The Effect of Energy Usage, Economic Growth, and Financial Development on CO₂ Emission Management: An Analysis of OECD Countries with a High Environmental Performance Index

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Abstract: The environmental performance index was developed to protect public health, and to sustain and manage the ecological vitality that is a crucial factor in countries' social and economic development. The increase in CO₂ emissions has been threatening environmental and human health. The main objective of this study is to evaluate the impact of economic growth, energy consumption, energy management, the urban population, trade openness, and financial development on CO₂ emissions in the OECD countries that have a high ranking in the environmental performance index by utilizing the panel data analysis method for the years spanning 1990–2014. This assessment finds positive relationships between economic growth, energy consumption, and the urban population, and CO₂ emissions. Moreover, it is put forward that a negative and significant relationship between financial development and CO₂ emissions exists. Despite displaying a similar negative correlation, the relationship between trade openness and CO₂ emissions is insignificant. In the Dumitrescu-Hurlin panel causality test conducted, it was seen that a two-way causality is prevalent between energy consumption and CO₂ emissions. In addition, interrelations where CO₂ emissions cause trade openness, and the urban population is an explanatory variable of the former relationship, were discovered.

Keywords: CO₂ emission; carbon management; economic growth; energy consumption; energy management; high environmental performance index; OECD countries

1. Introduction

Energy production and consumption have been rising in tandem with sustainable economic growth, industrialization, and urbanization. To meet these ever-increasing demands, fossil fuels such as coal, petroleum, and natural gas are used, leading to greenhouse gas emissions, which result in environmental pollution that adversely affects human health and the ecological niche. Nevertheless, the speedy developments in technology and globalization contributing to increasing knowledge and awareness on the importance of natural resources on environmental sustainability have translated into studies being conducted in many fields that focus on environmental factors. It is being widely accepted that, apart from social and economic measures, environmental indicators also play an essential role in assessing countries’ development levels.

The Environmental Performance Index, calculated biannually since 2006 by experts from Yale and Columbia Universities, has been developed to put forward a global standpoint on, and facilitate decision and policy making regarding, environmental performance.
The index has proven valuable in maintaining ecological health and sustaining environmental vitality. Indicators listed in this index can be grouped into two categories: indicators that identify and demonstrate the economies’ impact on the environment, and measures that define environmental limitations and facilitate resource usage efficiency [1,2]. The 2020 Environmental Performance Index considers data collected from international governing bodies, non-governmental organizations, and academic research centers, ranking 180 countries on a 0–100 scale scoring using 32 environmental performance indicators [3]. CO₂ emission is a significant parameter known to impact pollution directly, and therefore is used in the calculation of the index. Hence this study focuses on the interrelationships between economic growth, energy consumption, financial development, trade openness, urbanization, and CO₂ emissions. The work first assesses the adverse impact of scale economies arising from increasing economic activity, resulting in soaring CO₂ emissions and environmental pollution. Then, it also analyzes the positive effects of the utilization of eco-friendly production techniques, such as the utilization of clean and renewable energy, in managing the reduction in CO₂ emissions [4,5].

The connection between environmental quality and economic growth can be explained by the environmental Kuznets curve hypothesis, which posits that environmental pollution rises and reaches its maximum in the early stages of economic development. It then declines after a certain developmental threshold is passed. In summary, it explains the relationship between these two variables with concavity. Taking into account this lemma, one can state that economic growth, after a certain point, does not pose a threat to environmental sustainability, but rather facilitates it [1,6,7].

Economic growth can be loosely defined as a rise in the production of goods and services in a specific period. It plays a vital role in creating and maintaining human development and social welfare by facilitating industrialization, urbanization, life quality, and reducing unemployment and poverty [8–11]. Following World War II, economic growth has become the primary priority of all countries, and global economic growth has soared with the help of industrialization. Nevertheless, the population growth in the 1960s, coupled with industrialization and rising economic activity, has given rise to high levels of waste and thus, air, soil, and water pollution [12,13]. Environmental organizations have explained that the intrinsically-limited natural resources were diminished, pollution has risen, and the air, soil, and water have reached their maximum pollution capacities, putting forward that both economic growth and consumption should be curbed [14]. In 1972, the Club of Rome concluded that, due to the increasing speed of the growth in population, production, industrialization, pollution, and the depletion of natural resources, the world would overshoot its carrying capacity and be exposed to detrimental threats [15]. Environmental pollution is a phenomenon which threatens developed countries and continues to threaten developing economies. Energy, being one of the main variables facilitating economic growth, is vital in producing goods and services aimed at catering to the unlimited needs of people. Therefore, it can safely be stated that rising population and urbanization results in increased demands for energy [16–18]. Rising energy usage with industrialization gives rise to higher production and results in increased living standards and economic growth. However, greenhouse gas emissions emerge as a by-product of this relationship and contribute to global warming and climate change, some of the primary factors that hinder socio-economic development [11,19]. Greenhouse gas emissions arise from the combustion of fossil fuels. CO₂ is widely accepted to be one of those greenhouse gases whose emissions have a detrimental impact on global ecological pollution, via its adverse effects on environmental health, natural resources, and global economies [10,20].

