmental tax will negatively affect the economy.

2.4 Renewable Energy Sources and Environmental Quality

To reduce greenhouse gas emissions, shifting from fossil fuels to clean and renewable sources has become imperative worldwide. Therefore, researchers are becoming interested in studying the influence of generating energy from renewable sources on GHG emissions and most studies found a negative link between the two. (Tabrizian 2019, p. 543; Saidi & Omri, 2020, p. 8; Chen et al., 2023, p .9, Voumik et al., 2023, p.11).

2.5 Technological Innovation and Environmental Quality

Technological innovation is a crucial topic styling how environmentally friendly techniques can affect the quality of the environment. Many studies have explored the link between technological innovation and environmental quality in several dimensions. However, the results obtained from these studies were variant. On one side, some of them concluded that applying environmental-related technologies increases environmental quality with a negative impact on GHG emissions. (Adebayo et al., 2023, p. 8; Ahmad et al.,2023, p.10; Alola et al., 2023, p .7; Shabir et al., 2023, p. 9; Wei et al., 2023, p .180)

On the other side, other researchers have shown that technological innovation has a negative influence on environmental quality (Khattak et al., 2020, p. 13876; Dauda et al., 2021, p. 8; Usman & Hammar, 2021, p .15530)

2.6 Trade Agreements and Environmental Quality

Trade agreements could contribute to improving environmental quality and realizing climate-mitigation goals by including environmental provisions in these agreements. (Balogh & Mizik, 2023, p. 8). Several studies have examined the effect of these agreements on greenhouse gas emissions, but there was no general agreement on their effectiveness. Some studies have proved that environmental provisions in RTAs have a positive effect on the environment (Abman et al.,2024, p. 65). While other studies concluded that the free-trade agreements had unclear effects on emissions, as the countries of the World Trade Organization succeeded in lowering air pollution, however, countries that signed the regional trade agreements failed to mitigate carbon emissions. (Balogh & Mizik, 2023, p. 8).

Despite the growing body of research on the environmental impacts of renewable energy and economic growth, several gaps remain in understanding the overall effects of various strategies on environmental quality in high-income and renewable energy-using countries. Prior studies have often focused on either the macroeconomic impacts of renewable energy or its environmental outcomes in isolation. Few studies have combined multiple variables such as energy intensity (EI), renewable electricity generation (REI), environmental-related technologies (ETEC), environmental-related taxes (ETAX), real gross domestic product per capita (PRGDP), and regional trade agreements (RTA) to examine their combined long-term effects on CO2 emissions in countries with both high renewable energy reliance and high human development indices. Furthermore, methodological constraints persist in the existing literature, since simpler econometric models may fail to account for the complexities of integrated economic-environmental systems. The use of pooled Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) in this study provides a more refined approach to examining long-term relationships and causality, with the Dumitrescu-Hurlin causality test providing robust insights into the variables' directional impacts.

From the previous literature review, it can be concluded that this study adds to the current literature by concentrating on the nations that heavily rely on renewable energy. Furthermore, the incorporation of environmental provisions in RTAs used a different approach that was not followed by previous studies, by assigning fair weights to each nation depending on the provisions included in the agreements. Along with investigating the impact of key environmental factors such as environmental-related taxes (ETAX), on environmental quality. This research seeks to address these gaps by providing a comprehensive analysis that can assist policymakers in understanding the synergistic effects of economic and environmental strategies in high-income, renewable-dependent countries, allowing for the development of more effective policies to improve environmental outcomes while maintaining economic growth.

3. Data and Methodology

3.1 Data

The panel data employed consists of 17 countries that are the most reliant on renewable energy and in the meanwhile are among the ones with very high human development index ranging from the lowest, Uruguay and Norway (0.809), to the highest, Iceland (0.959) in 2021. Based on data availability, the study covers the period between 2003 and 2020. The dependent variable, carbon emissions, is used as a proxy for environmental quality, measured in metric tons per capita and extracted from the World Bank [(6)]. The selected independent variables along with their definitions and sources are illustrated in Table 1. RTA is derived from the Regional Trade Agreements Database WTO OMC [(7)]. This database includes all RTAs notified to the World Trade Organization (WTO) until 2024. RTAs with environmental provisions are those that, according to the World Trade Organization (WTO), cover the subject of "environmental provisions" (Baghdadi, L., et al.,2013, p .381). The RTA variable is a dummy variable, that takes values ranging from above 0 to 1 when country i has RTA with environmental provisions in force in year t, zero otherwise. The variable is generated as a weighted average as follows.

$$RTA_{i,t} = \frac{number\ of\ members\ in\ the\ agreements\ with\ enviroenemtal\ provisons\ in\ specific\ year}{number\ of\ all\ members\ in\ all\ the\ signed\ agreements\ in\ specific\ year}$$

Except for the regional trade agreements, all data are taken in logarithmic form to improve the normality of distribution and prevent scaling issues

(6) https://databank.worldbank.org/reports.aspx?source=2&country=UMC#selectedDimension_WDI_Series
(7) https://rtais.wto.org/UI/PublicMaintainRTAHome.aspx

