PROBLEMY EKOROZWOJU/ PROBLEMS OF SUSTAINABLE DEVELOPMENT
AN OPEN ACCESS ARTICLE DISTRIBUTED UNDER THE TERMS AND CODITIONS OF THE CC BY 4.0 LICENSE
SUBMITTED: 17.12..2024, ACCEPTED: 5.01..2025, PUBLISHED ON-LINE: 01.07.2025
2025, 20(2): 270-283, DOI: 10.35784/preko.6960

Dynamic Common Correlated Effects of Green Innovation Funding and Green Trade on Environmental Quality in OECD Countries

Dynamiczne wspólne skorelowane efekty finansowania zielonej innowacji i zielonego handlu a jakość środowiska w krajach OECD

Ke Xiao[1*], Gang Wang[2], Hongling Yi[3], Asad Nisar[4]

[1]Krirk University, International College, 3 Ram Inthra Rd, Anusawari, Bang Khen, Bangkok, 10220, Thailand*
E-mail (Corresponding Author): manyu5@126.com
[2]Sichuan Film and Television University, School of Marxism, No. 188 Jinshan Road, Anren Town, Dayi County, Chengdu, 611331, China
E-mail: wanggang666999@126.comi
[3]Changchun Sci-Tech University, Marxist College, Changchun, 130600, China
Email: 100074@cstu.edu.cn
[4]Central University of Finance and Economics, School of Finance, 39 College South Road, Haidian District, Beijing, 100081, PR China
E-mail: asadnisar@email.cufe.edu.cn

Abstract
Achieving the Sustainable Development Goals (SDGs) and carbon neutrality targets presents a critical challenge for the Organization for Economic Co-operation and Development (OECD) countries, which account for over 37% of global carbon emissions and have experienced rising ecological degradation over recent decades. While previous research has explored the effects of green innovation and trade on environmental outcomes, these studies overlook the funding dimension of green innovations and fail to isolate eco-friendly goods within trade measures. To address this gap, our study evaluates the dynamic impact of green innovation funding and green trade on environmental quality in OECD countries from 1994 to 2021. Unlike traditional models relying on trade openness indices, we focus specifically on the dynamic common correlated effects (DCCE) estimator to mitigate cross-sectional dependence issues neglected by AMG and MG estimators. Results reveal that public funding for green innovations, in the form of government allocations for research, development, and demonstration, significantly reduces carbon emissions. Additionally, green trade has a substantial negative effect on emissions, promoting environmental sustainability. The robustness of these findings is confirmed through PMG estimation. These findings suggest that policymakers in OECD countries should increase budget allocation for green technology innovations and expand trade volume of environmentally friendly goods and services to foster environmental quality and achieve environmental sustainability goals.

Key words: green innovation funding, green trade, environmental quality, OECD countries

Streszczenie
Osiągnięcie Celów Zrównoważonego Rozwoju (SDGs) i celów neutralności węglowej stanowi krytyczne wyzwanie dla krajów Organizacji Współpracy Gospodarczej i Rozwoju (OECD), które odpowiadają za ponad 37% globalnych emisji dwutlenku węgla i doświadczyły w ostatnich dekadach rosnącej degradacji ekologicznej. Podczas gdy poprzednie prace badały wpływ zielonych innowacji i handlu na wyniki środowiskowe, pomijały jednak wymiar finansowania zielonych innowacji i nie izolowały przyjaznych dla środowiska towarów w ramach środków

handlowych. Aby wypełnić tę lukę, nasza praca ocenia dynamiczny wpływ finansowania zielonych innowacji i zielonego handlu na jakość środowiska w krajach OECD w latach 1994–2021. W przeciwieństwie do tradycyjnych modeli opierających się na wskaźnikach otwartości handlu, skupiamy się konkretnie na estymatorze dynamicznych wspólnych skorelowanych efektów (DCCE), aby złagodzić problemy zależności przekrojowych pomijane przez estymatory AMG i MG. Wyniki pokazują, że publiczne finansowanie zielonych innowacji w formie rządowych alokacji na badania, rozwój i demonstracje znacznie zmniejsza emisję dwutlenku węgla. Ponadto zielony handel ma znaczący negatywny wpływ na emisje, promując zrównoważony rozwój środowiska. Solidność tych ustaleń potwierdza oszacowanie PMG. Wyniki te sugerują, że decydenci w krajach OECD powinni zwiększyć alokację budżetu na innowacje w zakresie zielonych technologii i zwiększyć wolumen handlu przyjaznymi dla środowiska towarami i usługami, aby wspierać jakość środowiska i osiągnąć cele zrównoważonego rozwoju środowiska.

Słowa kluczowe: finansowanie zielonej innowacji, zielony handel, jakość środowiska, kraje OECD

Introduction

Climate change and global warming are among the most crucial goals challenges facing current world today. It is widely accepted that carbon dioxide (CO_2) emission is the leading contribution to greenhouse gases (GHGs), which further drive environmental degradation and global warming. As per report of Intergovernmental Panel on Climate Change (IPCC) the emissions of these gases surged from 9,500 million tons to 35,000 million tons over 1960-2010 (Intergovernmental Panel on Climate, 2014). So, achieving the better environmental quality is the need of day and Sustainable Development Goal (SDG 13) directly deals with climate change issue (United Nations Framework Convention on Climate, 2017). The environmental degradation is directly connected to climate change that could results in dire outcomes of glacier melt, erratic rainfall, extreme weather conditions, food insecurity, species extinction, decreased agricultural yields, and water shortages (Dong et al., 2019; Shahbaz et al., 2018). Moreover, people and organizations require to protect and sustain natural environment for future generations (Hunt & Fund, 2016). This urgent need of fostering sustainable environment captured global attention and prompt countries to keeping the global temperature increase below the critical threshold of 1.5°C as stipulated by the Paris Agreement. To mitigate the adverse effects of human activities on the planet, various institutions, agencies, and organizations set goals for industries, communities, and individuals. In this regard, the European Union (EU) committed to reduce the emissions by 40% by 2030 compared to 1990 levels (Europa, 2018). Achieving carbon neutrality by 2050 is critical need of day to maintain the global temperature rise within the acceptable limit of 1.5°C (European Parliament, 2020).

The climate change challenge is particularly presented in the OECD countries, despite being home to only 17% of the global population, but responsible for almost 37% of the global carbon emissions as of 2020. This disparity highlights the neglected role of developed economies in both contributing to environmental degradation and mitigating climate change (Wang et al., 2021). In 2019, the total GHG emissions for OECD countries reported at 12.5 billion metric tons, with only carbon emissions account for 10 billion metric tons. Additionally, the energy sector remains the largest emitter of CO_2 in OECD countries, contributing to over 40% of the total emissions (Saidi & Omri, 2020; Yilmaz & Uysal, 2022). In response to these challenges, OECD countries adopt renewable energy solutions that could drive clean energy and foster environmental quality. However, the pace of transition to cleaner energy sources is required to accelerate to meet targets set under international agreements. The OECD countries pledged to reduce their GHG emissions by 40% by 2030, with the aim to achieve net-zero emissions by 2050 (Jin et al., 2023). To meet these goals, OECD countries are required to allocate research, development, and demonstration (RDD) budget for renewable technology and promote trade of environment friendly goods. OECD countries are at the forefront of technological and policy innovations to counteract the climate change, so they bear an additional responsibility to drive global efforts to set the paths for other economies. As shown in Figure 1, most of the OECD countries are successful in combatting the carbon emissions over last two decades.