While CO₂ emissions cause pollution, the latter factor influences both economic and financial development. Described as the total cost of financial instruments, markets, intermediaries, knowledge, applications, and transactions, financial development influences savings, investment decisions, and economic growth [21–24]. Trade openness, another explanatory variable of economic growth, is the sum of exports and imports corrected by
GDP, or can simply be defined as the country’s level of openness in engaging in international trade. Literature suggests a high and significant degree of correlation between trade openness and economic growth [25,26]. It is also acknowledged that economic growth encourages the development of modern industries and urbanization, where the latter has a direct, albeit limited, effect on economic growth [27–29]. Urbanization, owing to its ability to streamline access to multiple services, such as infrastructure, housing, education, health, and sanitation, accelerates rural migration and results in population growth. Urbanization also results in environmental problems, like the industrial waste of urban resources, and air and water pollution [30–32].

This study aims to explain the impact of economic growth, energy consumption, financial development, trade openness, and the urban population on CO\textsubscript{2} emissions by utilizing the panel data method and using data spanning 1990–2014, collected from 17 countries ranking the highest in the Environmental Performance Index (Denmark (82.5), Switzerland (81.5), United Kingdom (81.3), France (80.0), Austria (79.6), Finland (78.9), Sweden (78.7), Norway (77.7), Netherlands (75.3), Japan (75.1), Australia (74.9), Spain (74.3), Belgium (73.3), Ireland (72.8), Iceland (72.3), New Zealand (71.3), and Italy (71.0)) [3]. As a result, it is shown that economic growth, energy consumption, and the urban population positively impact CO\textsubscript{2} emissions. Moreover, a causal relationship between energy consumption and CO\textsubscript{2} emissions was demonstrated, interrelations were discovered in which CO\textsubscript{2} emissions open up trade, and the urban population is an explanatory variable for the former relationship [33].

The practical usage of environmental resources is crucial for sustainable economic development. The depletion of these resources and rising pollution levels have sparked interest in works focusing on these phenomena. This study fills a research gap and complements the existing research in the field of CO\textsubscript{2} emissions and environmental management by shedding a different light onto the existing literature by analyzing the impact of economic growth, energy consumption, financial development, trade openness, and the urban population on CO\textsubscript{2} emissions through a sample that contains OECD countries that ranked the highest in the 2020 Environmental Performance Index.

The work consists of three parts. First, a literature review is presented. Second, an econometric model is used, and then the results are discussed. Third, a general conclusion is formulated.

2. Literature Review

This section reviews the literature on CO\textsubscript{2} emissions, energy consumption, economic growth, trade openness, and the urban population dynamics, which were then taken as variables and used in the proposed model.

2.1. CO\textsubscript{2} Emissions Management

The rising global population and economic development have resulted in increased energy consumption, which led to the adverse by-products of global warming and climate change, phenomena that negatively impact the world. It is therefore absolutely imperative that economies implement strategies to manage and control greenhouse gas emissions. The primary goal should be to reduce greenhouse gas emissions, in order to inhibit their harmful effects, one of the most important of which is CO\textsubscript{2} [34,35]. Consequently, analyses conducted commonly use this variable as a value parameter and emphasize the urgency for policy-making and environmental management strategies directed at impeding carbon emissions [36,37]. It is proposed that renewable energy sources like wind, solar, and geothermal energy be used instead, as they reduce the density of greenhouse gases, unlike their fossil-based counterparts [38–41].

Research focusing on CO\textsubscript{2} emissions spanned within the context of this study are summarized below.

