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Does Internet Use Affect Air Pollution? Evidence from OECD Countries

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ABSTRACT

This study aims to analyze the relationship between the use of the internet, which has an important place in information and communication, and air pollution (Carbon Dioxide Emissions-CO_2). In this context, the relationship between the variables for the 1994-2019 period in 28 OECD countries selected was tested with the help of a panel data analysis with Fourier functions (Fourier unit root test, panel Fourier cointegration test and panel Fourier causality test). The results of the analysis show that internet use reduces air pollution, while economic growth increases air pollution. The results of the Panel Fourier Granger Causality test revealed a bidirectional causality relationship between internet use and air pollution and a unidirectional causality relationship from air pollution to economic growth throughout the panel. The analysis results present a policy proposal to the governments of OECD countries that they can reduce air pollution by investing in information and communication technologies (ICT) in their economic growth processes.

Keywords: Internet Use, Economic Growth, Air Pollution, Information and Communication Technologies, Fourier Functions
JEL Classifications: 033, 044, Q53, Q56

1. INTRODUCTION

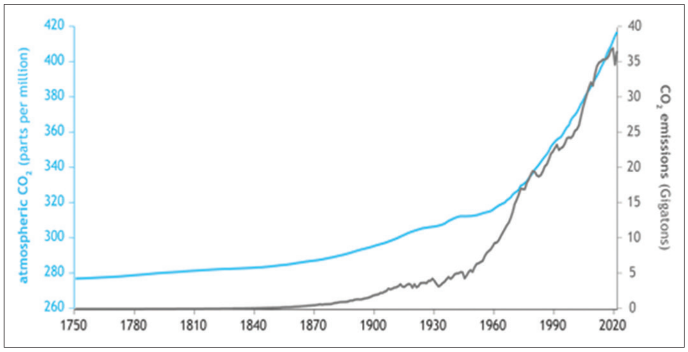
Today, environmental pollution has become one of the most critical problems in the world due to its socio-cultural, political, health, and economic effects. For this reason, the importance given to the protection of the environment, the efforts of countries to reduce environmental damage, and the safety of the ecological order are one of the essential focal points of today's world. In this context, countries have begun seeking solutions to prevent environmental destruction. One of the most critical policies in the solution process is to find the reasons for the emergence of the problem and to eliminate these reasons or to reduce the effects of these causes.

In the literature, the increase in carbon dioxide (CO_2) emissions over time is shown as the most crucial indicator of environmental and air pollution. It is possible to see this increase in CO_2 emissions from the Industrial Revolution to the present in Graph 1.

When Graph 1 is examined, it is seen that there has been a severe increase in CO_2 emissions since the beginning of the Industrial Revolution in the middle of the 18th century. Although these increases only occurred a little at the beginning of the 1900s, it is observed that the rate of increase in CO_2 emissions increased after this date, and especially after the 1980s, the rate of increase reached the highest level.

The fact that the increases have been so high in the last century has led to more studies investigating the factors that cause the rise in CO_2 emissions. When the studies in this field are gathered under a typical roof, the factors increasing CO_2 emissions: It is determined as economic growth, excessive use of energy (especially from non-renewable energy sources), urbanization, industrialization, non-modern technological production, globalization (Li et al., 2021), population growth and an increase in deforested areas. After identifying the determinants of CO_2 emissions, which significantly

Graph 1: Development of CO_2 emissions in the world CO_2 emissions data are from Global Carbon Protect. CO_2 data is from Our World in Data. NOAA Climate.gov graphic, from the original Dr Adapted by Howard Diamond (NOAA ARL)



Source: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide (Climate.gov 2023)

impact the environment and air pollution, studies have focused on research that highlights policy recommendations to reduce CO_2 emissions. The studies in this context show that applications that reduce CO_2 emissions can be carried out by increasing the use of renewable energy resources, establishing environmental cities, production with more modern techniques, and, most importantly, using bites in all areas of life.

Studies show that technological development and, accordingly, the use of ICTs are also effective in environmental and air pollution. However, it is impossible to say that the studies in this field have reached a common idea. While some studies argue that using ICTs increases environmental and air pollution by causing more energy use (Salahuddin, 2016; Kim, 2021; Magazzino, 2021; Zeeshan et al., 2022), some studies state that ICTs positively affect the environment and air pollution due to less energy consumption and greater efficiency (Zhang and Liu, 2015; Ozcan and Apergis, 2018; Mahdavi and Sojoodi, 2021; Chatti, 2021; Wang et al., 2022; Ozpolat, 2022; Zhang et al., 2022; Liu, 2022; Zafar et al., 2022; Zhu and Lu, 2023).

Today's production technologies support the second view because they are based on less labour-intensive and more capital-intensive technologies, and technologies compatible with sustainable development gain a more modern structure day by day. Thanks to this support, the importance of ITs is increasing daily.

ICTs consist of a wide range of tools. However, the usage weights of these vehicles are very different from each other. One of the most used tools among ICTs is the internet. Internet use is developing rapidly every day. The increase in internet usage over time increases the efficiency while reducing costs with less energy use, which has positive results both in economic and environmental terms. From this perspective, it aims to examine the effect of individual internet use, which is the final result of technological development, on CO_2 emissions, one of the most important indicators of air pollution. In line with the related purpose, it was deemed appropriate to conduct the study by considering 28 OECD countries, aiming to evaluate the country group to be examined in a wide range. The fact that very few similar studies in the literature can be expressed as an essential point that distinguishes the study from other studies. Although the econometric analysis to be applied in the study is panel data analysis, the fact that the tests used in the analysis are Panel Fourier tests is another important feature that distinguishes the study from other studies. Panel Fourier tests are the most up-to-date ones that minimize the error margin. In addition to the relevant tests, the Panel Fourier Granger Causality test will be used to determine the causality relationship between the variables.

In the study, following the introduction, respectively literature review, the analysis method to be applied and the data and model section where the formulations of the tests are expressed, the empirical findings and the conclusion section where the test results are expressed within the tables.

2. LITERATURE REVIEW

Although many studies analyze the effects of economic growth on air pollution or the environment, very few studies analyze the effects of internet use on air pollution. Most of these limited studies focus on the effects of information and communication technologies on air pollution. The literature review of the study consisted of two subsections. These are studies that deal with the relationship between information and communication technologies or internet use and air pollution, and studies that deal with the relationship between economic growth and air pollution or the environment.

2.1. Information Communication Technologies/Internet Use and Air Pollution

Various studies in the literature have investigate the relationship between information and communication technologies/internet use and environmental degradation/air pollution. Although studies detect a positive relationship between information communication technologies and environmental degradation (Salahuddin, 2016; Kim, 2021; Magazzino, 2021; Zeeshan et al., 2022), studies have suggested that information communication technologies reduce environmental degradation (Zhang and Liu, 2015; Ozcan and Apergis, 2018; Mahdavi and Sojoodi, 2021; Chatti, 2021; Wang et al., 2022; Ozpolat, 2022; Zhang et al., 2022; Liu, 2022; Zafar et al., 2022; Zhu, and Lu 2023). Additionally, also studies found an inverted U-shaped relationship (Jafariparvizkhanlou et al., 2021). Additionally, in some studies with a large sample group, different results were obtained on a country basis (Al-Mulali et al., 2015; Majeed, 2018).