However, achieving better environmental quality will only be possible if human activities have been fully comprehended that lead to environmental deterioration and present effective solutions to mitigate their negative impacts. Undoubtedly, human activities are the main drivers of environmental degradation, which, in turn, increases the climate change pressure (Ahmed & Le, 2020). International trade, a crucial contributor of economic output, is a significant factor to influence carbon emissions in various sectors (Hatfield-Dodds et al., 2015). On positive side, trade brings substantial economic advantages such as boosting economic activities and facilitating the exchange of goods and services (J. Buysse et al., 2018; Can & Gozgor, 2018), it also offers the pathways to import green and resource-efficient technologies (Managi et al., 2009). On negative side, it increases energy consumption and results in exploitation of natural resources, which in turn drives environmental degradation (Mrabet et al., 2021; United Nations Environment, 2019). This has led to lack of consensus among scholars regarding the real impact of trade on environmental quality such as some agree on its positive impact on environmental quality (Lv & Xu, 2019; Zhang et al., 2017), other oppose this view (Gozgor & Can, 2016; Kasman & Duman, 2015)

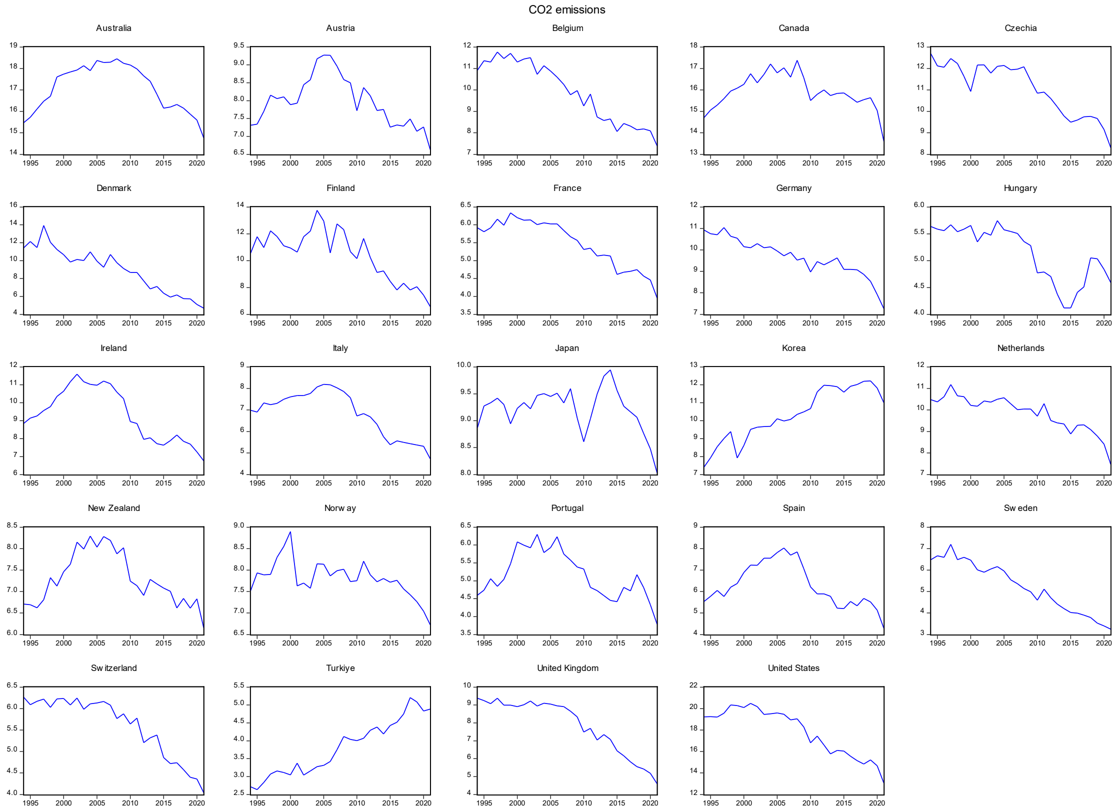

Figure 1. Carbon emissions in OECD countries (1994-2021)

Given the potential environmental losses linked with trade, one may argue that fostering a green economy to mitigate environmental degradation and to achieve carbon neutrality, there can be acceleration in trade of environment-friendly goods (United Nations Environment, 2011). This solution can ensure both environmental sustainability and economic growth. Accelerating the trade of green products contribute to environmental sustainability by reducing the environmental impact of production processes, particularly in terms of energy consumption (Paramati et al., 2020). Green products are categorized into two groups: *traditional environmental goods* and *environmentally preferable products* (EPPs). The first category includes those products that are specifically designed to address environmental concerns, such as air pollution control devices. The second category involves goods that are less damaging to the environment during their production, use, or disposal, such as electric vehicles, solar-power vehicles, or biodegradable jute bags (United Nations Conference on & Development, 1995). Overall, the trade of these both categories can promote environmental quality and address climate change challenges (Claro et al., 2007).

Additionally, government's commitment toward green economy can be a substantial effort to promote environmental quality. The government's allocation of research, development, and demonstration (RD&D) budgets for green technology can foster innovation and support transition to cleaner energy solutions. Investing in renewable energy sources could allow government to significantly reduce their dependency on fossil fuels, which are primary contributors to carbon emissions and global warming (Canton, 2021). Offering subsidies for research and development in green technologies can accelerate the creation of energy-efficient products and processes, thereby resulting in lesser industrial emissions (Popp, 2019). Governments can implement energy-efficient public infrastructure by using their budgets to lower emissions and reduce long-term operational costs (Grubler et al., 2018). Furthermore, supporting green technology startups through tax incentives and grants can accelerate sustainable economic growth and promote environmental quality as well (Wüstenhagen & Menichetti, 2012). By funding educational programs focused environmental awareness and green technologies, governments can cultivate a highly skilled workforce that would be capable of driving the green growth (Sovacool, 2016). Moreover, the allocation of a green technology budget enables the development of advanced waste management systems that would minimize landfill usage and promote recycling, thus reduces the environmental impact of waste (Zaman & Lehmann, 2013). So, with increased trade of environment friendly goods and a well-structured green technology budget can address various aspects of environmental degradation and drive the global shift towards a more sustainable future (Rennings, 2000).

In recent years, numerous studies investigated the impact of green products on environmental outcomes and they mainly used technological innovation metrics or green patent applications as proxies for green goods (Hao et al., 2021; Paramati et al., 2021). Unlink previous research, this study explains the impact of environment-friendly trade using the measure of trade volume of environment friendly goods (released by WDI World Bank), alongside the influence of government budgets allocated for green technology innovation, on environmental quality across 24 OECD countries from 1994 to 2021 within the Environmental Kuznets Curve (EKC) framework. We selected OECD countries for this study as these nations are at the forefront of innovation-driven green products, have high level of technological advancement, with better technical capacity and institutional quality, and skilled workforce, that all could contribute to environmental quality (Hu et al., 2020).This study uniquely positions itself by examining not just the trade of green products but also the pivotal role of government funding in green technology innovation to promote environmental quality of OECD countries. Moreover, this study acknowledges that OECD countries prioritize low-carbon research and provide substantial financing for such incentives, and thus adds a crucial dimension to understand the broader impacts on environmental sustainability (Al Mamun et al., 2018; Paramati et al., 2021).

Remaining of this paper is structured as follow: Section (2) covers the literature review, Section (3) presents methodology, data, and variables of study, Section (4) presents pre-diagnostic tests' results, dynamic common correlated estimations, and granger causality results, and Section (5) concludes the paper and uncovers policy implications.

Literature Review

The nexus between international trade and environmental quality is remained a subject of extensive research, particularly within the framework of Environmental Kuznets Curve (EKC) hypothesis. Previous studies shows that trade leads to both positive and negative environmental outcomes, depending upon the scale of economic activities based on international trade (Antweiler et al., 2001; Copeland & Taylor, 2004; Grossman, 1991). Some scholars argue that increased international trade accelerates the diffusion of green technologies and promotes environmental quality, while others emphasize the adverse effects of resource exploitation and increased production. The duality of these outcomes necessitates a deeper exploration of the specific mechanism through which trade impacts environmental quality, particularly in developed economies such as OECD nations. Trade liberalization, the process to mitigate barriers in way of international trade, has been associated with both positive and negative environmental outcomes. On one side, trade liberalization facilitates the diffusion of green technologies and best practices, thereby promoting environmental quality (Jeroen Buysse et al., 2018; Managi et al., 2009). On other side, it results in increased production and consumption, leading to higher emission and resource exploitation (Can et al., 2021). The net impact of trade liberalization on the environment in OECD countries could be complex and context-dependent.

