International Journal of Business & Economic Studies
Year: 2023, Vol: 5, No: 3, pp.195-207
https://doi.org/10.54821/uiecd.1331928

The Relationship Between Financial Innovation and Environmental Pollution in OECD Countries

OECD Ülkelerinde Finansal Yenilik ve Çevre Kirliliği Arasindaki İlişki

Murat Tekbaş
Assoc. Prof. Dr. Afyon Kocatepe University
mtekbas@aku.edu.tr
https://orcid.org/0000-0003-2589-2482

Received : 24.07.2023
Revised : 14.09.2023
Accepted : 20.09.2023
Type of Article : Research

Keywords:

Financial Innovation,
CO_2 Emissions
Urbanization
Economic Growth,
Panel Data Analysis

Jel Codes:

O31, O33, Q54

ABSTRACT

Climate changes as a result of environmental degradation have negative effects in many areas. Many studies in the economics literature have examined the effects of these negativities from different perspectives. In this study, the relationship between financial innovation and CO_2 emission, which is newly used in the literature, is examined for 14 OECD member countries. LLC and IPS unit root tests, Pedroni and Kao cointegration tests and FMOLS estimator were used in the analyses for the period between 2009 and 2019. According to the findings obtained from the analyses, it is seen that financial innovation, economic growth and urbanization have negative effects on CO_2 emissions. In addition, in the results of Dumitrescu-Hurlin causality test applied in the study, it was determined that there is a bidirectional causality relationship between economic growth, urbanization and CO2 emissions, and a unidirectional causality relationship between financial innovation and CO_2 emissions. In this direction, it is considered important that companies and governments should act together. It is considered that the creation of green loans by financial intermediaries for environmentally sensitive projects can encourage investors. In order to prevent environmental degradation from a holistic perspective, the government should take measures such as subsidies and tax reductions to encourage environmentally friendly projects.

Anahtar Kelimeler:

Finansal İnovasyon,
CO_2 Emisyonu,
Kentleşme,
Ekonomik Büyüme,
Panel Veri Analizi

Jel Kodları:

O31, O33, Q54

ÖZET

Çevresel bozulmalar sonucunda meydana gelen iklim değişiklikleri birçok alanda olumsuz etkiler oluşturmaktadır. Ekonomi literatüründe birçok çalışma farklı açılardan bu olumsuzlukların etkileri incelenmiştir. Bu çalışmada literatürde yeni kullanılan finansal inovasyon ile CO_2 emisyonu arasında ilişki OECD üyesi 14 ülke için incelenmiştir. 2009 – 2019 yılları arasındaki dönem için yapılan analizlerde LLC ve IPS birim kök testleri, Pedroni ve Kao eşbütünleşme testleri ve FMOLS tahmincisi kullanılmıştır. Analizlerden elde edilen bulgulara göre finansal inovasyon, ekonomik büyüme ve kentleşmenin CO_2emisyonu üzerinde negatif etkili olduğu görülmektedir. Ayrıca çalışmada uygulanan Dumitrescu-Hurlin nedensellik testi sonuçlarında ekonomik büyüme, kentleşme ve CO_2 emisyonu arasında çift yönlü, finansal inovasyon ile CO_2 emisyonu arasında tek yönlü nedensellik ilişkisi olduğu tespit edilmiştir. Bu doğrultuda firmaların ve hükümetlerin birlikte hareket etmesi gerektiği önemli görülmektedir. Finansal aracıların çevreye duyarlı projelere yönelik yeşil kredileri oluşturmaları yatırımcıları teşvik edebileceği değerlendirilmektedir. Çevresel bozulmanın bütüncül bir bakış açısıyla önlenebilmesi için ise devlet çevre dostu projeleri teşvik etmek üzere sübvansiyon ve vergi indirimleri gibi önlemleri almalıdır.

Suggested Citation: Tekbaş, M. (2023). The relationship between financial innovation and environmental pollution in OECD countries. *International Journal of Business and Economic Studies*, 5(3), 195-207, Doi: https://doi.org/10.54821/uiecd.1331928

1. INTRODUCTION

Increases in heat waves, droughts and floods caused by climate change are affecting many regions and billions of people around the world. Despite a temporary decline in carbon dioxide emissions (CO_2) in 2020, energy-related CO_2 increased by approximately 6% in 2021 as the demand for coal, oil and natural gas increased with the resumption of economic activity. Based on available data, global emissions are projected to increase by around 14% over the next decade. For this reason, it is accepted that the joint efforts of governments, the private sector and non-governmental organizations (NGOs) have a key role in preventing global environmental disasters (United Nations Secretary-General, 2022:19).

Under pressure from environmental degradation (ED) and social tensions, the Sustainable Development Goals (SDGs) for 2030 were endorsed in the last quarter of 2015, requiring nations to make efforts to combat climate change and its impacts. In December 2015, the Paris Climate Conference (COP21) was held to tackle global climate change and the Paris Agreement was adopted. Specifically, COP21 placed finance at the center of the solution to ED. Accordingly, it is aimed to develop green finance to provide financial support for low-carbon infrastructure investments, technological investments and other solutions to prevent ED (United Nations, 2015: 1; Lv & Li, 2021: 1). At this point, the relationship between finance and the environment needs to be put forward correctly. A well-functioning financial system affects environmental quality in three ways. First, stock market development enables listed companies to reduce financing costs, diversify risk and optimize their asset/liability structure. Secondly, financial development (FD) helps attract foreign direct investments (FDIs) and realize economic growth (GDPPC). However, this leads to an increase in CO_2 along with GDPPC. Thirdly, FD may provide the opportunity to adopt energy-saving production methods and environmentally-friendly consumption products (Ye et al., 2021: 1234).