Salahuddin (2016), one of the studies that found a positive relationship between information and communication technologies and environmental degradation, investigated the effects of economic growth and internet use on carbon dioxide emissions using OECD panel data. The results of the analysis revealed a positive relationship between internet use and CO_2 emissions, but there is no causality because the coefficient is insignificant. Additionally, it has been revealed that economic growth does not affect CO_2 emissions in the short and long term. Kim (2021) analyzed the effects of information and communication technology (ICT), economic growth, trade openness, and financial development on CO_2 emissions in Korea with the help of data from 1990 to 2016 using the autoregressive distributed lag (ARDL) test. When the results are analyzed, it is observed that other factors besides ICT do not have a significant effect on CO_2 emissions in the long run, but economic growth and information and communication technologies increase CO_2 emissions in the short run. Magazzino (2021) investigated the relationship between Information and Communication Technologies (ICT) penetration, economic growth, electricity consumption, and environmental pollution in 16 EU countries using a panel data analysis method using the data between 1990 and 2017. As a result of the analysis, it was revealed a one-way causality arising from the use of ICT and electricity consumption. Additionally, it has been determined that the use of ICT increases CO_2 emissions. Using Quantitative Panel Regression and Dynamic Fixed Effect estimation techniques, Zeeshan et al. (2022) analyzed the relationship between Information Communication Technologies, renewable energy use, and environmental quality between 2000 and 2018. The results of the study revealed that the use of ICT increases environmental degradation. Additionally, renewable energy has improved the environmental quality. Zhang and Liu (2015), one of the studies suggesting that information communication technologies reduce environmental degradation, investigated the impact of the ICT industry in China on CO_2 emissions using the STIRPAT model and panel data analysis. Ozcan and Apergis (2018) examined the impact of internet use on CO_2 emissions in 20 developing countries with the help of data from 1990 to 2015. According to the panel data results, it has been revealed that the increase in internet access reduces air pollution. Additionally, there is a unidirectional causality running from internet use to CO_2 emissions. Mahdavi and Sojoodi (2021) analyzed the relationship between Information and Communication Technologies (ICT) and environmental degradation in a group of high, middle, and low-income countries using the Generalized Method of Moments (GMM) with the help of data from 2005 to 2019. In line with the findings, it has been observed that the increase in the use of ICT reduces environmental degradation. Chatti (2021) analyzed the relationship between ICTs, transportation, and CO_2 emissions in 43 countries using the 2-step system Generalized Method of Moments (GMM) with the help of data from 2002 to 2014. The analysis findings revealed that if ICT is well adapted to the transportation sector, it reduces environmental pollution.

According to Zafar et al. (2022), the effects of ICT and education on environmental quality were analyzed with the Cup-FM test. The findings show that education, economic growth, and energy consumption increased carbon emissions in Asia between 1990 and 2018. Additionally, it has been determined that financial development and ICT have adverse effects on carbon emissions. Liu (2022) analyzed the effects of internet use on environmental pollution with the help of 2009-2019 panel data for 295 cities in China. In line with the findings, it has been revealed that the progress in the internet reduces urban pollution emissions. Zhang et al. (2022) analyzed the effects of information infrastructure on air pollution in 31 Chinese provinces with the entropy-TOPSIS method with the help of data covering the period 2013-2020. The results revealed that the air quality improved with the increase in the information infrastructure. Wang et al. (2022) analyzed the relationship between technological innovation, the digital inclusive finance index, and turbidity concentration in China with the help of data from 2011-2016. Panel data results showed that digital finance has a reducing effect on haze pollution. Ozpolat (2022) tested the relationship between environmental degradation and internet use with a panel data analysis method with the help of data covering the period 1990-2015 for G7 countries. According to the results of the analysis, it has been revealed that internet use has a negative effect on environmental degradation. Additionally, per capita GDP and energy use increased the environmental degradation.

Zhu and Lu (2023) investigated the impact of the pilot Broadband China Strategy (BCS) program on environmental pollution for 288 Chinese cities over the period 1999-2019. As a result of the study, it was determined that BCS reduces environmental pollution and this situation is more common in eastern cities of China. In addition to these, there are also studies that found an inverted u-shaped relationship. For example, Jafariparvizkhanlou et al. (2021) analyzed the impact of ICT on carbon dioxide emissions in the Persian Gulf countries using the panel data method with the help of data for the period 2000-2015. According to the analysis results, there is an inverted U-shaped relationship between ICT and carbon dioxide emissions. Additionally, the existence of the EKC hypothesis was also been confirmed. On the other hand, in some studies with a large sample group, it was observed that different results were obtained on a country basis. Among them, Al-Mulali et al. (2015) investigated the effect of internet retailing on carbon dioxide (CO_2) emissions in 77 developed and developing countries, using data from 2000-2013. The panel data analysis revealed that trade openness, electricity consumption, urbanization, and GDP growth are the main factors that increase CO_2 emissions. However, although it is seen that internet retailing has a reducing effect on CO_2 emissions in general, different results have been obtained in developed and developing countries. It has been determined that while internet retailing has a negative effect on CO_2 emissions in developed countries, it does not have a significant effect on CO_2 emissions in developing countries. Majeed (2018) conducted a comparative empirical analysis to investigate the relationship of ICT with the environment during the 1980-2016 period in 132 developed and developing countries. In line with the findings, it has been determined that ICT has heterogeneous consequences for environmental degradation in developed and developing countries. However, while positive results were observed in developed countries, negative effects were observed in developing countries.

2.2. Economic Growth and Air Pollution/Environmental Degradation

Among the studies examining the relationship between economic growth and environmental degradation, studies showing that economic growth and environmental pollution will decrease have an important place (Begum et al., 2015; Li et al., 2022; Ghorbal et al., 2022). There are also studies showing that environmental degradation increases with the increase in economic growth (Zhang et al., 2012; Ali et al., 2021). There are also studies in the literature in which there is no effect between these variables (Baz et al., 2020). On the other hand, while there are studies in which an N-shaped relationship is found (Awan and Azam, 2022), also studies detect an inverted U-shaped relationship (Al-Mulali et al., 2015; Nazir et al., 2018). Additionally, studies that determine that economic growth based on renewable or non-renewable energy reduce or increase carbon emissions are also included in the literature (Apergis and Payne, 2014; Rahman et al., 2017; Thombs, 2017). Additionally, in some studies with a large sample group, different results were obtained on a country basis (Al-Mulali and Sheau-Ting, 2014; Azevedo et al., 2017; Radmehr et al., 2022).