Table 1: Description of Variables

Symbol	Variables	Definition	Source
CO2	Carbon Dioxide Emissions ((metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	WDI
EI	Energy intensity level of primary energy (MJ/$2017 PPP GDP)	The energy intensity level of primary energy is the ratio between energy supply and gross domestic product measured at purchasing power parity. Energy intensity is an indication of how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of output.	WDI
REG	Renewable electricity generation	Renewable electricity, as a percentage of total electricity generation.	OECD
PRGDP	Per capita gross domestic product	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources. Data are in constant 2015 U.S. dollars.	WDI
ETEC	Environmental Related Technologies	Development of environmental-related technologies as a percentage of all technologies	OECD
ETAX	Environmental related taxes	Environmentally related taxes as a percentage of tax revenue	OECD
RTA	Regional Trade agreements	RTAs with environmental provisions are those that, according to the World Trade Organization (WTO), cover the subject of "environmental provisions	WTO [8]

Source: Authors' compilation; (WDI,2024) and (OECD,2023).

[8] https://rtais.wto.org/UI/PublicMaintainRTAHome.aspx

Table 2: Descriptive statistics

	Mean	St. Deviation	Min.	Max	Observations
CO2	8.046132	4.440286	1.355235	19.59762	306
PRGDP	40263.28	15804.31	9227.912	76712.29	306
EI	4.384248	2.505154	1.96	15.78	306
ETAX	6.013449	1.644132	2.12	10.95	306
ETEC	11.82826	4.223776	.0001	27.12	306
REG	48.14533	30.31459	2.68	99.99	306
RTA	.6010015	.4515146	0	1	306

Note: Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024).

Table 2 describes the variables. CO2 (8.046), PRGDP (40263), EI (4.384), REG (48.145), ETAX (6.013), ETEC (11.828), and RTA (0.601) are the averages based on available data. The PRGDP has the highest standard deviation, whereas the RTA has the lowest.

3.2 Methodology and Estimation Procedures

Based on previous studies, such as (Dogan, et al., 2017, p. 1708; Dogan, et al., 2022, p. 650), this study specified the form of function as illustrated in equation. (1), which will be practically examined:

$$CO_2 = \beta_0 + \beta_1 PRGDP_{i,t} + \beta_2 EI_{i,t} + \beta_3 ETAX_{i,t} + \beta_4 ETEC_{i,t} + \beta_5 REG_{i,t} + \beta_6 RTA_{i,t} + \varepsilon_{i,t} \quad \ldots. (1)$$

Where i stands for specific units country and t for specific time year, CO2 is the per capita carbon emissions, PRGDP is the real gross domestic product per capita, EI is the energy intensity, ETAX is the environmental-related taxes, ETEC is the environmental-related technologies, REG is the renewable electricity generation and the RTA is the regional trade agreements with environmental provisions. The error term $\varepsilon_{i,t}$ is assumed to be identically distributed and the β's are the parameters to be estimated. Finally, β_1 and β_2 signs are the only ones expected to be positive whereas all else are expected to be negative.

3.2.1 Cross-Section Dependence Problem and Slope Homogeneity Test

It's well known that cross-sectional dependence in the panel data model may emerge due to the presence of common shocks and unobserved components that become part of the error term. The following panel model will be employed to investigate cross-sectional dependence in panel data.

$$Y_{it} = \beta_i X_{it} + u_{it} \quad i = 1,2, \ldots\ldots, N, t = 1,2, \ldots\ldots, T \qquad (2)$$

Here, i represents the cross-section dimension while t stands for the time series dimension, Y_{it} is the dependent variable and X_{it} constitute matrix of regressors with the first column containing the unit vector for the constant, while the second column may show a trend. The null hypothesis is zero cross-equation error correlations.

Breusch and Pagan (1980) p.248 proposed the following LM statistic to test the null hypothesis of zero cross-equation error correlations:

$$LM = T\left[\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho_{ij}}^{2}\right] \to N(0,1) \qquad (3)$$

$\widehat{\rho_{ij}}^{2}$ is the sample estimate of the pairwise correlation of emerging residuals.

Furthermore, it is necessary to investigate slope homogeneity, and the test presented by Pesaran and Yagamata (2008) p. 52 was applied, where the test statistic is presented in Eqn. (4):

$$\hat{\Delta} = \frac{1}{\sqrt{N}}\left(\frac{\sum_{i=1}^{N}\bar{\bar{d}}_i - k_2}{\sqrt{2k_2}}\right) \qquad (4)$$

Eq. (4) defines $\bar{\bar{d}}_i$as the weighted difference between the cross-sectional unit-specific and the pooled estimate. K is the number of regressors.