As stated in the majority of theoretical and empirical studies today, it is not possible to explain the financial system and its development in terms of a few types of securities and a few basic financial institutions. Because today there is a wide variety of different financial products, many different types of financial institutions and the processes that these institutions use to do business (Tufano, 2003: 313). Accordingly, through the differentiation of financial opportunities, financial innovation (FINI) has emerged as a tool to explore financial progress (Nazir et al., 2020). FINI, which has shown a significant rise since the 1980s, is defined as a driving force that pushes an economic system towards higher economic competence in order to align it with the economic benefits arising from the evolving economic environment (Khan et al., 2021: 2).

To suffice innovation initiatives within a country, these products need to meet financial needs. Following the invention and diffusion components of innovation, FINI is realized through product and process innovations that are subject to the demand of nations' economic systems. While innovation efforts are directed at combating climate change, the financialization of these efforts is also expected to require certain levels of innovation. This neo-financialization channel is important because of the risk associated with projects. From this perspective, it is recognized that FINI can have a significant impact on ED, albeit through an indirect channel (Chisti & Sinha, 2022: 3).

This study will investigate the impact of FINI, GDPPC, and urbanization (URBN) on CO_2 in OECD member countries between 2009 and 2019. The study will contribute to the literature by selecting countries that rank high in the environmental performance index, energy-intensive production in these countries and using industry-based research and development (R&D) expenditure statistics in the commercial enterprise sector according to the International Standard Industrial Classification (ISIC) revision 4 instead of "loans to the private sector", which is frequently used in the literature to represent FD. The reason for choosing the 2009-2019 period in the study is the availability of financial innovation data generated by the OECD with a different calculation method between these years. In addition, the reason for using OECD countries in this study is that the countries with financial innovation data are limited to OECD member countries. This motivated study consists of four sections. In the first section, the scope of the study is explained by giving brief and descriptive information about the subject. The second section reviews the current literature on the subject of the study. The third section, model, data and methodology, presents information about the model, study constraints and analysis methods used in the study. The fourth section presents the evaluation and interpretation of the empirical results obtained from the analysis. Finally, in the conclusion and discussion section, the compatibility of the results with the literature will be evaluated and appropriate policy recommendations will be made.

2. LITERATURE REVIEW

In recent years, there have been many studies on environmental pollution (EP) in the economics literature. In these studies, the relationship between GDPPC and the environment is particularly emphasized and the Environmental Kuznets Curve hypothesis is tested. However, recent studies analyze the impact of different variables such as globalization, financial development, technology, renewable energy consumption (REC) on EP as potential determinants of ED. Since the relationship between FINI and EP will be evaluated in our study, studies with other variables will not be included in this section. Accordingly, in this section of the study, the studies analyzing the relationship between FD and EP in relation to our research topic will be discussed chronologically. Firstly, studies conducted on countries other than OECD countries and secondly, studies conducted for OECD countries will be analyzed.

Among the studies conducted for non-OECD countries, Omri et al. (2015) examined the relationship between FD, trade, GDPPC and CO_2 for a panel of 12 MENA countries. For the 1990-2011 period, the study found that the neutrality hypothesis was valid between FD and CO_2. Abbasi & Riaz (2016) for Pakistan investigated the impact of economic and FD on CO_2 for the period 1988-2011 using the ARDL bounds test method. The results of the study revealed that FD increased CO_2. However, it was stated in the study that FD did not reach the desired level and it would have been useful to develop new policies to reach this level. In the study of Salahuddin et al. (2018), the 1980-2013 period for Kuwait was analyzed and the relationship between GDPPC, electricity consumption, FDI, FD and CO_2 was investigated. In the study, the relationship between the variables was tested by applying the ARDL bounds test approach and it was found that a cointegration relationship existed between the series. The findings indicated that GDPPC, electricity consumption and FDIs had a decreasing effect on CO_2. However, no statistically significant relationship between FD and CO_2 was found in the analysis. Park et al. (2018) investigated the relationship between internet use, electricity consumption, GDPPC, trade openness (TO) and FD, and CO_2 over the period 2001-2014 for EU countries. Using the pooled mean group estimation method for panel data, the study concluded that internet use and electricity consumption had a positive effect on ED, while GDPPC, TO, and FD had a negative effect. Acheampong (2019) investigated the direct and indirect effects of FD on CO_2 for 46 Sub-Saharan African countries for the period between 2000 and 2015. Among the indicators used to represent FD, broad money, domestic loans to the private sector and domestic loans to the private sector by banks were found to increase CO_2. On the other hand, it was revealed that FDI liquid liabilities and domestic credit extended by the financial sector to the private sector did not affect CO_2. Mohammed Saud et al. (2019) analyzed the impact of energy consumption (EC), public expenditures and FD on CO_2 for Venezuela for the period 1971-2013 with the ARDL bounds test approach. The results of the analysis indicated that EC and public expenditures had a positive effect on environmental pollution. On the other hand, it was concluded that FD prevented ED in Venezuela. Zhoa & Yang (2020) investigated the relationship between the FD index of cities created since 2001 and CO_2 on a city basis. Panel analysis results revealed that an increase in the level of regional FD significantly reduces CO_2. The study also found that there was a bilateral causality between regional FD and CO_2 in the long run. Ozturk et al. (2020) analyzed the relationship between CO_2 emissions and economic growth, financial development and income inequality for Turkey for the period 1987-2019 using the NARDL method. The findings of the study show that financial development has a positive effect on CO_2 emissions.