One of the studies showing that environmental pollution will decrease with economic growth, Begum et al. (2015) tested the relationship between GDP and CO_2 Emissions in Malaysia for the period 1970-2009 and the validity of the EKC hypothesis with the ARDL analysis method. It has been concluded that the increase in GDP has a reducing effect on CO_2 emissions. The EKC hypothesis is invalid. Li et al. (2022) analyzed the relationship between CO_2 emissions, economic growth, and health expenditure variables using the Fourier ARDL method with the help of data between 2000 and 2019. The analysis findings revealed a cointegration relationship between the variables in the long run in Brazil and China, while there is negative causality in the short run in India. A negative causality relationship was found between CO_2 emissions and economic growth. Ghorbal et al. (2022) investigated the effect of foreign direct investment and GDP on CO_2 emissions in South Korea between 1980 and 2018. When the ARDL analysis results are examined, it is revealed that while GDP and patents positively affect carbon emissions, fossil energy consumption has a negative effect. It has been concluded that economic growth positively affects CO_2 emissions. For 128 countries, Ali et al. (2021), the relationship between economic growth, ecological footprint, and natural resources was investigated by panel data analysis method. The findings showed that GDP, trade, and globalization affect increasing the ecological footprint. There are also studies in the literature in which there is no effect between these variables. For example, Baz et al. (2020), who investigated the relationship between energy consumption, economic growth, and ecological footprint, used a panel data analysis method. The results obtained with the help of the data for the period 1971-2014 showed that there is a negative relationship between the environment and energy consumption. There is a neutral effect between environmental quality, economic growth, and capital. On the other hand, among the studies that found an N-shaped relationship, Awan and Azam (2022) analyzed the relationship between GDP and Per capita Income and CO_2 Emissions in G-20 countries with the help of data from 1993 to 2017. As a result of panel data analysis and cointegration tests, it has been revealed that GDP affects carbon emissions. It has been determined that there is an N-shaped relationship between CO_2 emissions and GDP per capita.

Al-Mulali et al. (2015), on the other hand, examined the relationship between GDP, CO_2 emissions, and financial development variables in Latin American and Caribbean countries between 1980 and 2010. In the analysis made with the help of FMOLS and VECM Granger Causality tests, it has been revealed that renewable energy does not positively affect CO_2. There is a causal relationship between GDP, RE, FD, and CO_2. Additionally, the findings confirmed the EKC hypothesis suggesting an inverted U-shaped relationship between CO_2 emissions and GDP. Nazir et al. (2018) investigated the relationship between GDP, energy consumption and CO_2 emissions with ARDL and Granger causality tests. For Pakistan, the existence of the EKC hypothesis was determined in the period 1970-2016. There is a bidirectional causality relationship between energy consumption and CO_2. In addition to these studies, studies that determined that economic growth based on renewable or non-renewable energy reduce or increase carbon emissions are also included in the literature. For example, Apergis and Payne (2014) investigated the impact of renewable energy and GDP on CO_2 emissions in 25 OECD countries using panel data analysis. As a result of the analysis made with the help of data for the period 1980-2011, it has been revealed a feedback relationship between GDP, CO_2, and REN. Additionally, it has been found that renewable energy increases economic growth while reducing carbon dioxide emissions. Thombs (2017) investigated the relationship between renewable energy consumption, GDP, and CO_2 with panel data analysis for 129 countries with the help of data from 1990 to 2013. It is concluded that renewable energy consumption has a negative effect on total carbon emissions and carbon emissions per unit of GDP. Rahman et al. (2017), who investigated the relationship between GDP, energy consumption, and CO_2 emissions in Malaysia between 1971 and 2014 using the Toda-Yamamato and Granger causality tests, found a relationship between GDP and CO_2 emissions. It has been revealed that economic growth based on using high-energy sources causes environmental pollution. Additionally, in some studies with a large sample group, different results were obtained on a country basis.

Al-Mulali and Sheau-Ting (2014), the relationships between trade-energy consumption, trade-CO_2 emission, export-energy consumption, export-CO_2 emission, import-energy consumption, and import-CO_2 emissions in 189 countries were investigated using FMOLS and panel data analysis. The results of the analysis show the existence of a long-term relationship between variables in countries other than Eastern Europe. Additionally, GDP has a significant impact on emissions. Azevedo et al. (2017) investigated how GDP affects CO_2 emissions in BRICS countries with the help of data from 1980 to 2011. In some countries, the relationship between variables is high, whereas GDP is not the only factor in CO_2 in other countries. While it was determined that economic growth had an increasing effect on CO_2 emissions in Brazil and Russia, there was no significant relationship between economic growth and CO_2 emissions for China, India, and South Africa. Radmehr et al. (2022) examined the relationships between renewable energy, human capital, economic growth, globalization, and ecological footprint in G-7 countries between 1990 and 2018 with panel data analysis. It has been demonstrated that human capital positively affects renewable energy. Financial globalization has a negative impact on the ecological footprint.

3. DATA AND METHODOLOGY

The study's main purpose is to analyze whether internet use affects air pollution in 28 selected OECD Countries (Austria, Belgium, Colombia, Costa Rica, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Rep. Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States) for the period 1994-2019. In the study, CO_2 (metric tons per capita), the most used in the literature, was used to represent air pollution as a dependent variable. As independent variables, individuals using the Internet (% of the population) and the real GDP per capita (constant 2015 US$) are included in the model to represent economic growth. All variables were obtained from the World Bank's World Development Indicators database.

Based on previous studies in the relevant literature (Zhang and Liu, 2015; Salahuddin et al., 2016; Ozcan and Apergis, 2018; Mahdavi and Sojoodi, 2021; Ozpolat, 2022; Liu, 2022), the panel model in which all the variables included in the analysis were defined in the study was created as follows.

$$CO_{2it}=\alpha_i+\beta_1 INT_{it}+\beta_2 GDP_{it}+\varepsilon_{it} \tag{1}$$

In the model, t=1994,.......2019 time period, i=1,2,3,.......28 number of countries, ε_{it} error term, α_i country-specific fixed effects, CO_2 carbon dioxide emissions, INT individuals using internet, and GDP It represents GDP per capita. β_1 and β_2 correspond to the long-run elasticities of CO_2 with respect to Individuals using the Internet (INT_{it}) and per capita real GDP ($GDPC_{it}$), respectively.

These variables will be subjected to more than one test to determine the relationship. Panel data analysis is the basis of the analyses in which the variables will be tested. In performing panel data analysis, two separate pre-tests are considered necessary to determine and apply the most appropriate test. The preliminary tests to be applied within the study are the cross-section dependency and homogeneity tests, respectively. In the study, the widening section test is expressed as the LM test. The homogeneity test will be performed after the relevant test, and the Fourier Panel Root Test, Fourier Panel Panel Integration Test (Olayeni et al., 2020) will be performed for estimating the coefficient of the cointegration relationship (IFE) and panel Fourier Granger Causality will be carried out.