For normally distributed errors, the corrected mean-variance bias (Δ) can be represented as follows in Eqn. (5)

$$\widehat{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\sum_{i=1}^{N}\bar{\bar{d}}_i - k_2}{\sqrt{Var(\tilde{z}_{i,T_i})}}\right) \qquad (5)$$

Where

$$Var(\tilde{z}_{i,T_i}) = \frac{2k_2 \ (T_i - K - 1)}{T_i - K_1 + 1}$$

3.2.2 Panel Unit Root Tests

First-generation panel unit root tests are used to investigate the variables stationarity to detect any spurious relationships with the null hypotheses of a series having a unit root. Each variable is assumed using intercept and constant. The equation utilized for the series is provided below, eqn. (6):

$$\Delta Y_{i,t} = \alpha + \delta_i Y_{i,t-1} + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where i represents the cross-section dimension and t stands for the time series dimension, Y_{it} is the variable to be tested and δ has the null hypothesis of non-stationarity. The tests utilized are Fisher-type Choi (2001) p. 253 and Breitung (2000) p .16. Breitung (2000) p .18, assumes that all panels have the same autoregressive parameter ($\delta_i = \delta$ for all i) whereas Choi (2001) p.250 considers the autoregressive parameter to be panel specific. Both tests are suitable for macro panels and Choi is relevant when the number of panels is finite.

The second-generation tests relax the assumption of cross-sectional independence. Equation (7) is known as the cross-sectionally augmented Dickey-Fuller (CADF) test and has the following form:

$$\Delta y_{it} = a_i + \rho^*{}_i\, y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + \varepsilon_{i,t} \qquad (7)$$

Where $\bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} y_{i,t}$, represents the average at time t of all n observations,$\bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} \Delta y_{i,t}$ *and* the regression error is $\varepsilon_{i,t}$ .in the absence of serial correlation, a basic CADF regression is run for each panel unit. The cross-sectional averages, $\bar{y}_{t-1}$ and $\Delta\bar{y}_t$, are included in (7) as a substitute for the unobserved common factor when (N) is big enough.

After running the CADF regression for each unit in the panel, Pesaran averages the t-statistics on the lagged value (also known as $CADFi$) to get the CIPS statistic. Using the individual CADF data, a modified version of the IPS T-bar test termed CIPS for Cross-sectionally Augmented (IPS) is developed, which accounts for both cross-section dependency and residual serial correlation. The CIPS test statistic is as follows:

$$\text{CIPS} = \frac{1}{N}\sum_{i=1}^{N} CADF_i \qquad (8)$$

To obtain the cross-sectional augmented dickey fuller statistic ($CADF_i$), uses the t-ratio of the OLS estimate of $\rho^*{}_i$ in the CADF regression (7). The t-test based on this model shows no cross-sectional dependency. These tests are applicable in both circumstances where $N > T$ and $T > N$.

3.2.3 Panel -Cointegration tests

To test long-term relationships, a variety of first-generation panel cointegration tests are utilized, including the Kao (1999) p.7 test, the Pedroni (1999 p 665 2004 p.605), and Westerlund (2005) p.306. The three tests are based on the following panel data model assuming that all of the variables are non-stationary at level, i.e.: I (1):

$$y_{it} = \beta_i \acute{X}_{it} + \gamma_i Z'_{it} + e_{it} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where $i = 1, \ldots\ldots, N$ refers to the panel units and $t = 1, \ldots, T$ refers to time. The cointegrating vector (β_i) may vary through the panels. γ_i is a vector of

z_{it} coefficients that can include panel-specific means and/or linear trends. ei is the error term. The Kao test assumes a common-integrating vector, but the Pedroni and Westerlund tests assume panel-specific cointegrating parameters.

3.2.4 Panel FMOLS and DOLS

Upon confirming cointegration, we use the pooled FMOLS and DOLS estimation techniques to confirm the long-term link between postulated variables. Both estimation techniques have various benefits; allow for serial correlation, endogeneity, and cross-sectional heterogeneity. However, based on Kao and Chiang (2000) p.185, the pooled DOLS estimator performs better in both cases of homogenous and heterogenous panel data models.

Based on the standard FMOLS of Phillips and Hansen (1990) p.5, Phillips and Moon (1999) p.1080 outlined the pooled FMOLS estimator with the modified dependent variable, and serial correlation correction terms as in eqnuations. (10) and (11) given the estimated average long-run covariances, $\widehat{\Phi}$ and $\widehat{\Omega}$ (Özcan & Öztürk, (2019) p.66):

$$\tilde{y}_{it}^{+} = \tilde{y}_{it} - \widehat{\omega}_{12}\,\widehat{\Omega}_{22}^{-1}\widehat{\upsilon}_{2} \qquad (10)$$

And

$$\hat{\lambda}_{12}^{+} = \hat{\lambda}_{12} - \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\widehat{\Phi}_{22} \qquad (11)$$

The pooled FMOLS estimator is then given by:

$$\hat{\beta}_{FP} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{X}_{it}X_{it}\right)^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\left(\tilde{X}_{it}y_{it}^{+} - \hat{\lambda}_{12}^{+}{}'\right) \qquad (12)$$

It is important to note that the pooled estimator merely adds cross-sections individually in the numerator and denominator.