Khezri et al. (2021) comprehensively examined the direct and spillover effects of FD on regional CO_2 with spatial econometric models in 31 Asia-Pacific countries in the period between 2000-2018. The study found that GDPPC, TO, energy intensity and URBN had a reducing effect on CO_2. On the other hand, it was concluded that the six FD criteria used in the study positively affected CO_2. In the results of the analysis of spatial effects, it was seen that neighboring countries had a significant effect on the CO_2 of the other country. Ye et al. (2021) examined the relationship between FD and CO_2 for Malaysia over the period 1987-2020. The results of the ARDL bounds test approach revealed that population growth, GDPPC, EC and FD had a positive effect on CO_2. In their comprehensive study, Khan & Ozturk (2021) investigated the relationship between FD and CO_2 in 88 developing countries over the period between 2000 and 2014. Using five different FD indicators, the study found that FD had a negative impact on environmental pollution in selected countries. The study also revealed that FD reduced the negative effects of income, TO, and FDI on CO_2. In a study of 97 countries, Lv & Li (2021) investigated whether there was a spatial correlation between FD and CO_2 in the 2000-2014 period. The findings indicated that FD had a significant impact on reducing CO_2 and that the environmental performance of a country neighboring nearby countries with high FD would have been positively affected. Okumuş & Erdoğan (2021) tested the environmental kuznet curve hypothesis for 6 countries in the top twenty in terms of tourism GDP in the period 1995 - 2014. As a result of the analysis, it was concluded that economic growth, energy consumption and trade reduce environmental pollution in the long term. Erdogan et al. (2022) examined the effect of cryptocurrencies on environmental pollution through Ripple, Bitcoin and Ethereum. In their study, Bitcoin and Ethereum, excluding Ripple, had causal effects on environmental degradation. Pata et al. (2023) analyzed the effect of urbanization on achieving sustainability targets in the period between 1970 and 2018 in their study on the German sample. The results obtained indicate that it reduces environmental pollution in the short and long term. Erdoğan et al. (2023) examined the impact of economic growth, renewable energy investments and technology on the environment in the G7 countries between 2004 and 2018 with second generation analysis methods. The study reveals that economic growth is an important factor in reducing environmental pollution.

Among the recent studies for OECD countries, Lee & Chen (2015) analyzed the relationship between CO_2 and EC, GDPPC and FD for 25 OECD countries for the period 1971-2007 using FMOLS (Fully Modified Ordinary Least Square) method. The findings indicated that the ECA was not valid and FD had a negative effect on CO_2 in eight countries, namely Austria, Denmark, Germany, Ireland, Ireland, the Netherlands, Norway, Portugal and the USA. Halkos & Polemis (2017) analyzed the relationship between FD and ED for the period 1970-2014. It is understood that the effect of FD on CO_2 was positive and statistically significant. Ganda (2019) analyzed the impact of FD on ED for the period 2001-2012 using static models and system GMM analysis. In the study, FDI, banks' domestic loans to the private sector and domestic loans to the private sector were considered as three indicators of FD. The findings indicated that banks' loans to the private sector had a negative impact on CO_2. On the other hand, the effect of domestic loans to the private sector, GDPPC and FDI on CO_2 was positive. In another study, Ganda (2020) analyzed the impact of FDI, GDPPC and FD on the environment in 26 OECD countries in the period 2000-2014. The findings of the study showed that FDI and FD have a negative effect on CO_2, while GDPPC had a positive effect. In another study by Zafar et al. (2019), the impact of EC, globalization and FD on the environment in 27 OECD countries in the period between 1990-2014 was analyzed. It was found that the EKC hypothesis was valid and globalization and FD had a negative impact on CO_2. In addition, the causality test applied in the study showed that there was a unilateral causality from CO_2 emission to FD. Shobande et al. (2022) conducted a study for 24 OECD countries and investigated the impact of FD and EC on environmental sustainability for the period 1980-2019 using the Standard Fixed Effects and Arellano-Bover/Bundell Bond dynamic panel approach. The empirical results revealed that FD and FDI had a negative impact on CO_2 within the scope of the basic model. Szymczyk et al. (2021) analyzed the relationship between GDPPC, EC, URBN, TO, and FD and CO_2 for OECD countries ranked high in the environmental performance index over the period 1990-2014. The findings indicated that there was a positive and statistically significant relationship between GDPPC, EC, URBN, and CO_2. The study also concluded that there was no statistically significant relationship between TO, and CO_2, while FD had a negative impact on CO_2. Dagar et al. (2022) investigated the impact of FD, natural resources, industrial production, REC and total reserves on ED for 38 OECD member countries. The results of the study for the period 1995-2019 indicated that REC and natural resources had a negative impact on ED, while FD, industrial production and total reserves had a positive impact on ED. Jianguo vd. (2022) investigated the impact of institutional quality, technological innovation, and FD on the environment for 37 OECD countries for the period between 1998 and 2018. Empirical results indicated that FD had a positive impact on CO_2. In addition, the study concluded that institutional quality and technological innovation reduced ED. In the study examining the impact of green finance and green innovation on the environment, Umar & Safi (2023) stated that the impact of green finance and innovation on CO_2 for the period 1990-2020 was negative and statistically significant. Erdogan et al. (2023), in their study for 25 OECD countries, examined the effects of economic growth and renewable and non-renewable energy consumption on environmental pollution with both first-generation and second-generation analysis methods. The findings obtained in the study show that in the long term, economic growth has an increasing effect on environmental pollution and renewable energy consumption has a reducing effect on environmental pollution.

Finally, Yuan et al. (2021), one of the few studies examining the relationship between FINI and CO_2, examined the relationship between FINI and green innovation in 23 OECD countries for the period 1994-2009. The results indicated that FINI supported green innovation in more technology-intensive sectors. The study also stated that the effect of FINI on green innovation had an incentive effect in countries with stricter environmental regulations and lower banking competition. Chisti & Sinha (2022) analyzed the impact of technology and FINI on CO_2 for BRICS countries using the second-generation Augmented Mean Group (AMG) and Common Correlated Effect Mean Group (CCEMG) approach. The results indicated that firstly, positive shocks from FINI had a negative impact on CO_2, while negative shocks had a positive impact. Secondly, positive shocks in technological innovation were found to be significantly effective in reducing CO_2, while negative shocks had no effect.