Recent research increasingly focused on the role of green trade – defined as the trade of environment-friendly goods and services – to promote environmental quality. Green trade posits to mitigate environmental degradation by encourage sustainable production practices and lowering carbon emissions (Zhang et al., 2017). The trade of eco-friendly products and renewable energy technologies results in reductions in carbon and other type emissions (Hao et al., 2021). The increasing volume of green trade enhances the potential of governments to counteract the environmental challenges such as climate change and global warming. By enhancing the volume of eco-friendly goods, there could have been positive contribution toward environment through enabling the industries to use green products and materials in their operations. However, the extent to which green trade offsets the environmental costs of conventional trade remain unanswered. So, there is need of empirical research to examine the effectiveness of green trade to address environmental degradation challenge.

Innovating green products, including the introduction of energy-efficient technologies and eco-friendly goods, is crucial strategy in modern world to reduce the environmental impact of economic activities. The innovation process can lead to significant improvements in environmental quality by reducing carbon emissions and conserving natural resources (Paramati et al., 2021; Wüstenhagen & Menichetti, 2012). The innovation capacity in OECD countries high and government support for RD&D activities can essentially support the sustainable environmental progress. The government's role in shaping green economy through budgetary allocations could be critical to accelerate environmental quality. Funding for research, development, and demonstration (RD&D) in renewable technologies can accelerate innovation and adoption of cleaner technologies, which in turn can promote environmental sustainability (Grubler et al., 2018; Popp, 2019). Green technology encompasses renewable energy, energy-efficient products, and pollution control technologies, and is widely regarded as the essential to achieve environmental sustainability. The adoption and implementation of green technology solutions reduces greenhouse gas emissions and promote environmental quality (Zaman & Lehmann, 2013). In OECD countries, the adoption of green technologies is relatively high, and government's commitment toward green economy could significantly support these countries to achieve environmental quality. Wüstenhagen and Menichetti (2012) argue that government investments in green technology leads to significant results in emissions and resource use. However, the effectiveness of these budge allocations can contingent on the alignment of government efforts to achieve environmental sustainability goals. Thus, literature highlights the need for coherent and sustained government support to realize the full potential of green technology innovation to improve environmental quality.

The EKC hypothesis posits an inverted U-shape relationship between economic growth and environmental degradation, suggesting that environmental quality is initially deteriorated by economic growth but improved lately as countries reach higher income levels (Dinda, 2004; Grossman, 1991; Shahbaz et al., 2016). OECD countries, with their advanced actions toward climate change, are often considered as best examples where transition towards improved environmental quality is actually occurred (Paramati et al., 2021). OECD countries are also part of International Energy Agency (IEA), which is at the forefront to set the environment-related goals, defining the paths for clean environment, guiding the policymakers in execution of green environment projection, enabling funding for industries, and monitoring its member countries' practices. These are the countries with high trade volume of eco-friendly goods, green technologies' budget allocations, and disclosure of data regarding their budget allocations and green trade volume. Therefore, there is need to examine the role of green technology innovation funding and green trade for environmental quality in these economies, to set pathways for other economies.

Despite extensive body research on the environmental impact of green technology and trade, still gap exists. Most studies rely on proxies, such as green products volume to measure green trade, and green patent applications to measure green innovation funding, which may not fully capture the complexity of these both factors (Hao et al., 2021; Paramati et al., 2020). Additionally, the majority of prior literature focuses on individual aspects of green technology of trade, often neglecting the interplay between these factors and their direct impact on environmental quality. Addressing this gap is crucial to develop effective policies that could leverage both green trade and green innovation funding to achieve environmental sustainability in OECD countries. Based on this gap, this study aims to examine the effects of green trade and government green innovation funding on environmental quality in OECD countries. We employ advanced econometric approaches of Dynamic Common Correlated Effects (DCCE) and Panel Mean Group (PMG) to show how green trade and green innovation funding would influence environmental sustainability, ultimately contributing to the development of more effective environmental polices in OECD countries, and providing footprint for other economies valuing environmental sustainability with economic progress.

Data and Methodology

This paper employs dynamic common correlated effects (DCCE) model to analyze the impact of green trade and green innovation funding on environmental quality in OECD countries. From the 38 member countries of the OECD, 24 are selected based on the data availability (see Appendix for the list of selected countries) covering the period of 1994 – 2021. Traditional methods such as Generalized Method of Moment (GMM), random effects, and fixed effects are utilized for panel data estimations in prior research on environmental quality (Ali et al., 2019; Feng & He, 2020; Xaisongkham & Liu, 2024). However, these methods mostly account for homogeneity and changes in the intercepts of cross-sectional units, while in reality, panel data often exhibit heterogeneity. As a result, there has been a growing concern among researchers to consider cross-sectional dependence. Numerous studies highlight that panel data often encounter cross-sectional dependence issues. It is due to unobserved factors and shocks that impact countries simultaneously, particularly in the context of financial or economic integration (De Hoyos & Sarafidis, 2006; Dogan et al., 2017; Latif et al., 2018). Therefore, it is crucial to assess whether cross-sectional units are uniformly influenced by these shocks or not. Advanced estimation approaches such as DCCE and PMG have garnered significant attention in macroeconomic research, especially in context of OECD countries where the interconnectedness of countries renders traditional methods less effect. In response to this, we need to assess stationarity of data, cross-sectional dependence, multicollinearity, and co-integration between variables.

To assess stationarity of panel data, this study employs Im, Pesaran, and Shin (IPS) test (Im et al., 2003), and the Levin, Lin, and Chu (LLC) test (Levin et al., 2002), as the first-generation unit root tests, based on the Augmented Dickey-Fuller (ADF) regression for panel data, and specified as follow:

$$\Delta y_{it} = \gamma_i y_{i,t-1} + \sum_{j=1}^{P} \varphi_j \Delta y_{i,t-j} + \varepsilon_{it} \quad (1)$$

where $\gamma_i = \rho_i - 1$ in both tests represents null hypothesis of unit root existence and states as $H_0 = \gamma_i = 0$ $(\rho_i = 1)$ against the alternative hypothesis of existence of stationarity H_1: $\gamma_i < 0$ $(\rho_i < 1)$. LLC test assumes that parameters are equal across all the panel units of study and thus argues that $\rho_i = \rho$ for all *i* countries in panel data series. Both, IPS and LLC tests don't account for cross-sectional dependence, which is a crucial issue to diagnose in our panel data. To identify the existence of cross-sectional dependence, this study utilizes Pesaran (2004) cross-sectional dependence (CSD) test, which assesses nexus of residuals across cross-sections, and is constructed as:

$$CD = \frac{\frac{1}{N}\sum_{i=1}^{N} \sum_{j=1}^{N} \hat{\rho}_{ij}}{\frac{1}{N(N-1)}\sum_{i=1}^{N} \sum_{j=1}^{N} \hat{\rho}_{ij}} \quad (2)$$

where *N* denotes the cross-sections' number, and $\hat{\rho}_{ij}$ is the residual correlation between cross-sections *i* and *j*. Along with the cross-sectional dependence, we also verify the existence of multicollinearity issue by estimating variance inflation factors for all variables of present study. Based on the results of cross-sectional dependence, we further employ Pesaran (2007) cross-sectional Augmented Ducky-Fuller (CADF) test to confirm the nature of panel data series, either it is stationary at levels or at first difference after accounting for cross-sectional dependence. After diagnosing the order of interaction, we test long-run cointegration between variables of study. This study employs Pedroni (2004) panel cointegration test to examine panel-specific cointegrating vectors. Addition to this we also employ Westerlund panel co-integration test to examine the long-run relationship between variables. Specifically, Pedroni co-integration test is based on panel data model for an *I(1)* explained variable *y*, and it is specified as:

$$y_{it} = x'^{it}\beta_i + z_{it}'\tau_i + e_{it} \quad (3)$$

where x^{it} denotes the covariables for each panel *i,* and this test requires that covariates are not integrated. After confirming the co-integration between variables, we further employ DCCE method which is built upon the principles of the Pooled Mean Group (PMG) technique introduced by Pesaran et al. (1996), the Mean Group (MG) estimation by Pesaran and Smith (1995), and the Common Correlated Effects (CCE) estimation by Pesaran (2006).This approach is adequate to address key issues overlooked by conventional methods, particularly by accounting for cross-sectional dependence through usage of averages and lags of the cross-sectional units. Additionally, it fully accommodates heterogenous slopes and dynamic common correlated effects to present more robust estimates. Another advantage of this technique is it suitable for the small sample sizes through the Jackknife correction method (Chudik & Pesaran, 2015). Moreover, this approach can also be employed to unbalanced panel data series (Ditzen, 2016), and provides robust results in presence structural breaks in the data (Kapetanios et al., 2011). The equation for the DCCE model is constructed as follows:

$$CO2_{it} = \alpha_i CO2_{it-1} + \delta_i X_{it} + \sum_{p=0}^{p_T} \gamma_{xip}\bar{X}_{t-p} + \sum_{p=0}^{p_T} \gamma_{yip}\bar{X}_{t-p} + \mu_{it} \quad (4)$$

where, $CO2$ is the carbon emissions per capita and its lag value is used as the independent variable and X_{it}denotes the list of independent and control variables, and P_T is the lag of cross-sectional averages. Table 1 further reports the variable type, symbol, definitions, and source for all variables, included in this study.

Table 1 Variables of study

Type	Variable	Symbol	Definition	Source
Dependent:	Environmental Quality	CO_2	CO_2 emissions (metric tons per capita)	WDI, World Bank
Independent:	Green innovation funding	GIF	Government budget of RD&D per thousand units of GDP	OECD and IEA
	Green Trade	GT	Environment related trade and goods	Climate Change, IMF
Control:	Environmental taxes revenue	ENV_TX	Environment related tax revenue (% of GDP)	WDI, World Bank
	Log of Energy Consumption	Energy	Energy use (kg of oil equivalent per capita)	WDI, World Bank
	Log Gross Domestic Product per Capita	GDP	GDP per capita (constant 2015 US$)	WDI, World Bank
	Manufacturing Value Added	MANF	Manufacturing, value added (% of GDP)	WDI, World Bank
	Total Trade	TRD	Trade (% of GDP)	WDI, World Bank

Results and Discussion

Tables 2 present the descriptive statistics, including both measures of dispersion and central tendency for all variables. CO_2 has the mean value of 8.924 with standard deviation of 3.814, indicating the tendency of changing environmental degradation across OECD countries. For GIF, mean value is reported as 0.317 and minimum and maximum values are 0.002 and 1.672 respectively, and thus indicate that OECD countries have different volume of budget allocations for green technology. GT reports mean value of 4.236, thus indicates that there is significant portion of environment-friendly goods and services traded by OECD countries. Additionally, the descriptive statistics for all other variables are within acceptable range and mean trend of variables is shown in figure 2.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
CO_2	672	8.924	3.814	2.638	20.470
GIF	672	0.317	0.256	0.002	1.672
GT	672	4.236	3.175	0.862	20.754
ENV_TX	672	2.362	0.807	0.650	5.350
Energy	672	3.601	0.176	2.984	3.955
GDP	672	4.520	0.241	3.730	4.940
MANF	672	15.899	5.027	5.595	34.755
TRD	672	79.384	39.962	15.723	252.495

Pairwise correlation results are reported in Table 3, and it can be observed that CO_2 has its significant relationship with all explanatory variables of study. Specifically, CO_2 has positive links with energy consumption (Energy) and economic output (GDP), while negatively associated with green innovation funding (GIF), green trade (GT), environmentally-related tax revenue (ENV_TX), manufacturing value-added (MANF), and total trade (TRD).

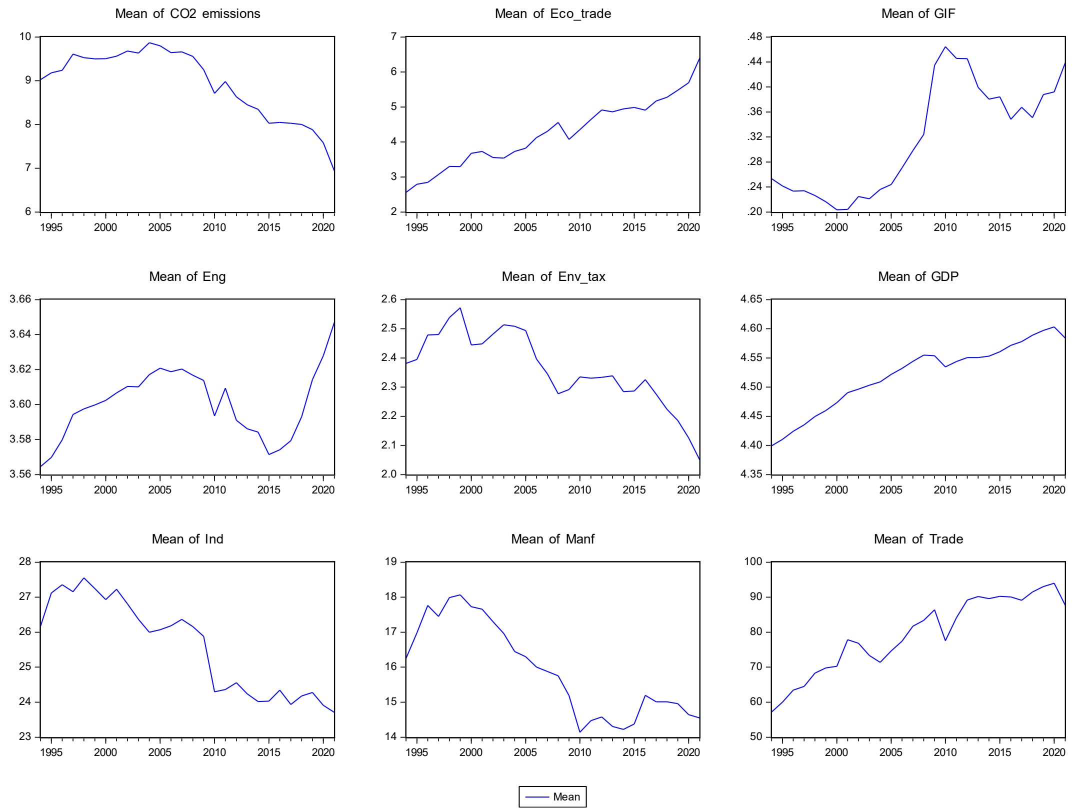

Figure 2: The mean of dependent, independent, and control variables over sample period

Table 3. Correlation matrix results

	CO_2	GIF	GT	ENV_TX	Energy	GDP	MANF	TRD
CO_2	1.000							
GIF	-0.057**	1.000						
GT	-0.175*	0.053	1.000					
ENV_TX	-0.261*	-0.059	0.228*	1.000				
Energy	0.705***	0.402**	-0.075	-0.295**	1.000			
GDP	0.302***	0.372**	-0.280**	-0.192**	0.623**	1.000		
MANF	-0.079**	-0.122*	0.287**	-0.007	-0.206**	-0.352**	1.000	
TRD	-0.187***	-0.059	0.623**	0.199**	-0.069	0.058	0.295**	1.000

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

As per the macroeconomic nature of the panel data series, there is need to assess unit-root issue, cross-sectional dependence, multicollinearity, and co-integration between variables. To evaluate this, we utilize several tests including first-generation unit-root tests of Levin et al. 2002 and Im et al. 2003, Pesaran (2004) CD test, Variance Inflation Factors (VIF) test, CADF test, Pedroni and Westerlund co-integration tests. The results of first-generation unit root tests of Levin, Lin, and Chu (LLC) and Im, Pesaran, and Shin (IPS) are presented in Table 4. It is shown that variables are stationary at levels but not at the first difference for both tests. However, the first-generation unit root tests not account for cross-sectional dependence, and it necessitates to assess whether there is existence of cross-sectional dependence across variables.