The pooled DOLS estimator, described by Kao and Chiang (2000) p.185, uses ordinary least squares for estimating an augmented cointegrating regression equation as follows. (13):

$$y_{i,t} = \beta X_{i,t} + \sum_{j=-q_i}^{r_i}\Delta X_{i,t+j\delta_i} - \tilde{\upsilon}_{1it} \ldots\ldots\ldots (13)$$

Taking into consideration that $y_{i,t}$ and $X_{i,t}$ are the data after removing the individual deterministic trends.δ_i represents the short-run dynamic coefficients and are allowed to be cross-section coefficients. Then, by assuming that Z_{it} are the regressors formed through interacting the $\Delta X_{i,t+j}$ with cross-section dummy variables and let $\acute{W}_{it} = (X_{\acute{i}t}Z_{\acute{i}t})'$, then the pooled DOLS estimator can be written as follows eqn. (14):

$$\begin{bmatrix}\hat{\beta}_{DP}\\ \hat{\gamma}_{DP}\end{bmatrix} = \frac{1}{\left(\sum_{i=1}^{N}\sum_{t=1}^{T}W_{it}W_{\acute{i}t}\right)}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}W_{it}y_{\acute{i}t}\right) \qquad (14)$$

3.2.5 Dumitrescu-Hurlin Panel Non-Causality Test (2012)

After establishing the long-run association among the examined variables, it's of interest to identify the causal relationship between the above-mentioned variables. Understanding the causative direction enables policymakers to implement appropriate policies for long-term relations between preserving the environment and at the same time not harming economic growth. The Dumitrescu-Hurlin causality test, developed by Dumitrescu and Hurlin (2012) p.1451 has been employed.

This causality technique applies to both $T > N$ and $T < N$, it also applies to unbalanced and heterogeneous panels. Dumitrescu and Hurlin (2012) p.1451 investigate the following linear heterogeneous model:

$$y_{it} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik}\, y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik}\, x_{i,t-k} + e_{i,t} \quad (15)$$

$$With\ i = 1, \ldots, N\ and\ t = 1, \ldots, T$$

where y_{it} and x_{it} are the variables to be investigated for the unit i in period t. The order of lag K is the same across all units, and the panel should be balanced. The null hypothesis suggests that there is no Granger causation across the investigated cross-sectional units, whereas the alternative hypothesis posits at least one causal link.

4. Results and Discussion

4.1 Preliminary analysis

This section shows the results of examining cross-sectional independence, panel unit root tests, and panel cointegration. Table 3 displays the cross-sectional dependency findings, demonstrating that the LM test of Breusch and Pagan's (1980) statistics cannot reject the null hypothesis of no correlation across panel units for all t. The LM test of Breusch and Pagan (1980), is more appropriate for the panel investigated since it needs $T > N$ and accordingly concludes that the panel units do not exhibit cross-sectional correlation.

Table 3: Cross-Sectional Independence

Test	Statistic
LM	143

Note:(1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024) (2). *** , * *, and * indicate the level of significance at 1%, 5%, and 10%, respectively.

The slope homogeneity results are shown in Table 4 indicating that the slope homogeneity hypothesis is rejected at the 1% level of significance and slope heterogeneity across the panel units is verified.

Table 4: Slope Homogeneity Test

Test	Delta
Δ	8.801***
Δ adj	11.259***

Note: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024) (2).**** , **** , * *, and * indicate the level of significance at 1%, 5%, and 10%, respectively.

After concluding the absence of cross-sectional correlation across the panel units, the researchers proceeded to examine the variables' stationary patterns. Although first-generation testing should be exact in this situation, the researchers also employed second-generation tests to verify its accuracy. First-generation tests employed the fisher type Choi (2001) and Breitung (2000) as shown in Table 5. Both tests yield nearly identical results, namely that all variables are stationary at the first difference; however, only the RTA is stationary at both the level and the first difference in both tests, and the environmental-related technologies variable is stationary at both the level and the first difference, according to Choi (2001). For robust analysis, the second-generation panel unit root test proposed by Pesaran (2004) was used as shown in Table 6. Results show that all variables are integrated at I (1) except for the RTA and taxes are integrated at I(0) and I(1). As a result, it can be inferred that all the variables have unit roots in the same order and meet the criteria for testing for the presence of a long-term relationship.

Table 5: First Generation Panel Unit Root Tests

Variable	Choi (2001)		Breitung (2000)	
	Level	Δ	Level(λ)	Δ
LPRGDP	47.0361	58.3655***	2.4027	-2.2895**
LCO2	7.7011	121.0803***	6.3718	-6.6041***
LREG	15.9328	201.3730***	4.4423	-7.5448***
RTA	128.1129***	355.9019***	-9.1724***	-11.8729***
LETAXES	21.7596	78.3236***	2.6148	-8.0092***
LETECH	63.8768***	87.8775***	-0.8407	-7.2984***
LEI	24.4031	205.4164***	6.2571	-9.1970***

Note: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024). (2) ***, * *, and * indicates the level of significance at 1%, 5%, and 10%, respectively

Table 6: Second Generation Panel Unit Root Tests (CIPS)

	Level	Δ
LPRGDP	-1.161	-1.998**
LCO2	-1.922	-3.730**
LREG	-3.015**	-4.187**
RTA	-4.967**	-6.049**
LETAXES	-1.630	-3.345**
LETECH	-1.536	- 3.568**

Note: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024). (2): ***, * *, and * indicates the level of significance at 1%, 5%, and 10%, respectively

As a next step in any econometric analysis, cointegration should be examined to be sure of the presence of a long-run relationship between the variables under examination. First-generation cointegration tests are applied after removing cross-sectional means to improve accuracy. Pedroni's cointegration test (2004) was selected owing to its strong assumption that it allows the existence of cross-sectional dependency, if any, among the panel units (Dogan et al., 2022, p.651).