3. METHODOLOGY

The study aims to examine the impact of FINI, GDPPC and URBN on CO_2 for OECD countries for the period 2009-2019. In the study, common data for 14 OECD member countries (Belgium, Canada, Czechia, Finland, Finland, Germany, Italy, Lithuania, Norway, Portugal, S. Korea, Spain, Turkey, the UK, the USA) are obtained and the analysis covers these countries. In the study, the model created within the framework of Chisthi & Sinha (2022) is as follows;

$$lnCO_{2it} = \alpha_0 + a_1 lnFINI_{it} + a_2 lnGDPPC_{it} + \alpha_3 lnURBN_{it} + u_{it} \quad (1)$$

Detailed information on the variables used in the analysis can be found in Table 1.

Table 1. Information on the Dataset

Variable Name	Description	Source
$lnCO_2$	CO_2 emissions (kg per 2015 US$ of GDP)	WDI
lnFINI	Total BERD / Financial and Insurance Activities 2015 US$	OECD
lnGDPPC	GDP per capita (constant 2015 US$)	WDI
lnURBN	Urban population	WDI

Methodologically, the stationarity of the series used in the study will first be investigated with Levin, Lin & Chu, (2002) (LLC), Im, Pesaran & Shin (IPS) unit root tests. Cointegration analysis between the series will be examined with the Pedroni and Kao cointegration test. FMOLS coefficient estimator will be used to determine the direction and coefficient of the cointegration relationship of the variables. The causality between the variables will be investigated with the Dumitrescu-Hurlin (D-H) causality test.

The Levin, Lin & Chu (2002) unit root test, which is used to determine the stationarity of the series in the study, claims that individual unit root tests have boundary power against the alternative hypothesis and that there are also quite persistent deviations from equilibrium. It is recognized that this will be even more severe in small samples. LLC proposes a more robust unit root test for each cross-section against individual unit root tests. In this test, the null hypothesis states that each individual time series has a unit root, while the alternative hypothesis states that each time series is stationary (Baltagi, 2005: 40). According to the Im, Peseran & Shin test, which proposes an alternative panel unit root test to the LLC, which proposes to apply the unit root test only to homogeneous cross-sections, the ADF is calculated for each individual in the panel and the average ADF test statistic is calculated. With T time-series and N cross-sections, the stochastic process yi,t is defined as follows in the first order autoregressive process (Göral, 2015:110).

In this study, the long-run cointegration of variables will be analyzed with the Pedroni cointegration test. In panel data analyses, it is widely used to test the existence of long-run cointegration between variables. The Pedroni cointegration tests (1999 & 2004) test the null hypothesis of zero cointegration for the case with multiple regressors and provide appropriate critical values for these cases. The tests allow for considerable heterogeneity across individual members of the panel, including both heterogeneity in the long-run cointegrating vectors and heterogeneity in the dynamics associated with short-run deviations from these cointegrating vectors.

The Pedroni cointegration test proposes two groups of tests to be applied to determine the cointegration relationship: panel tests and group tests. The formulation of test statistics is presented in Table 2.

Table 2. Pedroni Cointegration Test Statistics

	Within-dimension	
Part One	Panel v-statistic	$T^2N^{3/2}Zv_{N,T} \equiv T^2N^{3/2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}e_{i,t-1}^{2}\right)^{-1}$
	Panel p-Statistics	$T\sqrt{N}\,Z_{P_{N,T^{-1}}} \equiv T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}e_{i,t-1}^{2}\right)^{-1}$
	Panel t-statistic (Nonparametric)	$Z_{tN,T} \equiv \left(\sigma_{N,T}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}e_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}\left(e_{i,t-1}^{*}\Delta e_{it}-\lambda_i\right)$
	Panel t-statistic Parametric	$Z_{tN,T}^{*} \equiv \left(S_{N,T}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}e_{i,t-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}L_{1\,1i}^{-2}e_{i,t-1}^{*}\Delta e_{it}^{*}$
	Between-dimension	
Part Two	Group-p Statistics	$TN^{-1/2}Z_{P_{N,T^{-1}}} \equiv TN^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}e_{i,t-1}^{2}\right)^{-1}\sum_{t=1}^{T}\left(e_{i,t-1}\Delta e_{it}-\lambda_i\right)$
	Group-t Statistic (Nonparametric)	$N^{-1/2}Z_{P_{N,T^{-1}}} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sigma_i^2\sum_{t=1}^{T}e_{i,t-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}\left(e_{i,t-1}\Delta e_{it}-\lambda_i\right)$
	Group-t Statistic (Parametric)	$N^{-1/2}Z_{P_{N,T^{-1}}} \equiv N^{-1/2}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}s_i^{*2}e_{i,t-1}^{2*}\right)^{-1/2}\sum_{t=1}^{T}e_{i,t-1}^{*}\Delta e_{it}^{*}$

Source: Pedroni, (1999).

In this study, the FMOLS method developed by Pedroni is used to analyze the effect of independent variables on dependent variables. This method was developed to examine the asymptotic properties of cointegration regressions in dynamic panels with common cointegration vectors and to overcome the complications of parameter heterogeneity and the presence of fixed effects among individual members in dynamic panels.