To identify the existence of cross-sectional dependence, we employ Pesaran (2004) CD test, and results are presented in Table 5. The results of this test not only aid to determine the appropriate estimation technique but also leading us to perform second-generation unit root test, which accounts for cross-sectional dependence. As shown in Table 5, all variables' CD statistics are highly significant, indicating the existence of cross-sectional dependence across panel data series. Moreover, VIF value for each variable (reported in Table 5), is less than 10, suggesting that there is no multicollinearity exists in our panel data series.

Table 4. First generation Unit root test results.

Variable	Levin, Lin, and Chu (LLC)					Im, Pesaran, and Shin (IPS)			
	Level		1st Diff.			Level		1st Diff.	
	Stat	Prob	Stat	Prob		Stat	Prob	Stat	Prob
CO_2	-1.6739**	0.0471	-5.8906***	0.0000		1.6986	0.9553	-10.0184***	0.0000
GIF	-1.2547	0.1048	-5.0867***	0.0000		0.2063	0.5817	-8.3892***	0.0000
GT	1.6274	0.9482	-5.7077***	0.0000		1.5758	0.9425	-8.8810***	0.0000
ENV_TX	-1.6198	0.0526	-7.7338***	0.0000		0.0795	0.5317	-9.2991***	0.0000
Energy	4.8825	1.0000	-2.7864***	0.0027		3.5833	0.9998	-2.9369***	0.0017
GDP	-1.5703*	0.0582*	-0.6666***	0.0252		2.8719	0.9980	-6.0947***	0.0000
MANF	-1.4075	0.0796	-19.909***	0.0000		-2.664***	0.0039	-15.746***	0.0000
TRD	-1.6872**	0.0458**	-7.8300***	0.0000		-1.803**	0.0356	-11.119***	0.0000

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

After confirming the cross-sectional dependence in our panel data series, we run second generation unit-root test of CADF, and results are shown in Table 6. Pesaran (CADF) Unit Root Test accounts for cross-sectional dependence and shows that stats for most of the variables are not significant at levels, indicating the stationarity nature of panel data. However, at first difference, all variables' stats have been found significant and thus confirming that non-stationarity. These results indicate that first-difference variables should be used for the further inferential analysis.

Table 5. Cross-Sectional Dependence Test and Variance Inflation Factor

Variable	CD Test Result	VIF
CO_2	43.31***	
	(0.000)	
GIF	28.76***	1.33
	(0.000)	
GT	43.83***	2.35
	(0.000)	
ENV_TX	13.79***	1.19
	(0.000)	
Energy	35.84***	1.99
	(0.000)	
GDP	79.62***	2.66
	(0.000)	
MANF	36.65***	1.33
	(0.000)	
TRD	52.61***	2.31
	(0.000)	
Mean VIF		1.88

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

Table 6. Pesaran (CADF) Unit Root Test Results

Variable	Levels			1st Diff.	
	Stats	P-value		Stats	P-value
CO_2	-1.944**	0.026		-8.847***	0.000
GIF	0.372	0.645		-8.892***	0.000
GT	2.776	0.997		-5.974***	0.000
ENV_TX	2.021	0.978		-6.039***	0.000
Energy	-2.109**	0.017		-9.907***	0.000
GDP	0.481	0.685		-2.633***	0.004
MANF	-2.495***	0.006		-9.218***	0.000
TRD	1.163	0.878		-5.255***	0.000

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

Further, we applied the Pedroni (1999) cointegration test to evaluate the existence of long-term relationships among the variables, and results are presented in Table 7. As per the statistics, provided by Pedroni test, there is strong evidence of long-term relationship among the variables. The Westerlund cointegration test is a more advanced method that considers more varying situations, and provides more reliable results. The variance ratio is also found highly significant, rejecting the null hypothesis of no cointegration between variables, and confirming the presence of a long-term nexus among variables of study.

Table 7. Pedroni and Westerlund Cointegration Tests' results.

Test	Statistic	P-value
Pedroni Test		
Modified Phillips–Perron t	4.2533***	0.0000
Phillips–Perron t	-10.4926***	0.0000
Augmented Dickey–Fuller t	-8.2338***	0.0000
Westerlund Test		
Variance ratio	7.9240***	0.0000

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

In a globalized world, where changes in one country could impact others, the DCCE method is more robust to provide reliable estimates. Most of the OECD countries highly integrated to each other due to being in common regional and economic blocs such as European Union (EU) and International Energy Agency (IEA). To address this shortcoming of earlier methods, we apply the DCCE estimation approach, and the results are reported in Table 8. The results show positive effects of energy consumption (Energy), economic output (GDP), and manufacturing value-added (MANF) on environmental degradation (CO_2). These results confirm that with the increased energy consumption, accelerated economic growth, and higher manufacturing operations would lead to negatively affect the environmental quality in OECD economies. On other side, it is shown that GIF has dynamic common correlated coefficient of -0.454, suggesting the negative impact of green innovation funding on carbon emission. In same stride, the impact of green trade (GT) is found negative, reflected by -0.080. This finding renders the negative impact of green trade on carbon emissions in OECD countries. Overall, DCCE method proves the positive contribution of green trade and green innovation funding in OECD countries toward environmental quality. The impact of green innovation funding (GIF) is found relatively higher than green trade (GT) to foster the environmental quality in OECD bloc. These findings are consistent with previous studies, including Ahmed et al. (2022) Rafique et al. (2022) and Cutcu et al. (2023). Additionally, Figure 3 and Figure 4 present the regression link of Eco-Trade (GT) and Green innovation funding (GIF) with carbon emissions (CO_2) across selected 24 OECD countries. The trends in figure 3 shows that in most of OECD countries, there is existence of direct nexus between GIF and CO_2, implying that increased green innovation funding reduces the carbon emissions in OECD countries. In simple words, OECD countries are fostering environmental quality through increasing their budget allocations toward Research, Development, and Demonstration Expenditures. Figure 4 further confirms the significance of direct connection between Eco-trade and CO_2 in OECD countries, that shows the increased control over carbon emissions with the increased volume of trade of eco-friendly products. Overall, it can be concluded that higher volume of government allocations to RDD&D budget, and increased trade volume in environment-friendly goods promote environmental quality in OECD countries. OECD countries, being the members of IEA bloc, are more concerned about their environmental related actions to become at forefront in achieving sustainable development goals (SDGs), and thus setting example for other economies of world.

Table 8. Results of DCCE Estimation

Exogenous Variable	Coefficient	t-Statistic
L.CO_2	-0.016***	-3.27
GIF	-0.454***	-2.60
GT	-0.080***	-4.61
ENV_TX	-0.482***	-2.66
Energy	18.782***	6.37
GDP	6.547***	4.53
MANF	0.062***	6.24
TRD	-0.010	-1.62

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

To confirm the robustness of dynamic common correlated effects method results, we employ Pooled Mean Group (PMG) estimation approach as it accounts for both short-run and long-run equilibrium relationship while allowing for heterogeneity across groups (Blackburne III & Frank, 2007; Pesaran et al., 1999). To align the results of PMG estimation approach, we only reported long-run estimates in Table 9 so readers can ensure the consistency and reliability of the long-run relationships identified in the benchmark model. The PMG estimates reveal positive impact of Energy, GDP, and MANF on CO_2, indicating the contributing role of energy consumption, economic output, and manufacturing value-added toward environmental degradation. However, the effects of GIF, GT, and ENV_TX are reported as negative and highly significant. These findings suggest that government's increased innovation funding, higher trade volume of environment-friendly goods and services, and increased environmental tax revenues reduce the carbon emissions in OECD countries. These findings are in line with the benchmark estimates, and proves the promising role of green innovation funding and green trade to enhance environmental quality in OECD countries. The findings of DCCE and PMG approaches, confirm the role of green innovation funding and eco-trade to foster environmental quality and making the countries equipped with required infrastructure and materials that could make them ready to address climate change and global warming challenges.