Table 7 displays cointegration findings for the Kao test (1999); Two of the three tests, ADF t and Modified DF t, are statistically significant at 1% and 5%, respectively, rejecting the null of no-cointegration. Similarly, with the Pedroni test (1999, 2004), two of the tests, Modified PPt and ADF t, reject the null hypothesis at 1% and 5%, respectively, showing evidence of cointegration. Finally, at the 1% significance level, Westerlund's (2005) VR statistic verifies cointegration. As a result, cointegration is established for all three tests between the dependent variable and the other independent variables employed in this study.

Table 7: Results of First-generation Panel Cointegration Tests after Demean

Cointegration Test-Intercept	Kao Test			Pedroni Test H1: Panel-Specific AR coefficients			Westerlund Test
Test Statistic	ADF t	DF t	Modified DF t	Modified PP t	Panel PP	ADF t	VR
CO2	3.1375***	1.2756	1.4426**	5.1651 ***	-0.9327	- 1.8190**	2.3331***

Source: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024). (2): ***, * *, and * indicates the level of significance at 1%, 5%, and 10%, respectively. (3) PP = Phillips-Perron; ADF = Augmented Dickey-Fuller, VR=Variance Ratio. (4) Automatic lag selection, with 3 lags selected based on the AIC criterion for both. (5) Note: ***, * *, and * indicate the level of significance at 1%, 5%, and 10%, respectively

4.2 Long-Run Relationships and Analysis

After conducting the necessary investigations on the time series, the presence of heterogeneity, stationarity at the first difference, and long-term correlations between variables were confirmed. Accordingly, the long-term influences of environmental technologies, environmental taxation, energy intensity, renewable electricity generation, and economic growth on CO2 emissions are to be analyzed, using the FMOLS and DOSL methodologies, which are the best fit for the variables under discussion. Table 8 displays the results of the two estimating procedures.

Table 8: FMOLS and DOLS results: Dependent variable LCO2

Variables	FMOLS		DOLS	
	Coefficient	Prob	Coefficient	Prob.
LPRGDP	0.385500***	0.0048	0.365282***	0.0029
LEI	0.406713***	0.0009	0.385989***	0.0007
LETEC	-0.023941*	0.0736	-0.014672	0.2701
LETAX	0.066962	0.1807	0.068686	0.1668
LREG	-0.225968***	0.0000	-0.246207***	0.0000
RTA	-0.030337*	0.0937	-0.019892	0.2668
R^2	0.974619	-	0.974059	-
Adj R^2	0.972487	-	0.971642	-
S.E.of regression	0.090192	-	0.092174	-
Long-run Variance	0.014635	-	0.014794	-

Note: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024). (2) ***, * *, and * indicate the level of significance at 1%, 5%, and 10%, respectively.

According to the results of both techniques, economic growth is significantly positive and affects the CO2 emissions in the selected countries. A 1% increase in economic growth accelerates CO2 emissions by 0.38% and 0.36% for the FMOLS and DOLS respectively. These findings reveal that increased economic activity in these countries still leads to higher emissions, even though they are among the top users of renewable energy and very highly human-developed countries as mentioned earlier. This means that accelerated economic growth has a detrimental environmental impact on these countries, maybe as a result of rapid globalization and key economic trends, such as industries and industrial activities that rely significantly on fossil fuel energy. Abbasi et al., (2023) p.9 found that, in Iceland, for instance, long-term projections showed decreased Iceland's environmental quality owing to increased carbon intensity and economic expansion, suggesting that growing carbon intensity and economic expansion have negative environmental consequences. Likewise, Onofrei et al., (2022, pp.8-9), for 27 EU member states during the period from 2000 to 2017, found that a 1% change in the GDP leads to a 0.072% change in CO2 emissions in the same direction stressing the need of developing environmental regulations that can cut emissions during periods of economic expansion.

In terms of the influence of energy intensity on emissions in the selected countries, both FMOLS and DOLS show that the former has a significant positive effect on emissions, with a 1% increase in energy intensity resulting in a 0.40% and 0.38% increase in per capita emissions levels, respectively. According to the European Environment Agency (2023) [(9)], although climate change mitigation, in these countries, and increasing energy regulations have been successful in reducing carbon-intensive energy supply over time, high oil prices and nuclear shutdowns in 2022 led to increased consumption of coal in the power mix. According to the Climate Change Performance Index (2023) [(10)], per capita energy use is relatively high in most EU countries and considerably higher than in most developing countries. Furthermore, despite the gradual separation of GHG emissions from GDP, still, global GHG emissions are rising as energy consumption rises, and the carbon intensity of the energy supply does not decrease. Danish et al., (2020.p.6) for the United States during the period of (1985-2017), found that higher energy intensity leads to increasing pollution levels as well. Likewise, Bekun et al., (2021,p.51144) for 27 EU countries found that a 1% increase in the intensity of energy utilization will result in a rise in pollution of more than 25.4% and 23.4% respectively based on MG and AMG analysis. On the other hand, Chovancová et al., (2024,P.948), found that energy intensity had a negative influence on CO2 emissions for EU countries during the period from 1992 to 2019 justifying this conclusion by the possibility that specific sectors or businesses may have undertaken energy-saving measures or adopted greener technology, resulting in a decoupling of energy intensity and CO2 emissions.