The panel regression model based on the FMOLS method is as follows

$$Y_{it} = \alpha_i + \beta x_{it} + \mu_{it} \tag{2}$$

$$X_{it} = X_{it-1} + \varepsilon_{it} \tag{3}$$

where the vector error process $\xi_{it} = \mu_{it}$, ε_{it} asymptotic covariance matrix Ω_i is stationary. Thus X_{it}, Y_{it} cointegration vector of the variables for each member of the panel β with Y_{it} is cointegrated if it is integrated of the first order. α_i allows the cointegration relationship to include member-specific fixed effects. In line with the cointegration literature, this method does not require the exogeneity of regressors. Also, as always X_i can be an m-dimensional vector of regressors that are generally not cointegrated with each other. In summary, FMOLS explores methods for testing and inferring cointegration vectors in heterogeneous panels based on FMOLS principles. When properly constructed to account for potential heterogeneity in idiosyncratic dynamics and the fixed effects associated with such panels, the asymptotic distributions for these estimators will be centered around the true value and free of disturbing parameters. Moreover, based on Monte Carlo simulations, it has been found that the t-statistic generated from the cross-dimensional group mean estimator in particular performs very well with relatively small sample size distortion (Pedroni, 2000: 98).

We use the Dumitrescu & Hurlin (2012) panel causality test, which proposes a simple Granger causality test for heterogeneous panel data models with constant (rather than time-varying) coefficients. Within the framework of a linear autoregressive data generating process, extending standard causality tests to panel data requires testing cross-sectional linear restrictions on the coefficients of the model. As always, the use of cross-sectional information can extend the set of information on causality from one particular variable to another. Indeed, for many economic issues, if causality exists for one country or individual, it is likely to exist for some other country or individual. In this case, causality can be tested more efficiently in a panel context with NT observations. However, the use of cross-sectional information involves taking into account heterogeneity across individuals in the definition of causality (Dumitrescu & Hurlin, 2012: 1452-1453). The Panel Causality test, which is a simple adaptation of the bivariate causality test developed by Granger, is based on the average of individual Wald statistics computed for cross-sectional units in the context of Granger causality. First, this statistic is shown to converge sequentially to a standard normal distribution. Second, the quasi-asymptotic distribution of the mean statistic is defined for a fixed sample T. However, a standard statistic based on the estimation of the moments of the Wald statistics is proposed. In the third stage, Monte Carlo tests confirm that standard panel statistics have very good small sample properties even in the presence of cross-sectional dependence (Arıcı, 2015: 84).

4. ANALYSIS RESULTS

In this section, the results of the analysis conducted to determine the relationship between FINI, GDPPC and URBN and CO_2 in OECD member countries will be evaluated. Firstly, the results of Levin, Lin & Chu (2002), Im, Peseran & Shin (2003) unit root tests, which test the stationarity of the series, which is the most important issue in time series and panel data analyses, are presented in Table 3.

Table 3. Panel Unit Root Tests Results

Tests	LLC		IPS	
Level	Constant		Constant	
	t-statistic	Probability	t-statistic	Probability
ln CO_2	-0.664	0.253	3.459	0.999
lnFINI	-0.588	0.278	-1.127	0.129
lnGDPPC	-1.362[c]	0.086	1.640	0.949
lnURBN	-2.134[b]	0.016	2.173	0.985
Difference Values				
ΔlnCO_2	-9.814[a]	0.000	-6.828[a]	0.000
ΔlnFINI	-10..677[a]	0.000	-6.088[a]	0.000
ΔlnGDPPC	-9.155[a]	0.000	-4.424[a]	0.000
ΔlnURBN	-3.490[a]	0.000	-2.531[a]	0.005

Note: Δ : denotes the first difference of the series. ([a]) significant at 1% level, ([b]) significant at 5% level, ([c]) significant at 10% level.

Logarithms of the variables are taken and unit root tests are applied for both level and first differences. The maximum lag lengths that eliminate the problem of autocorrelation among errors are determined by the Schwarz information criterion. In addition, the Bartlett Kernel method is used along with the Newey-West bandwidth selection when calculating the LLC test. According to the results of the panel unit root test in Table 2, according to LLC and IPS unit root tests, (CO_2) carbon dioxide per capita and (FINI) financial innovation rate are non-stationary at level. In the results of other variables, (GDPPC) national income per capita and (URBN) URBN are found to be non-stationary according to the LLC method, but non-stationary according to the IPS method. Therefore, the difference process was applied to the series and it was observed that all series were stationary at the 1% level at the first difference level.

Table 4. Panel Cointegration Tests Results

Pedroni Panel Cointegration Test	t-statistic	Probability	Weighted t-statistic	Weighted Probability
Panel v-statistic	-0.116	0.546	-1.110	0.866
Panel rho-statistic	0.958	0.831	1.394	0.918
Panel PP-statistic	-4.713***	0.000	-4.667***	0.000
Panel ADF-statistic	-4. 409***	0.000	-3.150***	0.000
Group rho-statistic	2.969	0.998		
Group PP-statistic	-8.234***	0.000		
Group ADF-statistic	-6.897***	0.000		
Kao Panel Cointegration Test	**t-statistic**	**Probability**		
ADF	-1.770**	0.038		

Note: *** indicates significance at 1%, ** at 5%, * at 10% level.

After determining that the series are stationary in the panel unit root test results, the cointegration relations of the series are analyzed through Pedroni and Kao cointegration tests. The results of the analysis are presented in Table 4. According to these results, panel PP and panel ADF statistics from within-group statistics, group PP and group ADF statistics from between-group statistics are significant at a 1% significance level, while other within-group and between-group statistics are not significant. Although four of the seven statistics applied in the Pedroni cointegration test were significant, the Kao cointegration test was applied as an alternative to support the result. Accordingly, the results of the Kao cointegration test were found to be consistent with the results of the Pedroni cointegration test.

The direction and degree of cointegration relationship obtained in the study are analyzed by the FMOLS method. The results of the FMOLS method for OECD countries are presented in Table 5. According to the test results, FINI, GDPPC and URBN have a negative effect on CO_2 in OECD countries during the study period. Therefore, it is concluded that FINI, GDPPC, and URBN can reduce environmental pollution in OECD countries.