In the study, it was found by Breusch and Pagan (1980) investigated the cross-section dependency, and Pesaran (2004) and Pesaran et al. (2008) Lagrange Multiplier tests were used. The formulas for these tests were as follows.

$$CD_{LM}=\left(\frac{1}{N(N-1)}\right)^{\frac{1}{2}}\sum_{i=1}^{N-1}\sum_{j=_i+1}^{N}\left(T\,\hat{p}_{ij}^{\,2}-1\right) \tag{2}$$

$$LM_{adj}=\sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=_i+1}^{N}\frac{(T-k)\,\hat{p}_{ij}^{\,2}-\widehat{\mu}_{Tij}}{VT_{ij}} \tag{3}$$

The following formulas, found by Swamy (1970) and developed by Pesaran and Yamagata (2008), were used to perform the homogeneity test, another panel pre-test.

$$\tilde{\Delta}=\sqrt{N}\,\frac{N^{-1}\tilde{S}-k}{\sqrt{2k}} \tag{4}$$

$$\tilde{\Delta}_{adj}=\sqrt{N}\left(\frac{N^{-1}\tilde{S}-E(\tilde{Z}_{it})}{\sqrt{Var(\tilde{Z}_{it})}}\right) \tag{5}$$

The following formula will be used for the panel Fourier unit root test developed by Nazlioglu and Karul (2017) to be applied to the series after the preliminary tests.

$$\Delta y_{it}=\delta_{0i}+\delta_{1i}\Delta\sin\left(\frac{2\pi kt}{T}\right)+\delta_{2i}\Delta\cos\left(\frac{2\pi kt}{T}\right)+\varepsilon_{it} \tag{6}$$

The following formulas were used for the P_{LM} and Z_{LM} values calculated within the scope of this test.

$$P_{LM}(k)=N^{-1}\sum_{i=1}^{N}\tilde{\tau}_i(k) \tag{7}$$

$$Z_{LM}(k)=\frac{\sqrt{N}(P_\tau(k)-\xi(k))}{\zeta(k)}\sim N(0,1) \tag{8}$$

What will be applied after unit root testing and Olayeni et al. (2020), the following formula was used for the Panel Fourier Cointegration Test.

$$\tilde{v}_{i,t}=\hat{v}_{i,t}-\hat{\alpha}_i-\hat{\chi}_i\sin\left(\frac{2\pi kt}{T}\right)-\hat{\varphi}_i\cos\left(\frac{2\pi kt}{T}\right) \tag{9}$$

After determining the cointegration relationship, the following formula was used for the Interactive Fixed Effects (IFE) cointegration estimator test developed by Bai et al. (2009) to estimate the coefficient of the cointegration relationship.

$$Y_{it}=X'it\,\beta+\alpha_i+\xi_t+\varepsilon_{it} \tag{10}$$

$$\lambda'_i F_t=\alpha_i+\xi t \tag{11}$$

$$SSR\ (\beta,F,\lambda)=\sum_{0=1}^{N}(Yi-Xi^{2}-F\lambda i)'(Yi-Xi^{2}-F\lambda i) \tag{12}$$

Equation 10 evaluates the usual fixed effects. Equation 11 is used to estimate the fixed-effect parameters. The variable ξ_t is included in the model instead of interactivity. Equation 12 was used to estimate the sum of the squared residuals and coefficients.

After estimating the coefficients of the cointegration test and the cointegration relationship, the following equation was used for the Panel Fourier Causality Test, which was found by Enders and Jones (2014), and the panel Fourier causality test developed by Nazlioglu et al. (2016) and Yilanci and Gorus (2020).

$$y_{i,t}=\mu_i+\sum_{j=1}^{k_i+d_{max_i}}A_{11}y_{i,t-j}+\sum_{j=1}^{k_i+d_{max_i}}A_{12}x_{i,t-j}+A_{13}\sin\left(\frac{2\pi tf_i}{T}\right)+A_{14}\cos\left(\frac{2\pi tf_i}{T}\right)+u_{i,t} \tag{13}$$

$$x_{i,t}=\mu_i+\sum_{j=1}^{k_i+d_{max_i}}A_{21}y_{i,t-j}+\sum_{j=1}^{k_i+d_{max_i}}A_{22}x_{i,t-j}+A_{23}\sin\left(\frac{2\pi tf_i}{T}\right)+A_{24}\cos\left(\frac{2\pi tf_i}{T}\right)+u_{i,t} \tag{14}$$

Table 1: Descriptive statistics

Countries	Series	Mean	Max	Min	Std. Dev.
Austria	CO_2	8.055609	9.275614	7.133064	0.649624
	GDP	4.612815	4.668824	4.518024	0.044403
	INT	54.95859	87.93559	1.393423	30.09594
Belgium	CO_2	9.982364	11.76078	8.041711	1.360149
	GDP	4.575801	4.634462	4.486633	0.042891
	INT	53.87635	90.27543	0.695995	31.93146
Colombia	CO_2	1.525635	1.736028	1.347235	0.134513
	GDP	3.690096	3.806443	3.596991	0.077458
	INT	25.74821	65.00690	0.107174	24.36556
Costa Rica	CO_2	1.478445	1.711704	1.200721	0.156389
	GDP	3.962452	4.102517	3.829427	0.090452
	INT	30.86149	81.20260	0.279912	25.17980
Czech Rep.	CO_2	10.98611	12.28667	9.022786	1.123131
	GDP	4.172199	4.305489	4.022341	0.084337
	INT	44.32853	80.86694	1.259218	30.71444
Denmark	CO_2	9.051312	13.93482	5.107989	2.364480
	GDP	4.703430	4.757419	4.625900	0.034434
	INT	67.40580	98.04643	1.344308	34.37200
Finland	CO_2	10.56329	13.75596	7.372855	1.793104
	GDP	4.603494	4.666131	4.459578	0.061304
	INT	64.68817	91.51440	4.915099	29.16905
France	CO_2	5.525999	6.331489	4.459547	0.606402
	GDP	4.539320	4.589190	4.465940	0.034086
	INT	49.01488	83.75000	0.899867	32.10502
Germany	CO_2	9.713126	11.04000	7.911621	0.746909
	GDP	4.566145	4.636333	4.494695	0.044414
	INT	57.49608	88.13452	0.922541	32.24904
Greece	CO_2	7.832815	9.441123	5.596189	1.180948
	GDP	4.285124	4.381528	4.195679	0.053985
	INT	34.19567	75.67121	0.378174	26.33329
Hungary	CO_2	5.114801	5.744578	4.117988	0.529133
	GDP	4.026935	4.178478	3.878.085	0.087205
	INT	42.34274	80.37169	0.483581	30.92709
Ireland	CO_2	9.453982	11.59265	7.245143	1.424084
	GDP	4.664672	4.876445	4.414216	0.115814
	INT	48.61308	87.00014	0.558377	32.10783
Italy	CO_2	6.913293	8.189257	5.311315	1.005197
	GDP	4.499186	4.532513	4.453997	0.020776
	INT	37.44329	74.38718	0.192305	22.99392
Japan	CO_2	9.276324	9.908431	8.540980	0.323668
	GDP	4.515922	4.557714	4.469332	0.024954
	INT	58.13534	93.18272	0.799684	32.51028
Korea, Rep.	CO_2	10.43887	12.22525	7.919587	1.375344
	GDP	4.330400	4.500239	4.091888	0.125094
	INT	62.40135	96.15758	0.311359	33.91670
Luxembourg	CO_2	2.032237	2.682881	1.509216	3.387564
	GDP	4.987966	5.050835	4.874384	0.056576
	INT	61.58887	98.13670	0.496486	36.43533
Mexico	CO_2	3.899532	4.220752	3.410486	0.226672
	GDP	3.954489	4.005196	3.876786	0.032007
	INT	25.89226	70.06991	0.043339	23.12942
Netherlands	CO_2	9.922555	11.17929	8.437075	0.683857
	GDP	4.622498	4.685238	4.516407	0.046482
	INT	66.58032	93.95640	3.257309	31.96888
Norway	CO_2	7.825729	8.897529	6.722270	0.459545
	GDP	4.845334	4.880843	4.749134	0.036594
	INT	71.09327	98.00000	4.152450	31.80943
Poland	CO_2	8.087961	9.199373	7.515492	0.435629
	GDP	3.962131	4.177630	3.721177	0.13213
	INT	40.19539	80.43591	0.389098	28.78848
Portugal	CO_2	5.241660	6.295808	4.339768	0.606018
	GDP	4.273908	4.334804	4.181645	0.035637
	INT	39.07762	75.34638	0.718906	25.42168
Slovak Rep.	CO_2	6.782239	7.901.904	5.617637	0.746376
	GDP	4.079001	4.261084	3.854100	0.129056
	INT	48.68586	82.85366	0.31851	32.44309
Spain	CO_2	6.392997	8.029202	5.091351	0.959497
	GDP	4.391616	4.448519	4.291172	0.044318
	INT	46.11195	90.71867	0.28007	31.42889
Sweden	CO_2	5.268708	7.199413	3.405038	1.118321
	GDP	4.651155	4.728275	4.525196	0.061997
	INT	69.34951	94.78360	3.412810	31.14557
Switzerland	CO_2	5.630076	6.244939	4.359041	0.641635
	GDP	4.888763	4.940136	4.827789	0.036319
	INT	63.23080	93.14609	2.720004	30.21805
Turkey	CO_2	3.783277	5.066401	2.637958	0.700542
	GDP	3.901584	4.076960	3.730474	0.110162
	INT	28.12433	73.97670	0.049869	24.56931
United Kingdom	CO_2	7.924054	9.377834	5.220514	1.397362
	GDP	4.615818	4.676617	4.519344	0.04452
	INT	60.46926	94.77580	1.036609	33.83765
United States	CO_2	17.99577	20.46981	14.67341	2.013947
	GDP	4.710341	4.783174	4.615059	0.046422
	INT	59.16153	89.43028	4.862781	24.97978