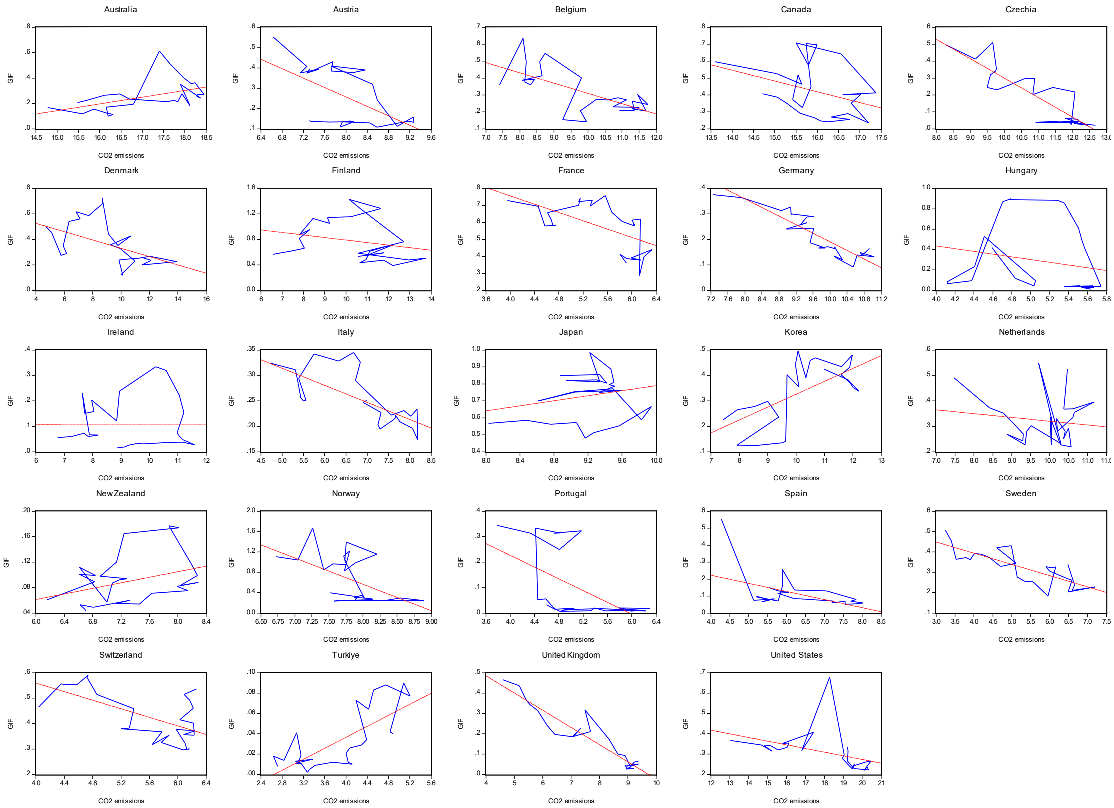

Figure 3. GIF to CO_2 emissions in OECD countries with regression line

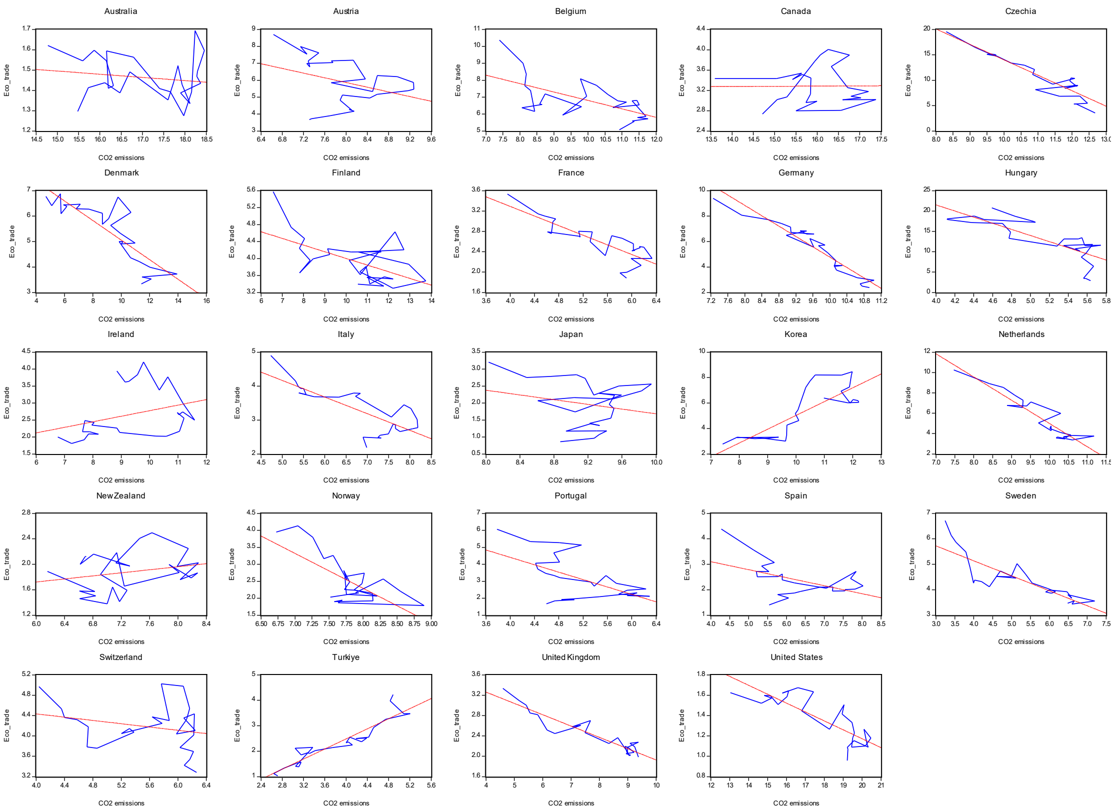

Figure 4. GT to CO_2 emissions in OECD countries with regression line

Table 9. Results of PMG Estimation

Independent Variables	Coefficients	t-statistic
GIF	-0.329***	-4.72
GT	-0.024***	-3.13
ENV_TX	-1.082***	-2.74
Energy	1.006***	3.15
GDP	14.804***	4.74
MANF	0.166*	1.76
TRD	-0.006	-0.21
_cons	5.081**	3.12

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

Furthermore, we perform Granger Non-Causality test to determine whether one time series may predict another, and to identify the bidirectional relationships between variables of study (Judois et al., 2021). It evaluates that whether past values of one variable may significantly improve the prediction of another variable, and results of this test are presented in Table 10. The Granger non-causality test results show that GIF does not Granger-cause carbon emission, as indicated by its negative and insignificant coefficient of -0.239. This finding suggests that changes in government innovation funding may not have a significant predictive effect on carbon emissions within the given model. For GT, Table 10 shows a negative and marginally significant relationship with CO_2, which suggests that increase in GT leads to subsequently decrease carbon emissions.

Table 10. Granger Non-Causality Test Results

Variable	Coefficient	z-Statistic
GIF	-0.239	-1.57
GT	-0.042*	-1.84
ENV_TX	-0.404***	-9.03
Energy	4.162***	4.01
GDP	0.189	0.29
MANF	0.047***	3.24
TRD	-0.002	-0.63

Note: ***, **, and * indicates the significance at 1%, 5%, and 10% respectively.