Table 5. FMOLS Estimation Results

Model	$lnCO_{2it} = \alpha_0 + a_1 lnFINI_{it} + a_2 lnGDPPC_{it} + \alpha_3 lnURBN_{it} + u_{it}$	
Variables	**Coefficient**	**Probability**
lnFINI	-0.122*	0.084
lnGDPPC	-0.844***	0.000
lnURBN	-0.767***	0.000

Note: *** indicates significance at 1%, ** at 5%, * at 10% level.

When the results obtained are evaluated, it is seen that they are not compatible with the studies of Abbasi & Riaz (2016); Çetin & Ecevit (2017); Acheampong (2019); Khezri et al. (2021); Halkos & Polemis (2017); Ganda (2019); Çetin & Yüksel (2018); Dagar et al. (2022); Doğan et al. (2023), which examine the relationship between FD and CO_2. On the other hand, the results of the study are in line with Mohammed Saud et al. (2019); Zhoa & Yang (2020); Khan & Ozturk (2021); Kılavuz et al., (2021); Lv & Li (2021); Lee & Chen (2015); Ganda (2020); Zafar et al. (2019); Shobande et al. (2022); Shahbaz et al. (2023a). In addition, the results are consistent with Yuan et al. (2021); Chisti & Sinha (2022), which examine the relationship between FINI and CO_2. When the results of the relationship between economic growth and CO_2 emissions are evaluated, it is understood that it is compatible with the studies of Şeker et al. (2015); Shahbaz et al. (2023b); Çetin et al. (2020); Dong et al. (2018); Ertugrul et al. (2016). When the relationship between urbanization and CO_2 emissions is examined, it is determined that the results of the analysis are not compatible with the studies of Çetin et al. (2022); Raza et al. (2023), whereas they are compatible with the studies of Rasool et al. (2022); Ullah et al. (2023); Zheng et al. (2023).

Finally, the causality between the variables in the model constructed in the study is analyzed by the D-H panel Granger causality test. The results of D-H causality test are presented in Table 6.

Table 6. D-H Granger Causality Test Results

Null Hypothesis	**Wald Statistic**	**Z-bar Statistic**	**Probability**
$lnFINI \nrightarrow lnCO2$	2.236	1.117	0.263
$lnCO2 \nrightarrow lnFINI$	2.932**	2.047	0.040
$lnGDPPC \nrightarrow lnCO2$	5.235***	5.125	0.000
$lnCO2 \nrightarrow lnGDPPC$	3.530***	2.846	0.004
$lnURBN \nrightarrow lnCO2$	11.576***	13.599	0.000
$lnCO2 \nrightarrow lnURBN$	4.077***	3.577	0.000

Note: *** indicates significance at 1%, ** indicates significance at 5%, * indicates significance at 10% level.

The D-H causality test results in Table 6 show that there is a unilateral causality between FINI and CO_2 and this relationship is from CO_2 to FINI. In other results, there is a strong bilateral causality between GDPPC and URBN and CO_2. In line with these results, it is understood that URBN and GDPPC are effective factors on EP. The results obtained are consistent with the studies of Çetin & Ecevit (2015); Shahbaz et al. (2016); Çetin et al. (2018); Topcu et al. (2023).

5. CONCLUSION

Following the invention and diffusion components of innovation, FINI is also realized through product and process innovations that are subject to the demand of nations' economic systems. Since the development of the pollution trading market, FINI has been envisioned as a means to finance environmental projects. In the US, FINIs such as debt-for-nature swaps and individually transferable fishing quotas are among the policies introduced to prevent ED. In addition, allowing the trading of renewable energy certificates in the secondary market also plays an important role in renewable energy solutions. Thanks to these innovative financial products, a significant portion of developed countries have started to reduce their dependence on fossil fuels (Chisti & Sinha, 2022).

Although many studies have been conducted to examine the relationship between FD and ED, there are few studies with data prepared with a different method and perspective. This study analyzes the relationship between FINI and CO_2 for OECD countries in order to make a different contribution to the literature. The model also investigates the impact of GDPPC and URBN on CO_2. Pedroni and Kao cointegration method and FMOLS estimator, which are first generation data analysis methods, are used in the study. The analysis shows that GDPPC, URBN, and FINI have a negative impact on CO_2 in 14 OECD countries with common data for the period covering 2009-2019. Accordingly, it is evaluated that FINI may have an important role in preventing ED in these countries.

When the findings of the analyses and the literature are analyzed, policy recommendations can be summarized as follows. Firstly, policy makers should involve all stakeholders such as firms, managers, relevant public institutions and organizations and NGOs in the process of determining environmental policies. Secondly, financial resources should be transferred to research and development activities that reduce ED in order to use them more efficiently rather than consumer financing. Thirdly, the necessary legislation should be prepared for the necessary incentive policies and tax exemptions for the transition to a green economy.

AUTHORS' DECLARATION

This paper complies with Research and Publication Ethics, has no conflict of interest to declare, and has received no financial support.

AUTHORS' CONTRIBUTIONS

All sections are written by the author.

REFERENCES

Abbasi, F., & Riaz, K. (2016). CO_2 emissions and financial development in an emerging economy: An augmented VAR approach. *Energy policy*, 90, 102-114.

Acheampong, A. O. (2019). Modelling for insight: Does financial development improve environmental quality?. *Energy Economics*, 83, 156-179.

Arıcı, T. (2015). *Liberalizasyon ve ekonomik büyüme: Geçiş ekonomileri.* (Master dissertation, Sakarya University).

Çetin, M., & Ecevit, E. (2015). Urbanization, energy consumption and CO_2 emissions in Sub-Saharan countries: A panel cointegration and causality analysis. *Journal of Economics and Development Studies*, 3(2), 66-76.

Cetin, M., & Ecevit, E. (2017). The impact of financial development on carbon emissions under the structural breaks: Empirical evidence from turkish economy. *International Journal of Economic Perspectives*, 11(1).