Jia et al. [42] assess the impact of renewable energy sources on CO\textsubscript{2} emissions and conclude that the former has a significant effect on reducing the latter. Moreover, the
study also refers to some developing countries adopting renewable energy utilization and reducing their emissions. Mao, Li, and Zhang [43] compare the effect of battery-electric and conventional diesel buses on CO₂ emissions. It was deduced from the experiments that battery-electric buses are more effective in reducing emissions, and policies aimed at increasing the traffic efficiency of highway networks and subsidizing inter-city electric trade are proposed. In their study, Wu, Tambunlertchai, and Pornchaiwiseskul [44] identify the carbon emission trading channels in pilot markets in China and observe these channels’ influence on CO₂ emissions. The authors suggest that China’s carbon emission trading policy facilitates green development in pilot areas, encourages technology usage, and SO₂ emission reduction which accelerates green development. Musarat et al. [45] evaluate the relationship between the Malaysian construction sector’s inflation rate and CO₂ emissions. The study finds that, despite the decrease in the inflation rates resulting in lower prices for building materials and a higher added value of construction, this fastened economic activity creates CO₂ emissions and worsens environmental sustainability.

Moreover, it is recommended that a CO₂ emission calculation model be developed by entrepreneurs and partners investing in the sector and/or the government. Another study co-authored by Novak Mavar, Gaurina-Medimurec, and Hrmcevic [46] determines the role of petroleum recovery on the reduction in CO₂ emissions, concluding that only large-scale, CO₂-strengthened petroleum recovery projects can reach the reduction target without compromising profitability. He et al. [47] conduct an input-output analysis of CO₂ emissions and suggest that energy and the input effectiveness of production processes should be improved to reduce carbon emissions in the energy sector. Nam, Lee, and Jeon [48] analyze the non-linear connection between CO₂ emissions and economic development. In contrast to the existing literature, the model developed defines the income coefficient of CO₂ emission as a function of both income and time. The study finds that, in developed economies, income elasticity decreases with time, whereas this relationship is the opposite for their low-income counterparts. When discussing issues related to the management of greenhouse gas emissions, it is worth mentioning Kihombo et al. [49], who draw attention to the effects of technological innovation, financial and economic development, and growth (GDP) on the ecological footprint (EF), and indicate that a 1% increase in technological innovation reduces EF by 0.010%, and a 1% increase in financial development (FD) increases the EF level by 0.0016%, which can be considered as a factor stimulating ecological degradation. A similar study has been done by Umar et al. [50]. An interesting look at the problem of carbon dioxide emissions and a proposal to solve the problem is the study by Shan et al. [51] on the impact of energy prices and non-linear fiscal decentralization on carbon dioxide emissions. The authors consider institutional quality and gross domestic production in the model. It is worth mentioning that a cointegrating equilibrium relationship has been shown between the studied variables and that the linear term of fiscal decentralization promotes carbon dioxide emissions, and the non-linear term mitigates it.