(*Contd*...)

After explaining the data, model and methods used in the study, a summary of the descriptive statistics of the variables of the selected 28 OECD countries is given in Table 1.

When Table 1 is examined, it is seen that the average CO_2 emissions vary between 1.478445 in Costa Rica and 17.99577 in the United States. Regarding Internet users, Colombia has the lowest number of Internet users (25,74821), while Norway has the highest (71,09327) Internet users. According to GDP per capita, Colombia is the poorest country (3.690096), while Luxembourg is the wealthiest country (4.987966). While the countries with the highest variations in CO_2 emissions, GDP per capita, and internet users are Luxembourg, Poland, and Luxembourg, respectively, the countries with the lowest variations are Colombia and Italy.

After the descriptive statistics were explained in the study, the results of the other pre-tests, panel Fourier unit root test, panel Fourier cointegration test, interactive fixed effects cointegration estimator test, and panel Fourier causality test were reported in the 4th section of the study.

4. EMPIRICAL FINDINGS

The first step of the empirical analysis will investigate whether cross-sectional dependence and homogeneity exist in 28 OECD countries included in the study. The cross-section dependency and homogeneity tests will be applied primarily in this context. The application of the expressed tests is important in determining the appropriate generation test. Table 2 was created to test the cross-sectional dependence and homogeneity in CO_2, GDP, and INT variables for 28 OECD countries.

When the cross-section dependency test results were examined, Cross-Sectional Dependence Lagrange Multiplier 1, Cross-Sectional Dependence Lagrange Multiplier 2, and Cross-Sectional

Dependence Lagrange Multiplier Adjusted tests were found to have cross-sectional dependence of dependent and independent variables. Additionally, when the results of the homogeneity test of the slope coefficients were examined, it was concluded that the slope coefficients were homogeneous. After determining the cross-sectional dependence and homogeneity, the Fourier unit root test results are given in Table 3. In Table 3, the Fourier unit root test results of 28 OECD countries, respectively, are included, but there is a general test result for all countries at the bottom of the table.

According to the results of the panel Fourier Lagrange multiplier unit root test developed by Nazlioglu and Karul (2017), the unit root was determined at level values in all the variables used in the panel.

Another test within the study, the results of which can be observed in Table 4, is the Olayeni panel Fourier cointegration test developed by Olayeni et al. (2020). While applying the Olayeni panel Fourier cointegration test, the relationship between the dependent variable and the independent variables was evaluated

Table 2: Results of cross-sectional dependence test

Test	Cross-sectional dependence lagrange multiplier 1		Cross-sectional dependence lagrange multiplier 2		Cross-sectional dependence lagrange multiplier adjusted	
Variable	Statistic	Prob	Statistic	Prob	Statistic	Prob
CO_2	2346.448***	0.000	71.592***	0.000	26.126***	0.000
GDP	2741.431***	0.000	85.957***	0.000	34.890***	0.000
INT	916.771***	0.000	19.595***	0.000	72.337***	0.000
Panel	3657.404***	0.000	119.271***	0.000	149.175***	0.000
Slope Homogeneity Test			**Statistic Value**		**Probability Value**	
Delta Tilde			−3.072		0.999	
Delta Tilde Adjusted			−3.266		0.999	

Cross-Sectional Dependence Lagrange Multiplier 1 (Breusch and Pagan 1980), Cross-Sectional Dependence Lagrange Multiplier 2 and Cross-Sectional Dependence (Pesaran 2004), Cross-Sectional Dependence Lagrange Multiplier Adjusted (Pesaran et al., 2008), Delta Tilde and Delta Tilde Adjusted (Peseran and Yamagata 2008) and "*", "**" and "***" indicate significance at the 10%, 5% and 1% level, respectively