Çetin, M., & Yüksel, Ö. (2018). Türkiye ekonomisinde enerji tüketiminin karbon emisyonu üzerindeki etkisi. *Mehmet Akif Ersoy Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 5(2) , 169-186.

Çetin, M., Aslan, A., & Sarıgül, S. S. (2022). Analysis of the dynamics of environmental degradation for 18 upper middle-income countries: The role of financial development. *Environmental Science and Pollution Research,* 29(43), 64647-64664.

Cetin, M., Ecevit, E., & Yucel, A. G. (2018). Structural breaks, urbanization and CO_2 emissions: Evidence from Turkey. *Journal of Applied Economics & Business Research,* 8(2), 122-139.

Chishti, M. Z., & Sinha, A. (2022). Do the shocks in technological and financial innovation influence the environmental quality? Evidence from BRICS economies. *Technology in Society*, 68, 101828.

Dagar, V., Khan, M. K., Alvarado, R., Rehman, A., Irfan, M., Adekoya, O. B., & Fahad, S. (2022). Impact of renewable energy consumption, financial development and natural resources on environmental degradation in OECD countries with dynamic panel data. *Environmental Science and Pollution Research*, 29(12), 18202-18212.

Doğan, M., Raikhan, S., Zhanar, N., & Gulbagda, B. (2023). Analysis of dynamic connectedness relationships among clean energy, carbon emission allowance, and BIST indexes. *Sustainability*, *15*(7), 6025.

Dong, K., Sun, R., Jiang, H., & Zeng, X. (2018). CO_2 emissions, economic growth, and the environmental kuznets curve in China: What roles can nuclear energy and renewable energy play?. *Journal of cleaner production*, 196, 51-63.

Dumitrescu, E. I., & Hurlin, C. (2012). Testing for granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4), 1450-1460.

Erdogan, S., Ahmed, M. Y., & Sarkodie, S. A. (2022). Analyzing asymmetric effects of cryptocurrency demand on environmental sustainability. *Environmental Science and Pollution Research*, 1-11.

Erdogan, S., Okumus, I., & Guzel, A. E. (2020). Revisiting the environmental kuznets curve hypothesis in OECD countries: the role of renewable, non-renewable energy, and oil prices. *Environmental Science and Pollution Research*, 27, 23655-23663.

Erdogan, S., Pata, U. K., & Solarin, S. A. (2023). Towards carbon-neutral world: the effect of renewable energy investments and technologies in G7 countries. *Renewable and Sustainable Energy Reviews*, 186, 113683.

Ertugrul, H. M., Cetin, M., Seker, F., & Dogan, E. (2016). The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries. *Ecological Indicators*, 67, 543-555.

Ganda, F. (2019). The environmental impacts of financial development in OECD countries: a panel GMM approach. *Environmental Science and Pollution Research*, 26(7), 6758-6772.

Ganda, F. (2020). Effect of foreign direct investment, financial development, and economic growth on environmental quality in OECD economies using panel quantile regressions. *Environmental Quality Management*, 30(2), 89-118.

Halkos, G. E., & Polemis, M. L. (2017). Does financial development affect environmental degradation? Evidence from the OECD countries. *Business Strategy and the Environment*, 26(8), 1162-1180.

Im, K. S., Pesaran, M. H., Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 53-74.

Jianguo, D., Ali, K., Alnori, F., & Ullah, S. (2022). The nexus of financial development, technological innovation, institutional quality and environmental quality: Evidence from OECD economies. *Environmental Science and Pollution Research*, 29(38), 58179-58200.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, 90(1), 1-44.

Khan, A. B., Fareed, M., Salameh, A. A., & Hussain, H. (2021). Financial innovation, sustainable economic growth, and credit risk: A case of the ASEAN banking sector. *Frontiers in Environmental Science*, 9, 729922.

Khan, M., & Ozturk, I. (2021). Examining the direct and indirect effects of financial development on CO_2 emissions for 88 developing countries. *Journal of environmental management*, 293, 112812.

Khezri, M., Karimi, M. S., Khan, Y. A., & Abbas, S. Z. (2021). The spillover of financial development on CO_2 emission: A spatial econometric analysis of Asia-Pacific countries. *Renewable and Sustainable Energy Reviews*, 145, 111110.

Kılavuz, E., Oralhan, B., Sarigül, S. S., & Uluğ, E. E. (2021). The validity of the tourism-induced EKC hypothesis: The case of Turkey. *International Journal of Business and Economic Studies*, *3*(2), 124-138.

Lee, J. M., Chen, K. H., & Cho, C. H. (2015). The relationship between CO_2 emissions and financial development: Evidence from OECD countries. *The Singapore Economic Review*, 60(05), 1550117.

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.

Lv, Z., & Li, S. (2021). How financial development affects CO_2 emissions: A spatial econometric analysis. *Journal of Environmental Management*, 277, 111397.

Mohammed Saud M, A., Guo, P., Haq, I. U., Pan, G., & Khan, A. (2019). Do government expenditure and financial development impede environmental degradation in Venezuela?. *PloS one*, 14(1), e0210255.

OECD,(2023).https://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=BERD_INDU&ShowOnWeb=true&Lang=en, Date of Access: 01.05.2023.

Okumus, I., & Erdogan, S. (2021). Analyzing the tourism development and ecological footprint nexus: evidence from the countries with fastest-growing rate of tourism GDP. *Strategies in Sustainable Tourism, Economic Growth and Clean Energy*, 141-154.

Omri, A., Daly, S., Rault, C., & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Economics*, 48, 242-252.

Ozturk, S., Cetin, M., & Demir, H. (2022). Income inequality and CO_2 emissions: Nonlinear evidence from Turkey. *Environment, Development and Sustainability*, 24(10), 11911-11928.

Pata, U. K., Erdogan, S., & Ozcan, B. (2023). Evaluating the role of the share and intensity of renewable energy for sustainable development in Germany. *Journal of Cleaner Production*, 138482.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, 61(1): 653- 570.