Taxation mechanisms provide significant opportunities for preserving the environment and the ecosystem to reduce environmental degradation, preserve biodiversity, reduce GHG emissions, and combat global warming. This can be done through introducing appropriate signals into the market, to internalize the externalities, while at the same time boosting the effectiveness of environmental rules. The selected countries are among the top countries using the highest carbon

[(9)] https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1
[(10)] https://ccpi.org/which-european-countries-are-the-worst-climate-polluters-and-why/

tax rate. For instance, Sweden in March 2023 imposed a tax rate per ton of CO2 emissions of $125.56 [11]. However, the examination of the effect of environmental taxes on carbon emissions revealed that the former had no significant impact on the latter. Several reasons could be behind such a conclusion; for example, low tax rates might not create an incentive for polluters to change their behavior. According to the Tax Foundation [12], Spain and the UK have relatively low carbon taxes per metric ton of $16.31 and $22.28 respectively. Also, environmental taxes may have limited coverage, meaning they do not apply to all sectors or activities that contribute to carbon emissions. For instance, in Denmark, the influence of carbon taxes on reducing CO2 emissions is debated (Nar, 2021, p.123). In Holland, governments apply carbon tax exemptions for energy-heavy sectors while Sweden allows for a tax discount by giving subsidies for some industries as well which leads to reducing the benefits from tax implementation below the expected level (WB, 2015). Additionally, even if environmental taxes are designed and implemented properly, their effectiveness can be compromised if there is a lack of enforcement or compliance or even resistance from the public. Ewald et al., (2022,p.16) have shown for Sweden that, while carbon pricing is an effective tool for combating environmental deterioration, it has been employed substantially less than predicted due to public opposition based on the perceived fairness of taxation.

Generally, some literature studies doubt the effectiveness of carbon-energy taxes in reducing greenhouse gas emissions, and their practical implementation remains a topic of debate. Recent research by Murray and Rivers (2015,p.17) suggests that the carbon price implemented in British Columbia had little impact on greenhouse gas emissions. Nar, M.,(2021, p.6) has illustrated the negative insignificant effect of carbon taxes on carbon emissions for a group of OECD countries from 1990-2018. On the contrary, Komanoff and Gordon (2015, p.11) found that Between 2008 and 2013, British Columbia saw a 12.9% drop in per capita emissions, which was significantly larger than the 3.7% reduction observed in the rest of Canada during the same period. This suggests that the introduction of the carbon tax in BC led to a noticeable reduction in emissions, making them considerably lower than what they would have been without this policy. The carbon tax appears to have had a strong impact on reducing emissions compared to the rest of the country.

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(11) https://taxfoundation.org/data/all/eu/carbon-taxes-in-europe-2023/
(12) ibid

Moving on to the renewable electricity generation effect on carbon emissions, according to the findings of Table 8, both FMOLS and DOLS reveal that renewable electricity generation has a negative significant influence on carbon emissions, with a 1% increase in REG resulting in 0.22% and 0.24% reductions in CO2 emissions respectively. Such an outcome is favorable because renewable electricity generation is vastly growing in EU countries, as the EU has committed to being carbon neutral by 2050 (Kartal et al., 2024, p.1). Similar results were achieved by Kartal et al., (2024, p.12) for the top 10 CO2 emitting countries from 2019 to 2023 and they advocated the use of hydroelectric power generation in Germany, solar power generation in Italy and Austria, and wind power generation in all other nations as the most promising options for developing a carbon-neutral economy. Renewable energy sources such as solar, wind, hydroelectric, and geothermal power produce electricity without emitting CO2 during the generation process. By reducing reliance on fossil fuels and harnessing clean, sustainable sources of energy, renewable electricity generation plays a crucial role in mitigating climate change and reducing CO2 emissions. It forms a key pillar of transitioning to a low-carbon and sustainable energy system. Several studies have confirmed the negative relationship between renewable electricity generation and CO2 emissions (Wang et al., 2021, p.365; Petruška et al., 2022, p.12; Erdoğan et al., 2024, p.80). On the contrary, Piłatowska and Geise (2021, p.12) found that in France and Spain, clean energy consumption didn't succeed in separating economic growth from carbon emissions. The researchers found that despite increased renewable energy and mitigation strategies, CO2 emissions have not significantly dropped in these countries

Environmental innovation technologies are a critical factor that influences environmental quality. Environmental innovation aims to improve energy efficiency in a variety of industries, including transportation, manufacturing, and buildings. By inventing and adopting energy-efficient technology and practices, less energy is wasted, lowering the quantity of CO2 released per unit of production. Nevertheless, environmental innovation can promote the adoption of a circular economy, in which resources are used more effectively, waste is reduced, and products are recycled or repurposed. By lowering the demand for new manufacturing and minimizing waste output, several sectors' carbon footprints may be drastically decreased. Table 8 shows how environmental technology improvement has a significant negative influence on CO2 emissions, as calculated using the FMOLS approach. Similarly, but not significantly, the