Table 3: Results of the panel fourier lagrange multiplier unit root test

Variables	CO_2			GDP			INT		
Countries	Fourier LM tau k=1	Fourier LM tau k=2	Fourier LM tau k=3	Fourier LM tau k=1	Fourier LM tau k=2	Fourier LM tau k=3	Fourier LM tau k=1	Fourier LM tau k=2	Fourier LM tau k=3
Austria	−0.1139	−15.951	−0.8894	−12.077	−11.689	−0.6605	−32.751	−20.253	−17.643
Belgium	−0.3519	−15.912	−0.8559	−12.309	−11.730	−0.6683	−31.873	−22.004	−20.476
Colombia	−16.893	−25.081	−23.555	−12.174	−11.635	−0.6474	−21.790	−36.222	−21.310
Costa Rica	−15.602	−21.689	−21.106	−12.036	−11.469	−0.6343	−21.829	−37.739	−21.730
Czech Rep.	−12.645	−17.964	−17.469	−10.183	−11.349	−0.6639	−12.499	−15.188	−11.111
Denmark	−13.335	−18.420	−18.574	−10.692	−11.596	−0.6964	−14.309	−15.900	−11.713
Finland	−0.8883	−10.190	−12.627	−0.278	−0.4309	−0.6037	−14.715	−18.128	−15.272
France	−0.7771	−0.7336	−10.162	−0.1263	−0.2736	−0.4949	−15.333	−17.521	−13.347
Germany	−0.6251	−0.5527	−0.8632	0.2497	−0.0855	0.0845	−26.284	−32.759	−28.440
Greece	−0.7815	−0.5751	−0.9348	0.2117	−0.1083	0.0466	−27.715	−33.928	−28.275
Hungary	−0.5249	−0.1308	−0.517	−0.2287	−0.4428	−0.4261	−23.614	−28.535	−24.334
Ireland	−0.6809	−0.2016	−0.6659	−0.0524	−0.2349	−0.3004	−23.014	−27.646	−24.140
Italy	−0.392	−0.1766	−0.4212	−0.2116	−0.3653	−0.4623	−22.775	−29.892	−23.418
Japan	−0.3674	−0.1313	−0.4739	−0.2945	−0.4176	−0.605	−23.176	−30.728	−23.378
Korea, Rep.	−0.571	−0.2967	−0.6899	−0.6481	−0.863	−0.8486	−20.891	−30.396	−20.208
Luxembourg	−0.2759	−0.0129	−0.4195	−0.5934	−0.8191	−0.8128	−20.433	−29.127	−19.725
Mexico	−16.781	−15.759	−17.048	−0.2577	−0.369	−0.5434	−19.562	−24.840	−17.799
Netherlands	−15.699	−12.873	−14.882	−0.2252	−0.3184	−0.552	−17.497	−20.078	−14.527
Norway	−27.239	−26.238	−26.758	−0.0361	−0.1944	0.2267	−0.8535	−10.548	−0.8909
Poland	−25.939	−25.500	−26.048	−0.0768	−0.2105	0.1877	−0.9536	−11.468	−0.9023
Portugal	−26.414	−22.731	−19.328	−0.1812	−0.2913	0.0442	−20.291	−12.961	−15.507
Slovak Rep.	−21.612	−19.813	−17.326	−0.1464	−0.2428	0.0967	−21.789	−16.589	−16.413
Spain	−30.238	−31.200	−29.630	−0.7587	−0.8844	−0.5529	−10.163	−0.7077	−10.845
Sweden	−32.067	−32.622	−31.349	−0.7508	−0.8676	−0.5294	−10.407	−0.7923	−11.192
Switzerland	−0.8363	−20.698	−26.431	0.0837	−0.2623	0.0959	−0.4727	−0.4937	−0.2884
Turkey	−0.9237	−20.301	−26.822	0.0882	−0.2577	0.1031	−0.299	−0.3678	−0.1528
United Kingdom	−0.5518	−20.914	−17.836	0.0042	−0.3881	0.0118	−0.8436	−0.7323	−0.6632
United States	−0.4354	−19.557	−16.932	0.0591	−0.3608	0.0447	−0.8971	−0.7419	−0.7433
P_{LM}	−1.2337	−1.5054	−1.5757	−0.3970	−0.5584	−0.3486	−1.7711	−2.0029	−1.5972
Z_{LM}	14.7888	5.1842	4.0050	21.9898	12.0939	13.9070	10.1637	1.5549	3.8314
P-value	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.9400	0.9999

Table 4: Results of the panel fourier cointegration test (CO_2 and INT)

Countries	GLS				PP			
	Stat	%1	%5	%10	Stat	%1	%5	%10
Austria	−3.853**	−4.509	−3.587	−3.206	−4.184***	−4.084	−3.330	−3.032
Belgium	−4.254**	−4.612	−3.595	−3.107	−4.151**	−4.226	−3.348	−3.012
Colombia	−4.748***	−4.637	−3.613	−3.292	−4.995***	−4.899	−3.918	−3.462
Costa Rica	−4.395***	−4.104	−3.471	−3.005	−4.455***	−4.351	−3.577	−3.191
Czech Rep.	−4.065**	−4.632	−3.813	−3.409	−6.091***	−4.718	−3.717	−3.390
Denmark	−3.208*	−4.059	−3.359	−2.983	−5.961***	−4.286	−3.392	−3.018
Finland	−4.245**	−4.517	−3.842	−3.406	−10.316***	−4.736	−3.719	−3.311
France	−4.702**	−4.759	−3.917	−3.562	−6.613***	−5.019	−4.015	−3.600
Germany	−4.589***	−4.268	−3.662	−3.232	−5.329***	−4.218	−3.512	−3.125
Greece	−3.835**	−4.384	−3.835	−3.181	−4.162**	−4.313	−3.581	−3.210
Hungary	−4.401**	−4.614	−3.825	−3.353	−4.447**	−4.970	−3.830	−3.434
Ireland	−3.958**	−4.311	−3.672	−3.193	−4.268***	−4.167	−3.530	−3.109
Italy	−4.108**	−4.764	−3.743	−3.255	−4.710***	−4.223	−3.467	−3.130
Japan	−3.883**	−4.668	−3.443	−3.054	−3.769**	−4.113	−3.216	−2.930
Korea, Rep.	−4.168**	−4.503	−3.739	−3.317	−4.524***	−4.210	−3.323	−2.989
Luxembourg	−4.211**	−4.654	−3.781	−3.366	−4.666***	−4.658	−3.589	−3.256
Mexico	−4.370**	−4.586	−3.769	−3.271	−3.410*	−3.998	−3.423	−3.115
Netherlands	−3.942**	−4.407	−3.482	−3.024	−5.152***	−4.166	−3.333	−3.035
Norway	−4.484***	−4.369	−3.630	−3.113	−4.592***	−4.324	−3.454	−3.047
Poland	−3.265*	−4.476	−3.678	−3.217	−4.379***	−4.245	−3.519	−3.189
Portugal	−3.229	−4.744	−3.809	−3.406	−5.313***	−5.088	−3.798	−3.478
Slovak Rep.	−4.452**	−4.660	−3.685	−3.266	−4.071**	−4.300	−3.539	−3.197
Spain	−3.137	−4.062	−3.556	−3.205	−4.034**	−4.423	−3.555	−3.179
Sweden	−4.060**	−4.413	−3.489	−3.086	−4.930***	−3.851	−3.245	−2.969
Switzerland	−6.052***	−4.968	−3.964	−3.534	−12.290***	−5.080	−4.072	−3.645
Turkey	−4.346**	−4.656	−3.832	−3.473	−4.080**	−4.662	−3.698	−3.380
United Kingdom	−4.225**	−4.379	−3.541	−3.219	−5.190***	−4.088	−3.439	−3.088
United States	−4.163**	−4.743	−3.637	−3.251	−6.811***	−4.592	−3.579	−3.204
Group Statistic						Group Statistic		
Mean	−4.155**	Prob	0.020		−5.246***		Prob	0.003
Max	−6.052***	Prob	0.000		−12.290***		Prob	0.000
Median	−4.211**	Prob	0.018		−4.666***		Prob	0.007

"*", "**" and "***" indicate significance at 10%, 5% and 1% level, respectively

Table 5: Results of the panel fourier cointegration test (GDP and CO_2)