2.2. Energy Consumption Management

Energy is indispensable for the sustainability of human life. In line with this, the primary focus in energy consumption should be on renewable energy sources such as solar, wind, electric, geothermal, and wave, therefore contributing to the reduction in CO₂ emissions and the protection of the environment. Moreover, these sources promote employment and provide opportunities for less foreign-dependent energy policy [52]. There is a direct relationship between energy consumption and CO₂ emissions. It is a common consensus that one of the significant root causes of climate change and global warming is the non-and-under utilization of renewable energy sources. In other words, the consumption of fossil fuels increases the greenhouse gas density and speeds up CO₂ emissions. In conclusion, it is proposed that countries become more responsive to responsible energy consumption and direct their policies towards finding and utilizing new renewable energy sources.
Salari, Javid, Noghanibehambari [53] test the relationship between CO$_2$ emissions, energy consumption, and economic growth in the USA between 1997 and 2016. The authors define total energy, renewable energy, non-renewable energy, and residential energy as energy consumption. They discover that a long-term relationship exists between all energy types and carbon emissions. In addition, while total energy, non-renewable energy, and residential energy positively impact emissions, the magnitude of causality is reversed when renewable energy is the explanatory variable. In line with the findings, the study suggests encouraging and subsidizing renewable energy usage as an effective method for carbon emissions reduction. Similar findings can be found in the research of Adebayo et al. [54], Zhang et al. [55], or in Orhan et al. [56], who investigate the impacts of agriculture, economic growth, trade openness, and energy consumption on CO$_2$ emissions. In their research, Osobajo et al. [11] investigate the impact of energy consumption and economic growth on CO$_2$ emissions via Granger causality analysis. A two-way causality between population, capital stock, economic growth, and CO$_2$ emissions, and a one-way causality between energy consumption and CO$_2$ emissions, are found. Moreover, a long-term relationship between energy consumption, economic growth, and CO$_2$ emissions is identified. The study emphasizes the necessity of large investments that provide climate funding and facilitate a low-carbon economy to transition to natural and clean energy effectively. Salazar-Nuñez, Venegas-Martinez, and Tinoco-Zermeño [57] assess energy consumption and CO$_2$ emissions on economic growth via grouping 79 countries by their per-capita income and utilizing the Granger causality analysis. The study posits that those countries belonging to high, upper-middle, and lower-middle-income groups see a two-way causality between the factors aforementioned in the short- and long-term, two-way causality between energy consumption and CO$_2$ emissions in the long-term, and a one-way causality directed from energy consumption to CO$_2$ emissions in the short-term. Khan, Teng, and Khan [58] evaluate the impact of energy consumption and economic growth on carbon emissions for Pakistan, based on the newly developed ARDL dynamic simulation method. The results indicate that economic growth contributes to environmental disruption caused by energy consumption in both the long- and short-term. As a result, the usage of renewable energy resources to combat these disruptions is proposed. Nordin and Sek [59] investigate the inter-relationship between energy consumption, carbon emissions, and economic growth in petroleum exporting and importing countries. For the latter, it is found that carbon emissions are influenced by energy consumption and economic growth in the short-term. In contrast, for the former, a two-way causality is identified between economic growth and energy consumption. Saidi and Hammami [60] assess the effects of CO$_2$ emissions and economic growth on energy consumption for a sample of 58 countries. The empirical findings show that CO$_2$ emissions and economic growth have a positive and significant impact on energy consumption. Al-Mulali and Sheau-Ting [61] measure the connections between trade, import, export, energy consumption, and CO$_2$ emissions for 189 countries in six different regions. Consequently, they discover a long-term positive relationship between trade-energy consumption and trade-CO$_2$ emissions for all regions considered, excluding Eastern Europe. Papiez [62] evaluates the causality between CO$_2$ emissions, energy consumption, and economic growth for the Visegrad Group countries using data from 1992 to 2010. The panel reintegration tests conducted put forward that a long-term relationship is prevalent between the variables. In addition, long-term equilibrium shows that energy consumption has a positive and statistically significant effect on CO$_2$ emissions. The study also undertakes panel short-term Granger causality tests where results point to the existence of a two-way causality between CO$_2$ emissions and economic growth. Moreover, it is concluded that energy consumption is a causal factor of CO$_2$ emissions and economic growth in the short-term, whereas no such reverse causal direction exists. Arouri et al. [63] investigate the correlations between CO$_2$ emissions, energy consumption, and economic growth in Middle East and North African (MENA) countries. The study deduces that energy consumption has a positive and significant impact on CO$_2$ emissions in the long-term. In addition, findings suggest that since countries can reduce carbon
emissions via energy savings without bearing any adverse costs on economic growth, MENA countries do not need to sacrifice economic potential to reach reduction targets. Paul and Bhattacharya [64] study the carbon emissions resulting from energy consumption in India with the objective of identifying the factors influencing the critical changes in energy-related CO\textsubscript{2} emission levels. Those factors are modelled as the pollution coefficient, energy density, structural changes, and economic activity. The results show that economic growth has a positive impact of a high magnitude on CO\textsubscript{2} emissions in all major industries. Carbon emissions in industrial and transportation sectors show a tendency to decline due to improved energy efficiency and fuel transfer; no statistically significant effect is discovered for the relationship between the pollution coefficient, energy density, and CO\textsubscript{2} emissions in the agricultural sector.

2.3. Economic Growth

Economic growth can loosely be described as the increase in the real gross domestic national product. To put it differently, it is the rightward shift of the production possibilities frontier. Economic growth depends on multiple factors, namely capital accumulation, technological development, human capital, development, and excesses in industrial production. These factors can also influence the alteration of the economic structure [65]. It is widely accepted that there is a direct relationship between economic growth and CO\textsubscript{2} emissions. The energy usage required for fast growth leads to economic development; however, it also raises carbon emissions and disrupts the environment [66–68].