Pedroni, P. (2000). *Fully modified ols for heterogeneous cointegrated panels,* in Baltagi, Badi H. (Ed.), Nonstationary Panels, Panel Cointegration and Dynamic Panels (Advances in Econometrics), New York: Elsevier Science Inc. 93–130.

Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels, *Review of Economics and Statistics*, 83, 727-931.

Pedroni, P. (2004). Panel cointegration, asymptotic and finite sample properties of pooled time series tests with an application to the purchasing power parity hypothesis, *Econometric Theory*, 20(3), 597-625.

Rasool, S. F., Zaman, S., Jehan, N., Chin, T., Khan, S., & uz Zaman, Q. (2022). Investigating the role of the tech industry, renewable energy, and urbanization in sustainable environment: Policy directions in the context of developing economies. *Technological Forecasting and Social Change*, *183*, 121935.

Raza, M. Y., Hasan, M. M., & Chen, Y. (2023). Role of economic growth, urbanization and energy consumption on climate change in Bangladesh. *Energy Strategy Reviews*, 47, 101088.

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO_2 emissions in Kuwait. *Renewable and Sustainable Energy Reviews*, 81, 2002-2010.

Secretary-General, U. N. (2022). Progress towards the sustainable development goals: Report of the secretary-general. https://unstats.un.org/sdgs/files/report/2022/secretary-general-sdg-report-2022--EN.pdf, Date of Access: 04.05.2023.

Seker, F., Ertugrul, H. M., & Cetin, M. (2015). The impact of foreign direct investment on environmental quality: A bounds testing and causality analysis for Turkey. *Renewable and Sustainable Energy Reviews*, 52, 347-356.

Shahbaz, M., Dogan, M., Akkus, H. T., & Gursoy, S. (2023a). The effect of financial development and economic growth on ecological footprint: Evidence from top 10 emitter countries. *Environmental Science and Pollution Research*, 1-16.

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. *Renewable and Sustainable Energy Reviews*, 57, 83-93.

Shahbaz, M., Topcu, B. A., Sarıgül, S. S., & Doğan, M. (2023b). Energy imports as inhibitor of economic growth: The role of impact of renewable and non-renewable energy consumption. *The Journal of International Trade & Economic Development*, 1-26.

Shobande, O. A., & Ogbeifun, L. (2022). The criticality of financial development and energy consumption for environmental sustainability in OECD countries: Evidence from dynamic panel analysis. *International Journal of Sustainable Development & World Ecology*, 29(2), 153-163.

Szymczyk, K., Şahin, D., Bağcı, H., & Kaygın, C. Y. (2021). The effect of energy usage, economic growth, and financial development on CO_2 emission management: An analysis of OECD countries with a high environmental performance index. *Energies*, 14(15), 4671.

Topcu, B. A. (2023). An Empirical Analysis of the impact of environmental taxes, renewable energy consumption, and economic growth on environmental quality: Evidence from twelve selected countries. *International Journal of Business and Economic Studies*, *5*(2), 98-108.

Tufano, P. (2003). Financial innovation. Handbook of the economics of finance, 1, 307-335.

Ullah, A., Tekbaş, M., & Doğan, M. (2023). The impact of economic growth, natural resources, urbanization and biocapacity on the ecological footprint: The case of Turkey. *Sustainability*, *15*(17), 12855.

United Nations Secretary-General, (2013). Initial input of the secretary-general to the open working group on SDGs https://sustainabledevelopment.un.org/owg1.html, Date of Access: 04.05.2023.

United Nations, (2015). Transforming our world: the 2030 agenda for sustainable development. outcome document for the un summit to adopt the post-2015 development agenda: draft for adoption, New York

Worldbank, (2023). https://databank.worldbank.org/source/world-development-indicators , Date of Access: 01.05.2023.

Ye, Y., Khan, Y. A., Wu, C., Shah, E. A., & Abbas, S. Z. (2021). The impact of financial development on environmental quality: Evidence from Malaysia. *Air Quality, Atmosphere & Health*, 14, 1233-1246.

Yuan, G., Ye, Q., & Sun, Y. (2021). Financial innovation, information screening and industries green innovation-industry-level evidence from the OECD. *Technological Forecasting and Social Change*, 171, 120998.

Zafar, M. W., Saud, S., & Hou, F. (2019). The impact of globalization and financial development on environmental quality: Evidence from selected countries in the organization for economic co-operation and development (OECD). *Environmental Science and Pollution Research*, 26, 13246-13262.

Zhao, B., & Yang, W. (2020). Does financial development influence CO_2 emissions? A chinese province-level study. *Energy*, 200, 117523.

Zheng, S., Irfan, M., Ai, F., & Al-Faryan, M. A. S. (2023). Do renewable energy, urbanisation, and natural resources enhance environmental quality in China? Evidence from novel bootstrap Fourier Granger causality in quantiles. *Resources Policy*, *81*, 103354.

APPENDIX

Appendix 1. List of Abbreviations

Acronyms			
OECD	Organization For Economic Co-Operation and Development	**CCEMG**	Common Correlated Effect Mean Group
CO2	Carbon Dioxide Emissions	**FDI**	Foreign Direct Investments
LLC	Levin-Lin ve Chu	**FINI**	Financial Innovation
IPS	Im-Pesaran ve Shin	**MENA**	Middle East and North Africa
FMOLS	Fully Modified Ordinary Least Squares	**ISIC**	International Standard Industrial Classification
NGOs	Non-Governmental Organizations	**ARDL**	Autoregressive Distributed Lag Model
SDGs	Sustainable Development Goals	**FD**	Financial Development
ED	Environmental Degradation	**AMG**	Augmented Mean Group
GDP	Gross Domestic Product	**URBN**	Urbanization