Countries	GLS				PP			
	Stat	1%	5%	10%	Stat	1%	5%	10%
Austria	−3.908**	−4.536	−3.614	−3.266	−4.263***	−3.914	−3.274	−2.987
Belgium	−5.083***	−4.529	−3.627	−3.286	−5.436***	−4.436	−3.628	−3.267
Colombia	−4.756***	−4.516	−3.653	−3.332	−4.970**	−5.060	−3.957	−3.506
Costa Rica	−4.935***	−4.699	−3.695	−3.283	−5.366***	−4.874	−3.816	−3.372
Czech Rep.	−4.494**	−4.693	−3.672	−3.232	−3.603**	−4.264	−3.577	−3.186
Denmark	−1.798	−3.870	−3.239	−2.818	−4.847***	−3.677	−2.991	−2.748
Finland	−4.247**	−4.621	−3.792	−3.330	−9.586***	−4.609	−3.706	−3.279
France	−4.852***	−4.304	−3.628	−3.222	−6.117***	−4.156	−3.428	−3.173
Germany	−4.232**	−4.461	−3.527	−3.217	−4.127**	−4.315	−3.487	−3.205
Greece	−4.611***	−4.127	−3.368	−2.966	−4.856***	−4.170	−3.410	−2.918
Hungary	−4.510**	−4.804	−3.719	−3.237	−5.468***	−4.673	−3.629	−3.197
Ireland	−3.370**	−4.020	−3.302	−2.914	−3.500**	−3.781	−3.108	−2.811
Italy	−4.282**	−4.343	−3.268	−2.803	−3.278**	−3.947	−3.115	−2.795
Japan	−3.799**	−4.250	−3.497	−3.144	−3.715**	−4.064	−3.344	−3.058
Korea, Rep.	−4.907***	−4.772	−3.732	−3.320	−4.359**	−4.716	−3.537	−3.113
Luxembourg	−4.200**	−4.469	−3.788	−3.143	−4.748***	−4.133	−3.408	−3.017
Mexico	−4.768***	−4.727	−3.608	−3.157	−4.764***	−4.126	−3.465	−3.241
Netherlands	−4.387**	−4.445	−3.524	−3.110	−4.959***	−4.196	−3.386	−3.045
Norway	−4.609***	−4.472	−3.637	−3.244	−5.368***	−4.169	−3.541	−3.233
Poland	−3.299*	−4.461	−3.578	−3.113	−4.239**	−4.245	−3.555	−3.126
Portugal	−3.051*	−4.175	−3.247	−2.838	−3.458**	−3.750	−3.148	−2.757
Slovak Rep.	−4.103**	−4.873	−3.913	−3.496	−5.106***	−4.830	−4.003	−3.528
Spain	−3.635**	−4.061	−3.350	−2.926	−3.567**	−3.896	−3.256	−2.845
Sweden	−5.394***	−5.090	−3.917	−3.418	−8.378***	−4.004	−3.608	−3.217
Switzerland	−4.168**	−4.408	−3.670	−3.253	−4.074**	−4.104	−3.419	−3.117
Turkey	−4.178**	−4.499	−3.841	−3.377	−4.049**	−4.335	−3.393	−3.185
United Kingdom	−3.275*	−4.039	−3.300	−2.924	−3.294**	−3.842	−3.008	−2.724
United States	−5.099***	−4.661	−3.704	−3.236	−6.529***	−4.175	−3.452	−3.104
Group Statistic						Group Statistic		
Mean	−4.212**	Prob	0.016		−4.858***		Prob	0.004
Max	−5.394***	Prob	0.001		−9.586***		Prob	0.000
Median	−4.282**	Prob	0.014		−4.764***		Prob	0.004

"*", "**" and "***" indicate significance at 10%, 5%, and 1% level, respectively

Table 6: Results of panel IFE

Dependent variable	Number of country	Observations	Series	Coefficient	Probabilty value
CO_2	28	728	Constant	−27.46129	0.000
			INT	−0.0100237	0.000
			GDP	8.15358	0.000

Table 7: Results of the Panel Fourier Causality Test (CO_2 and INT)

Country	CO_2→INT			INT→CO_2			Result
	Lag	Wald Stat	Prob	Lag	Wald Stat	Prob	
Austria	1	4.9466**	0.0261	1	4.1103**	0.0426	CO_2↔INT
Belgium	1	7.5033***	0.0062	1	3.0426*	0.0811	CO_2↔INT
Colombia	1	2.1244	0.145	1	9.1386***	0.0025	INT→CO_2
Costa Rica	1	3.0309*	0.0817	1	0.0239	0.8771	CO_2→INT
Czech Rep.	1	5.2849**	0.0215	1	2.9019*	0.0885	CO_2↔INT
Denmark	1	1.9458	0.163	1	0.0177	0.8941	CO_2−INT
Finland	1	1.9046	0.1676	1	0.8184	0.3657	CO_2−INT
France	1	11.3431***	0.0008	1	5.0217**	0.0250	CO_2↔INT
Germany	1	0.7526	0.3857	1	0.3136	0.5755	CO_2−INT
Greece	1	14.4399***	0.0001	1	7.5542***	0.0060	CO_2↔INT
Hungary	2	5.0746**	0.0243	2	5.1031**	0.0239	CO_2↔INT
Ireland	2	15.3359***	0.0001	2	12.7123***	0.0004	CO_2↔INT
Italy	1	3.4381	0.1792	1	0.0366	0.9819	CO_2−INT
Japan	1	0.5951	0.4405	1	0.6863	0.4074	CO_2−INT
Korea, Rep.	1	3.2598	0.1959	1	12.1487***	0.0023	INT→CO_2
Luxembourg	1	22.7178***	0.0000	1	1.9310	0.3808	CO_2→INT
Mexico	1	6.7569**	0.0341	1	2.2322	0.3276	CO_2→INT
Netherlands	1	4.2119**	0.0401	1	3.3503*	0.0672	CO_2↔INT
Norway	1	2.5624	0.1094	1	1.1048	0.2932	CO_2−INT
Poland	2	0.0063	0.9367	2	9.9085***	0.0016	INT→CO_2
Portugal	1	6.0636**	0.0138	1	1.3644	0.2428	CO_2→INT
Slovak Rep.	1	2.6030	0.1067	1	0.3553	0.5512	CO_2−INT
Spain	2	7.7749***	0.0053	2	3.3621*	0.0667	CO_2↔INT
Sweden	1	2.5262	0.1120	1	1.1276	0.2883	CO_2−INT
Switzerland	1	2.3466	0.1256	1	1.3790	0.2403	CO_2−INT
Turkey	3	4.8577**	0.0275	3	2.8146*	0.0934	CO_2↔INT
United Kingdom	1	2.1706	0.1407	1	1.8417	0.1748	CO_2−INT
United States	1	5.7780**	0.0162	1	0.0224	0.8812	CO_2→INT
Panel Z		14.9194***		Panel Z	7.8029***		CO_2↔INT
P-value		0.0000		P-value	0.0000		
10%		2.5343		10%	1.9922		
5%		3.0089		5%	2.7180		
1%		3.9717		1%	4.0149		

"*", "**" and "***" indicate significance at 10%, 5% and 1% level, respectively

one by one. In this direction, firstly, the existence of a long-term relationship between CO_2 and INT is examined in Table 4, taking into account the GLS and PP tests. In this context, the cointegration equation, whose results are given in Table 4, is formed as $CO_{2it}=\alpha_i+\beta_2 INT_{it}+\varepsilon_{it}$.

When the fractional frequency flexible Fourier form panel cointegration test results are examined, Various levels of a cointegration relationship between CO_2 and INT have been identified for all countries.

The existence of a long-term relationship between GDP and CO_2, which is another independent variable, is examined in Table 5, taking into account the GLS and PP tests. Accordingly, the cointegration equation, the results of which are given in Table 5, is formed as $CO_{2it}=\alpha_i+\beta_2 GDP_{it}+\varepsilon_{it.}$

Olayeni et al. when the results of the fractional frequency flexible Fourier form panel cointegration test developed by (2020) are examined, a cointegration relationship at various levels has been determined between CO_2 and GDP for all countries.