Concluding remarks and recommendations

In response to the global warming and climate change challenges, countries are taking active steps to attain carbon neutrality targets. In prior literature, scholars mentioned the beneficial impacts of green innovations and trade of green goods, however they did not present the impact of funding aspect of green innovations and dynamic role of eco-friendly trade of goods. In previous studies, the international trade basket, represented by trade openness index, is used as the measure of environment-friendly, which actually include both environment-friendly goods and not-environment-friendly goods. Therefore, present study evaluates the dynamic common correlated effects of green innovation funding and green trade on environmental quality in OECD countries by using panel data for the period of 1994 to 2021. We employed advanced econometric approach of DCCE to tackle the weaknesses of earlier methods of panel data such as AMG and MG estimators. Based on the pre-diagnostic results, we employed DCCE approach and found that green innovation funding, in form of government's budget allocations for research, development and demonstration, significantly improves the environmental quality by negatively affecting the carbon emissions in OECD economies. It is also found that green trade has substantial negative effects on carbon emissions in OECD countries, and thus positively contributing toward environmental quality. These results conclude that increased budget allocation for green technology and higher trade volume of environment-friendly goods and services significantly improve environmental quality. Furthermore, the impact of green innovation funding and green trade on environmental quality is found robust across PMG estimation approach.

Based on these findings, there could be numerous implications for OECD and environment-intensive countries. First, OECD countries are required to increase the trade volume of environment friendly goods and services to directly support the sustainable economic growth. This green trade will not only substitute conventional trade to support the economic output but also achieve better environmental quality. Second, policymakers should prefer green innovation funding to facilitate the diffusion of cleaner and renewable energy technologies for achieving sustainable development goals (SDGs) like better health, low-cost and green energy, openness, green infrastructure, and responsible consumption and production. Third, policymakers should adopt the strategies through which green innovation funding and green trade can be strongly linked to support the environmental quality in OECD countries as their individual effects are found highly positive for environmental sustainability. Lastly, OECD countries should support the development of green technology solutions through the gateways of international and bilateral trade, so there can be enhanced integration of SDGs across these nations.

References

1. AHMED Z., ADEBAYO T. S., UDEMBA E. N., MURSHED M., KIRIKKALELI D., 2022, Effects of economic complexity, economic growth, and renewable energy technology budgets on ecological footprint: the role of democratic accountability, *Environmental Science and Pollution Research* 29(17), 24925-24940.
2. AHMED Z., LE H. P., 2020, Linking Information Communication Technology, trade globalization index, and CO_2 emissions: evidence from advanced panel techniques. *Environmental Science and Pollution Research* 28, 8770-8781, https://doi.org/https://doi.org/10.1007/s11356-020-11205-0.
3. AL MAMUM M., SOHAG K., SHAHBAZ M., HAMMOUDEH S., 2018, Financial markets, innovations and cleaner energy production in OECD countries, *Energy Economics* 72, 236-254.
4. ALI H. S., ZEQIRAJ V., LIN W. L., LAW S. H., YUSOP Z., BARE U. A. A., CHIN L., 2019, Does quality institutions promote environmental quality? *Environmental Science and Pollution Research* 26, 10446-10456.
5. ANTWEILER W., COPELAND B. R., TAYLOR M. S., 2001, Is free trade good for the environment? *American economic review* 91(4), 877-908.
6. BLACBURNE III, E. F., FRANK M. W., 2007, Estimation of nonstationary heterogeneous panels, *The Stata Journal* 7(2), 197-208.
7. BUYSSE J., CAN M., GOZGOR G., 2018, Globalisation outcomes and the real output in the subSaharan Africa LICs: a cointegration analysis, *Economic research-Ekonomska istraživanja* 31(1), 338-351.
8. BUYSEE J., CAN M., GOZGOR G., 2018, Globalization outcomes and the real output in the sub-Saharan Africa LICs: a cointegration analysis. *Economic Research* 31(1), 338-351, https://doi.org/https://doi.org/10.1080/1331677X.2018.1426471
9. CAN M., AHMED Z., MERCAN M., KALUGINA O. A., 2021, The role of trading environment-friendly goods in environmental sustainability: Does green openness matter for OECD countries? *Journal of Environmental Management* 295, 113038.
10. CAN M., GOZGOR G., 2018, Effect of export product diversification on quality upgrading: an empirical study, *Journal of International Trade & Economic Development* 27(3), 293-313, https://doi.org/https://doi.org/10.1080/09638199.2017.1370006.
11. CANTON H., 2021, International energy agency (IEA), *The Europa Directory of International Organizations 2021*, Routledge, 684-686.
12. CHUDIK A., PEASARAN M. H., 2015, Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors, *Journal of Econometrics* 188(2), 393-420.
13. CLARO E., LUCAS N., SUGATHAN M., MARCONINI M., LENDRO E., 2007, Trade in Environmental Goods and Services and Sustainable Development: Domestic Considerations and Strategies for WTO Negotiations, *ICTSD Environmental Goods and Services Series, Policy Discussion Paper,* International Centre for Trade and Sustainable Development.
14. COPELAND B. R., TAYLOR M. S., 2004, Trade, growth, and the environment, *Journal of Economic literature* 42(1), 7-71.
15. CUTCU I., BEYAZ A., GERLIKHAN S. G., KILIC Y., 2023, Is ecological footprint related to foreign trade? Evidence from the top ten fastest developing countries in the global economy, *Journal of cleaner production* 413, 137517.
16. DE HOYOS R. E., SARAFIDIS V., 2006, Testing for cross-sectional dependence in panel-data models, *Stata Journal* 6(4), 482-496.
17. DINDA S., 2004, Environmental Kuznets curve hypothesis: a survey, *Ecological economics* 49(4), 431-455.
18. DITZEN J., 2016, Estimating dynamic common correlated effects in Stata, *SEEC Discussion Papers.*
19. DOGAN E., SEKER F., BULBUL S., 2017, Investigating the impacts of energy consumption, real GDP, tourism, and trade on CO_2 emissions by accounting for cross-sectional dependence: a panel study of OECD countries, *Current Issues in Tourism* 20(16), 1701-1719.
20. DONG K., DONG X., DONG C., 2019, Determinants of the global and regional CO_2 emissions: what causes what and where? *Applied Economics* 51, 5031-5044, https://doi.org/https://doi.org/10.1080/00036846.2019.1606410.
21. EUROPA, 2018, *2030 Climate & Energy Framework,* https://ec.europa.eu/clima/policies/strategies/2030_en.
22. EUROPEAN PARLIAMENT, 2020, What Is Carbon Neutrality and How Can it Be Achieved by 2050? https://www.europarl.europa.eu/news/en/headlines/society/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050.
23. FENG Y., HE F., 2020, The effect of environmental information disclosure on environmental quality: Evidence from Chinese cities, *Journal of cleaner production* 276, 124027.
24. GOZGOR G., CAN M., 2016, Export product diversification and the environmental Kuznets curve: evidence from Turkey, *Environmental Science and Pollution Research* 23, 21594-21603, https://doi.org/https://doi.org/10.1007/s11356-016-7403-9.
25. GROSSMAN G., KRUEGER A.B., 1991, Environmental Impacts of a North American Free Trade Agreement, https://ideas.repec.org/p/nbr/nberwo/3914.html.
26. GRUBLER A., WILSON C., BENTO N., BOZA-KISS B., KREY V., McCOLLUM D. L., RAO N. D., RIAHI K., ROGELJ J., DE STERCKE S., 2018, A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies, *Nature energy* 3(6), 515-527.