DOLS indicates a negative influence of environmental innovation on pollution. This highlights how environmental technological innovation helps these countries cut carbon emissions and enhance the environment. As environmental technology progresses, these economies may expect to minimize harmful emissions. These results are consistent with Shabir, M., et al. (2023, p.8) for the APEC countries. Also, Mongo et al., (2021, p.6) established the same negative significant effect of environmental innovation on CO2 emissions in the long run but not in the short run for 15 European nations. Similarly, Kirikkaleli et al., (2023,p.50119), for Denmark found an increase in patents on environmental innovations contributes to lower CO2 emissions, indicating that green technology innovation has a direct and considerable influence on CO2 emissions.

Concerning joining RTAs that include environmental requirements and their impact on CO2 emissions, the research key finding is that the former statistically reduces the levels of CO2. Table 8 findings reveal that both the FMOLS and DOLS techniques show a negative relationship between joining RTAs and reducing CO2 emissions, however, this result is only significant for the FMOLS approach. A one percent increase in joining RTAs, with environmental provisions, reduces emissions by only 0.03%. Governments of the examined countries appear to be adhering to climate-related obligations in RTAs, possibly contributing to global warming mitigation efforts in the long- run. Sorgho et al. (2020, p.22) studied the effect of signing preferential trade agreements with climate-related provisions on pollutant emissions for 165 nations from 1995 to 2012 and discovered a significant negative effect, with signing an extra agreement lowering a country's per-capita CO2 emissions by 1.8% (36.9 metric tons). Environmental provisions in RTAs can serve as a platform for international collaboration and coordination in addressing these transboundary concerns. This may include steps to avoid and decrease pollution, promote sustainable resource management, and combat the illegal trafficking of endangered species. Environmental provisions of RTAs can help to promote green trade and investment, and develop and spread clean technology, renewable energy, and sustainable products by lowering obstacles to trade and creating incentives for the exchange of environmentally friendly goods and services. This can assist drive the transition to a low-carbon and resource-efficient economy.

The EU, for example, has included environmental safeguards in some of its regional trade agreements. For example, the EU-Canada Comprehensive Economic and Trade Agreement (CETA) contains a chapter on trade and sustainable development that covers environmental concerns such as climate change, biodiversity protection, and sustainable natural resource management. Also, the North American Free Trade Agreement (NAFTA) and the United States-Mexico-Canada Agreement (USMCA): The original NAFTA, which has been superseded by the USMCA, had an environmental accord known as the North American Agreement on Environmental Cooperation (NAAEC). The NAAEC formed a cooperative framework and tackled issues such as pollution management, biodiversity protection, and environmental law enforcement. likewise, the Pacific Agreement on Closer Economic Relations (PACER) Plus is a trade agreement with numerous Pacific Island countries, Australia, and New Zealand. The agreement contains a chapter on the environment that encourages sustainable development, biodiversity protection, and environmental cooperation.

These are only a few examples; many additional regional trade agreements have environmental measures. The particular clauses and scope may differ across agreements, but the overarching goal is to include environmental issues in trade policy and encourage sustainable development.

4.3 Dumitrescu and Hurlin (2012)

The above investigation in section (4.2), does not show the direction of causation between the variables. In this part, we use the panel causality test developed by Dumitrescu and Hurlin (2012) to examine the causal relationship between CO2 and regressors in the studied nations from 2003 to 2020. The results of the causality test are shown in Table 9. The outcomes show evidence for a bidirectional causal relationship between CO2 emissions and economic growth highlighting the unfortunate reality of the deteriorating environmental impact of increased growth in these nations. Regarding the causative link between renewable power generation and emissions, bidirectional causation has been demonstrated, emphasizing the relevance of renewable electricity in negatively reducing emission levels in these countries. Even though no significant relationship was found between environmental taxes and CO2 emissions using both the FMOLS and DOLS models, bidirectional causation was established between the two. This causal link may allude to the notion that increased environmental taxes can be effective tools for lowering CO2 emissions in the long run. Furthermore, a bidirectional causal relationship has been identified between energy intensity and pollution levels, implying that policies aimed at reducing energy consumption, such as improving energy efficiency or investigating new energy sources, should be considered.

On the other hand, a negative unidirectional causal link has been identified between CO2 emissions and technical developments that contribute to environmental enhancement. This means that when pollution levels rise, there are more incentives to utilize environmentally friendly technology. Green technology may reduce energy consumption and conserve energy, improve the economy, and lower emissions. Accordingly, policymakers should prioritize innovative research to ensure economic prosperity and environmental sustainability.