Leitao [69] analyzes the interdependencies between economic growth, corruption, renewable energy, international trade, and CO\textsubscript{2} emissions in various European countries, like Portugal, Spain, Italy, Ireland, and Greece, between 1995 and 2015. The findings show that corruption indexes and economic growth have a statistically significant positive effect on carbon emissions. The results of the model are compliant with the environmental Kuznets curve (EKC), and it is put forward that economic growth accelerates climate change and global warming. Koengkan, Fuinhas, and Silva [70] investigate renewable energy consumption’s influence on reducing the outdoor air pollution mortality rate in 19 Latin American and Caribbean countries from 1990 to 2016. Econometric tests show that economic growth and fossil fuel consumption positively affect CO\textsubscript{2} emissions, whereas this relationship becomes negative when renewable energy consumption is the explanatory variable.

Moreover, it is deduced that fossil fuel consumption facilitates mortality and obstructs economic development. Balsalobre-Lorente, Leitao, and Bekun [71] focus on the need for clean, economic, and responsible energy consumption, sustainable economic growth, and climate change mitigation. They conducted econometric tests which validate the environmental Kuznets curve assumptions, which postulate that renewable energy mitigates CO\textsubscript{2} emissions. A direct relationship between the urban population and environmental disruption is prevalent for the countries studied. The authors suggest designing policies that aim for economic growth and environmental sustainability. Bouygrissi, Berjaoui, and Khanniba [72] evaluate the relationship between renewable and non-renewable energy consumption, CO\textsubscript{2} emissions, and economic growth in Morocco from 1990 to 2014. They find that renewable energy has started to demonstrate its favorable effects on the economic extent of sustainable development, and causality exists from renewable energy to economic growth, and from economic growth to CO\textsubscript{2} emissions. The importance of encouraging renewable energy usage is emphasized, as facilitating economic growth through non-renewable energy sources increases CO\textsubscript{2} emissions. In addition, the authors suggest that renewable energy consumption will decrease the costliness of the Moroccan economy, thus the strengthening the economy’s competitiveness without an adverse effect on economic growth. Ike, Usman, and Sarkodie [73] evaluate the effect of petroleum production on carbon emissions between the years 1980 and 2010, while considering electricity production, economic growth, democracy, and trade. The study finds an open relationship between economic growth and CO\textsubscript{2} emissions and accepts the environmental Kuznets curve hypoth-
esis. It is shown that, despite producing varying effects, petroleum production increases carbon emissions. The study also demonstrates that electricity production contributes to CO₂ emissions, trade activities intensify emissions in all aspects, and democracy positively affects all of the dependent variables [66,67]. Leitao and Lortente [74] investigate the interdependencies between economic growth, renewable energy, the number of visitors, trade openness, and CO₂ emissions in EU-28 countries. They conclude that trade openness and renewable energy impede climate change and environmental disruption.

Additionally, the work shows that economic growth positively impacts emissions, and a negative correlation exists between the number of visitors and CO₂ emissions. Ko-Engkan and Fuinhas [75] evaluate the transition to renewable energy in Latin American and Caribbean countries from 1990 to 2015, and its impact on CO₂ emissions. They assert that the transition process can obstruct environmental degradation in the Caribbean, and economic growth, trade openness, and urbanization contribute to the increased level of CO₂ emissions. Bouznit and Pablo-Romero [76] assess the relationship between economic growth and CO₂ emissions in Algeria by incorporating energy usage, electricity consumption, imports, and exports into their proposed model. The econometric analysis demonstrates that economic growth, rising electricity consumption, and import activities in Algeria contribute to CO₂ emissions, whereas exports explain negative effects on the variable. Kasperowicz [77] tests the relationship between economic growth and CO₂ emissions in 18 European Union countries from 1995 to 2012. The study asserts that economic growth necessitates intensive energy consumption that results in soaring CO₂ emissions. Therefore, pollution is related to economic growth and development. Stolyarova [78] studies the same relationship with a dataset comprising 93 countries and spans the time between 1960 and 2008, concluding that the increase in CO₂ emissions in per capita GDP has a positive and negative correlation with per capita GNP growth and energy mixture growth, respectively. The study posits that economic growth facilitates CO₂ emissions.