27. HAO L.-N., UMAR M., KHAN Z., ALI W., 2021, Green growth and low carbon emission in G7 countries: how critical the network of environmental taxes, renewable energy and human capital is? *Science of the Total Environment* 752, 141853.
28. HATFIELD-DODDS S., SCHANDL H., ADAMS P. D. et al., 2015, Australia is 'free to choose' economic growth and falling environmental pressures, *Nature* 527, 49-53, https://doi.org/https://doi.org/10.1038/nature16065.
29. HU G., CAN M., PARAMATI S. R., DOGAN B., FANG J., 2020, The effect of import product diversification on carbon emissions: New evidence for sustainable economic policies, *Economic Analysis and Policy* 65, 198-210.
30. HUNT R. A., FUND B. R., 2016, Intergenerational fairness and the crowding out effects of well-intended environmental policies, *Journal of Management Studies* 53, 878-910, https://doi.org/https://doi.org/10.1111/joms.12202.
31. IM K. S., PESARAN M. H., SHIN Y., 2003, Testing for unit roots in heterogeneous panels, *Journal of econometrics* 115(1), 53-74.
32. IPPC (Intergovernmental Panel on Climate), 2014, *AR5 Synthesis Report: Climate Change 2014*, https://www.ipcc.ch/report/ar5/syr.
33. JIN C., LV Z., LI Z., SUN K., 2023, Green finance, renewable energy and carbon neutrality in OECD countries, *Renewable Energy* 211, 279-284.
34. JUODIOS A., KARAVIAS Y., SARAFDIS V., 2021, A homogeneous approach to testing for Granger non-causality in heterogeneous panels, *Empirical economics* 60(1), 93-112.
35. KAPETANIOS G., PEASARAN M. H., YAMAGATA T., 2011, Panels with non-stationary multifactor error structures, *Journal of Econometrics* 160(2), 326-348.
36. KASMAN A., DUMAN Y. S., 2015, CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis, *Economic Modelling* 44, 97-103, https://doi.org/https://doi.org/10.1016/j.econmod.2014.10.022.
37. LATIF Z., LATIF S., XIMEI L., PANTHAN Z. H., SALAM S., JIANQIU Z., 2018, The dynamics of ICT, foreign direct investment, globalization and economic growth: panel estimation robust to heterogeneity and cross-sectional dependence, *Telematics and Informatics* 35(2), 318-328.
38. LEVIN A., LIN C.-F., CHU C.-S. J., 2002, Unit root tests in panel data: asymptotic and finite-sample properties, *Journal of econometrics* 108(1), 1-24.
39. LV Z., XU T., 2019, Trade openness, urbanization and CO_2 emissions: dynamic panel data analysis of middle-income countries, *Journal of International Trade & Economic Development* 28(3), 317-330, https://doi.org/https://doi.org/10.1080/09638199.2018.1534878.
40. MANAGI S., HIBIKI A., TSURUMI T., 2009, Does trade openness improve environmental quality? *Journal of Environmental Economics and Management* 58(3), 346-363.
41. MRABET Z., ALSAMARA M., MIMOUNI K., MNASRI A., 202,. Can human development and political stability improve environmental quality? New evidence from the MENA region, *Economic Modelling* 94, 28-44, https://doi.org/https://doi.org/10.1016/j.econmod.2020.09.021.
42. PARAMATI S. R., MO D., HUANG R., 2020, The role of financial deepening and green technology on carbon emissions: evidence from major OECD economies, *Finance Research Letters,* https://doi.org/https://doi.org/10.1016/j.frl.2020.101794.
43. PARAMATI S. R., MO D., HUANG R., 2021, The role of financial deepening and green technology on carbon emissions: Evidence from major OECD economies, *Finance Research Letters* 41, 101794.
44. PEDRONI P., 2004, Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis, *Econometric theory* 20(3), 597-625.
45. PESARAN M. H., 2004, General diagnostic tests for cross section dependence in panels, *Economics* 1240(1), 1.
46. PESARAN M. H., 2006, Estimation and inference in large heterogeneous panels with a multifactor error structure, *Econometrica* 74(4), 967-1012.
47. PESARAN M. H., 2007, A simple panel unit root test in the presence of cross-section dependence, *Journal of applied econometrics* 22(2), 265-312.
48. PESARAN M. H., SHIN Y., SMITH R. J., 1996, *Testing for the 'Existence of a Long-run Relationship'*, Faculty of Economics, University of Cambridge.
49. PESARAN M. H., SHIN Y., SMITH R. P., 1999, Pooled mean group estimation of dynamic heterogeneous panels, *Journal of the American statistical Association* 94(446), 621-634.
50. PESARAN M. H., SMITH R., 1995, Estimating long-run relationships from dynamic heterogeneous panels, *Journal of Econometrics* 68(1), 79-113.
51. POPP D., 2019, Environmental policy and innovation: a decade of research, *International Review of Environmental and Resource Economics* 13(3-4), 265-337, https://doi.org/10.1561/101.00000111.
52. RAFIQUE M. Z., NADEEM A. M., XIA W., IKRAM M., SHOIAB H. M., SHAHZAD U., 2022, Does economic complexity matter for environmental sustainability? Using ecological footprint as an indicator, *Environment, Development and Sustainability* 24(4), 4623-4640.
53. RENNINGS K., 2000, Redefining innovation - eco-innovation research and the contribution from ecological economics, *Ecological economics* 32(2), 319-332.
54. SAIDI K., OMRI A., 2020, Reducing CO_2 emissions in OECD countries: do renewable and nuclear energy matter? *Progress in Nuclear Energy* 126, 103425.
55. SHAHBAZ M., NASIR M. A., ROUBAUD D., 2018, Environmental degradation in France: the effects of FDI, financial development, and energy innovations, *Energy Economics* 74, 843-857, https://doi.org/10.1016/j.eneco.2018.07.020.
56. SHAHBAZ M., SOLARIN S. A., OZTURK I., 2016, Environmental Kuznets curve hypothesis and the role of globalization in selected African countries, *Ecological Indicators* 67, 623-636.

57. SOVACOOL B. K., 2016, How long will it take? Conceptualizing the temporal dynamics of energy transitions, *Energy research & social science* 13, 202-215.
58. UNITED NATIONS Conference on Trade & Development, 1995, Definitions and classifications regarding green goods, https://unctad.org/system/files/official-document/td180vol1_en.pdf.
59. UNITED NATIONS Environment, 2011, Materials regarding green economy and sustainable development, https://sdgs.un.org/publications/unep-2011-towards-green-economy-pathways-sustainable-development-and-poverty
60. UNITED NATIONS Environment, 2019, Published materials regarding environmental impact assessments and recommendations, https://unece.org/publications/environmental-assessment.
61. UNITED NATIONS, 2017, Framework Convention on Climate Change, https://treaties.un.org/doc/source/recenttexts/unfccc_eng.pdf
62. WANG W.-Z., LIU L.-C., LIAO H., WEI Y.-M., 2021, Impacts of urbanization on carbon emissions: An empirical analysis from OECD countries, *Energy policy* 151, 112171.
63. WUSTENHAGEN R., MENICHETTI E., 2012, Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research, *Energy policy* 40, 1-10.
64. XAISONGKHAM S., LIU X., 2024, Institutional quality, employment, FDI and environmental degradation in developing countries: Evidence from the balanced panel GMM estimator, *International Journal of Emerging Markets* 19(7), 1920-1939.
65. YILMAZ F., UYSAL P., 2022, The role of information communication technologies on carbon emissions in OECD countries: new evidence from method of moments quantile approach, *Environmental Science and Pollution Research* 29(54), 81396-81417.
66. ZAMAN A. U., LEHMANN S., 2013, The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city', *Journal of cleaner production* 50, 123-132.
67. ZHANG B., LIU L., WANG Z., 2017, The impact of economic globalization on CO_2 emissions: the case of high-income OECD countries, *Environmental Science and Pollution Research* 24, 20078-20088, https://doi.org/https://doi.org/10.1007/s11356-017-9623-8.