After determining the cointegration relationship between the dependent and independent variables, the Interactive Fixed Effects (IFE) cointegration estimator test developed by Bai et al. (2009) was applied to estimate the coefficient of the cointegration relationship and the results are given in Table 6.

According to the Interactive Fixed Effects estimation results, a negative statistically significant relationship exists between CO_2 and INT and a positive relationship between CO_2 and GDP.

After estimating the cointegration relationship and coefficient between the variables, the causality relationships between

Table 8: Results of the panel fourier causality test (CO_2 and GDP)

Country	CO_2→GDP			GDP→CO_2			Result
	Lag	Wald Stat	Prob	Lag	Wald Stat	Prob	
Austria	4	4.8910**	0.0270	4	0.2019	0.6532	CO_2→GDP
Belgium	1	6.0272**	0.0141	1	0.0096	0.9218	CO_2→GDP
Colombia	1	1.9090	0.1671	1	14.4304***	0.0001	GDP→CO_2
Costa Rica	1	12.6555***	0.0018	1	1.8788	0.3909	CO_2→GDP
Czech Rep.	2	4.8853**	0.0271	2	0.3386	0.5606	CO_2→GDP
Denmark	1	2.2353	0.1349	1	1.7939	0.1805	CO_2–GDP
Finland	1	1.4585	0.2272	1	0.3014	0.583	CO_2–GDP
France	1	8.3145***	0.0039	1	0.1821	0.6696	CO_2→GDP
Germany	5	8.9264***	0.0028	5	4.1926**	0.0406	CO_2↔GDP
Greece	1	14.8654***	0.0006	1	2.0031	0.3673	CO_2→GDP
Hungary	1	1.2028	0.2728	1	0.0962	0.7564	CO_2–GDP
Ireland	2	25.3387***	0.0000	2	4.8535*	0.0883	CO_2↔GDP
Italy	1	1.8149	0.4035	1	0.3562	0.8369	CO_2–GDP
Japan	1	4.8703**	0.0273	1	0.2698	0.6035	CO_2→GDP
Korea, Rep.	5	5.2263**	0.0222	5	4.1562**	0.0415	CO_2↔GDP
Luxembourg	1	0.5689	0.4507	1	0.0819	0.7748	CO_2–GDP
Mexico	1	9.0519**	0.0108	1	1.3244	0.5157	CO_2→GDP
Netherlands	1	6.7951***	0.0091	1	0.3422	0.5586	CO_2→GDP
Norway	3	2.1623	0.1414	3	0.0026	0.9597	CO_2–GDP
Poland	2	0.4973	0.4807	2	5.1674**	0.023	GDP→CO_2
Portugal	1	4.0638**	0.0438	1	0.077	0.7814	CO_2→GDP
Slovak Rep.	2	9.4460***	0.0021	2	0.2591	0.6107	CO_2→GDP
Spain	1	7.5758**	0.0226	1	1.3520	0.5086	CO_2→GDP
Sweden	1	7.7033***	0.0055	1	0.1099	0.7403	CO_2→GDP
Switzerland	1	4.6843**	0.0304	1	0.0136	0.9071	CO_2→GDP
Turkey	3	7.9111***	0.0049	3	0.5666	0.4516	CO_2→GDP
United Kingdom	1	1.8898	0.1692	1	1.3750	0.2409	CO_2–GDP
United States	1	7.4476***	0.0064	1	1.5616	0.2114	CO_2→GDP
Panel Z		17.0283***		Panel Z	1.6126		CO_2→GDP
P-value	0.0000			P-value	0.1068		
10%	3.2004			10%	2.0988		
5%	3.7779			5%	2.6806		
1%	5.0362			1%	3.6591		

"*", "**" and "***" indicate significance at 10%, 5% and 1% level, respectively

the independent variables and the dependent variable were investigated in Tables 7 and 8 with the help of the panel Fourier granger causality test developed by Nazlioglu et al. (2016) and Yilanci and Gorus (2020).

According to the results of the panel Fourier granger causality test, in which the causality relationship between CO_2 and INT was examined, There is a bidirectional relationship between CO_2 and INT throughout the panel. Unidirectional causality exists from CO_2 to INT in Costa Rica, Luxemburg, Mexico, Portugal, and the United States.In Colombia, Korean Republic, and Poland, a one-way causality relationship from INT to CO_2 was determined. Bidirectional causality from CO_2 to INT has been found in Austria, Belgium, the Czech Republic, France, Greece, Hungary, Ireland, the Netherlands, Spain, and Turkey.

According to the results of the panel Fourier granger causality test, in which the causality relationship between CO_2 and GDP was examined, Unidirectional causality from CO_2 to GDP exists in Austria, Belgium, Costa Rica, the Czech Republic, France, Greece, Japan, Mexico, the Netherlands, Portugal, Slovak Republic, Spain, Sweeden, Switzerland, Turkey, and the United States. In Colombia and Poland, there is a one-way causality relationship from GDP to CO_2. Germany, Ireland, and Korea have a bidirectional causality relationship between CO_2 and GDP. Additionally, a one-way causality relationship from CO_2 to GDP was determined throughout the panel.

5. DISCUSSION AND CONCLUSIONS

Recently, air pollution and global warming have started to occupy an important place on the world's agenda. Although there are various reasons for the rapid warming of the world and the increase in the ecological footprint, the use of information and communication technologies/internet has an important place among them. The widespread application of information and communication technologies has significantly affected the environment and economy. In this study, it is aimed to examine the relationship between the use of the internet, which has an important place in information and communication, and air pollution. In this context, the relationship between the variables during the 1994-2019 period was tested with the help of panel data analysis with Fourier functions (Fourier unit root test, panel Fourier cointegration test, and panel Fourier causality test). The main results of the analysis for 28 selected OECD countries reveal that internet use reduces air pollution, while economic growth increases air pollution. The Panel Fourier Granger Causality test results show a unidirectional causality relationship between air pollution and economic growth and a bidirectional causality relationship between internet use and air pollution throughout the panel.

These results are significant for policymakers. Policies that reduce air pollution should be implemented by investing in information and communication technologies in economic growth processes. In this direction, green technologies should be included in the production processes for the low-carbon economy target. Financial subsidies and incentives should be provided to increase ICT product construction and ICT products used to reduce environmental degradation. The government should improve the legal structure regarding ICT and give due importance to investment in technological innovation. Financial resources allocated to R&D studies should be increased to improve the ICT infrastructure. In particular, the increase in the use of ICT in the industry and transportation sector will be an essential step in energy efficiency. At the same time, governments should support the development of a cohesive digital financial system to better serve the development of the real economy. The state's tax policies should be revised toward the development of ICT. On the other hand, internet access infrastructure should be developed and thus the spread of various applications such as online training, online meetings, home working, and online shopping, which allows the effective use of resources.

When the relationship between information and communication technologies/internet use and air pollution is considered in general, various support and subsidies should be provided by targeting ICT-based economic growth by giving due importance to education, R&D, taxation, investment, and infrastructure activities for adopting ICT-based energy-saving lifestyles.

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