Table 9:D-H Causality

Causality Direction	Zbar-Stat	Decision
LPRGDP ≠ LCO2	11.3796***	Bidirectional causality
LCO2 ≠ LPRGDP	2.5656**	
LREG ≠ LCO2	3.9784***	Bidirectional causality
LCO2 ≠ LREG	5.6203***	
LETAX ≠ LCO2	3.4868***	Bidirectional causality
LCO2 ≠ LETAX	2.3738**	
LETEC ≠ LCO2	-0.9974	Unidirectional causality
LCO2 ≠ LETEC	8.8063***	
LEI ≠ LCO2	5.1351***	Bidirectional causality
LCO2 ≠ LEI	4.8255***	
LRTA≠ LCO2	2.5651**	Unidirectional causality
LCO2 ≠ LRTA	-0.345	

Note: (1) Authors' compilation, using data available in Table 1 obtained from (OECD,2023) and (WDI,2024). (2) ***, * *, and * indicate the level of significance at 1%, 5%, and 10%, respectively. ≠ means doesn't cause.

Finally, joining RTA improves environmental quality by lowering emission levels, with a one-way causal link between RTA and CO2 emissions. Linking environmental problems to regional trade agreements can help protect the environment and combat climate change. This suggests that RTAs with environmental provisions can be important policy tools in the battle against climate change. However, they should be viewed with caution since they imply some coercion in enforcing these terms and duties with trading partners.

For future research, a stronger focus should be given to comparing a legalized versus a managerial approach in PTA's climate provisions. Due to the limited scope, the study at hand could only shed light on the enforcement side of the legalized approach. However, only when both are compared and analyzed, can broadly applicable policy implications be given. Reciprocal policy learning seems like an approach that would particularly resolve many of the governance issues related to coercion and should be researched further. Finally, to address the reverse causality concerns, future research should also focus on the effects of PTAs, depending on whether they are between two strong, two weak, or a strong and a weak country. In broader terms, insights are still widely missing in understanding why environmental provisions are included in some PTAs and not in others. Also, attention should be paid to taxes and to more research on their impact on various industries and how it would affect the economy at the micro level.

5. Conclusion, Recommendations, and Future Research

5.1 Conclusion

Results analysis show that although the studied countries are among the top renewable energy users, greater economic activities in these nations still result in higher emissions. It could be the case that economic expansion is faster than the transition toward a low-carbon economy. Moreover, using the FMOLS and DOLS techniques, it was found that a 1% increase in energy intensity leads to a 0.40% and 0.38% increase in per capita emissions levels respectively, therefore it is highly recommended that these countries should further support environmental legislation, financial incentives, and public awareness campaigns that can speed up the transition process.

Since FMOLS and DOLS reveal that renewable electricity generation has a negative significant influence on carbon emissions, it is critical to promote the broad use of renewable energy technologies such as solar, wind, hydroelectric, and geothermal power through applying feed-in tariffs, tax breaks, and renewable portfolio requirements.

Concerning the influence of environmental taxes on carbon emissions, it has been concluded that it has an insignificant impact on emissions in the long run. This result is consistent with the study of Lin and Li (2011) that found no significant differences in carbon emissions in all examined countries, except for Finland, suggesting that the effects of a carbon tax may fade over time. Accordingly, it is recommended that more studies should be conducted to examine the influence of environmental taxes on emissions in the long term.

In addition, based on the FMOLS approach, technological innovation is found to have a considerable negative influence on carbon emissions, urging governments, private-sector organizations, and university institutions to spend more on R&D for environmental innovation. This includes sponsoring research into sustainable technology, renewable energy, energy efficiency, carbon capture and storage (CCS), and other creative solutions that have the potential to significantly reduce CO2 emissions. Providing financial incentives, grants, and tax breaks to environmental research and development organizations can also assist in encouraging innovation.

Finally, RTAs recently incorporated clauses promoting the harmonization of environmental standards across member nations, and this action is supported by the research findings implying that RTAs with environmental provisions have a positive effect on environmental quality even though very small. Moreover, these provisions can help ensure a fair playing field and avoid a "race to the bottom" scenario in which countries compete by decreasing environmental rules.

5.2 Recommendations

Among the recommendations is to speed the transition to a low-carbon economy by establishing and enforcing strong environmental legislation to reduce emissions and encourage sustainable activities. Financial incentives such as subsidies, tax breaks, and grants are provided to stimulate investments in renewable energy and energy-efficient technology. Furthermore, a certain percentage of electricity should be required to come from renewable sources and should be continuously monitored. Moreover, increases resources for research and development of sustainable technology and climate solutions and at the same time, promotes collaboration among academics, businesses, and government to speed up technological progress. Furthermore, governments should include stronger environmental measures in RTAs to encourage harmonization and avoid a "race to the bottom."

5.3 Future research

There should be opportunities to assess the success of various forms of environmental taxes (e.g., carbon taxes, pollution taxes), as well as other mechanisms such as cap and trade, in meeting emissions reduction targets. In addition, compares the long-term effect of environmental taxes over multiple decades assessing their effectiveness among different economic cycles.

Furthermore, one might investigate the trade-offs between economic advantages and environmental preservation in RTAs. Perform cross-country comparisons to find the best practices in renewable energy policies that have resulted in considerable reductions in carbon emissions.

Instead of analyzing countries, we might focus on analyzing high-emission industries (such as manufacturing, transportation, and agriculture) and investigate individual approaches that potentially result in significant emission reductions.

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