2.4. Trade Openness

Trade openness removes international limitations that restrain or eliminate the free movement of goods and services among countries and obstruct competitiveness. The majority of countries have restructured their trade policies due to trade liberalization’s growing importance in the global economy [79]. These adjustments have led governments to adopt policies that are of a less interventional, and more liberal, nature [80]. Trade liberalization can be described as modifying trade policies that focus on government intervention to restrain or eliminate trade flows. These changes can either be price regulations that include policies such as tariffs, taxes, and additional payments, or non-tariff limitations like quotas, license rights, and prohibitions [81].

Trade openness is used to measure a country’s trade liberalization level, and this indicator’s relationship with CO₂ emissions can vary depending on the policies undertaken in respective countries. Therefore, it may prove faulty to make a direct and conclusive assessment regarding the interdependencies between trade openness and CO₂ emissions. Mahmood, Maalel, and Zarrad [82] study the asymmetric effects of trade openness on CO₂ emissions and the hypotheses of the environmental Kuznets curve in Tunisia from 1971 to 2014, where the latter was verified by the level of GDP, and Tunisia being found at the first phase of the EKC. The results also demonstrate that trade openness has a positive, yet statistically insignificant, effect on CO₂ emissions. Mutascu [83] evaluates the interaction between CO₂ emissions and trade openness in France in 1960–2013. The findings discover no co-movement between trade openness and gas emissions, but identify CO₂ emissions as a positive determinant of trade openness at a medium frequency. Moreover, it shows that trade openness positively drives gas emissions at a low frequency. Fan and Hossain [84] try to analyze and compare the short-to-long-term dependencies between technological development, trade openness, economic growth, and CO₂ emissions in China and India between 1974 and 2016. They put forward that for China, technological improvements, trade openness, and CO₂ emissions all have a positive and significant
impact on economic growth in the long-term. While trade openness and CO$_2$ emissions have a long-term positive effect on economic growth, this impact is negated in the short-term. The causality test reveals a two-way causality between economic growth and trade openness, technological developments, and CO$_2$ emissions, and a one-way causality from technological developments and CO$_2$ emissions to trade openness in China. For India, one-way causalities are deduced from economic growth, technological improvements, and trade openness to CO$_2$ emissions, as well as from technological developments to trade openness. Shahbaz et al. [85] investigate the interaction between trade openness and carbon emissions for 105 countries grouped based on their income levels. The study asserts that trade openness obstructs environmental quality, despite bearing different magnitudes for the different groups of countries, and that trade openness is the Granger cause of CO$_2$ emissions for low- and high-income countries. Hossain [85] conducts a panel estimation for CO$_2$ emissions, energy consumption, economic growth, trade openness, and the urban population for newly-industrialized countries. The analysis fails to find long-term causality among variables, but identifies various short-term, one-way causality interactions from economic growth and trade openness to CO$_2$ emissions, economic growth to energy consumption, trade openness to economic growth, the urban population to economic growth, and trade openness to the urban population. In addition, it is emphasized that high energy consumption contributes to pollution via its positive impact on CO$_2$ emissions in newly industrialized countries.

2.5. Financial Development

The financial system comprises financial institutions and financial markets. A robust financial system will allocate resources to lucrative investments, facilitating high efficiency. In addition, a developed financial system will increase savings and investment rates, speed up capital allocation, and thus, contribute to economic growth. Economic theory shows that financial systems that distribute capital for the most effective use promote economic growth [86]. It is thought that a relationship exists between financial development and carbon emissions, since the financial development achieved through a robust financial system is correlated with economic growth. Therefore, one can deduce that financial development has an impact on CO$_2$ emissions.

Godil et al. [87] investigate the effect of financial development, information and communication technologies, and corporate quality on CO$_2$ emissions in Pakistan, demonstrating that, in the long-term, a positive correlation exists between economic growth, corporate quality, and CO$_2$ emissions. Moreover, the negative impact of financial development and information and communication technologies on CO$_2$ emissions, regardless of the emission level, shows that the two explanatory variables can play a role in mitigating CO$_2$ emissions. Salahuddin et al. [88] evaluate the empirical effects of economic growth, electricity consumption, direct foreign investment, and financial development on CO$_2$ emissions in Kuwait via time series data from 1980 to 2013. It is deduced that economic growth, electricity consumption, and foreign direct investments contribute to CO$_2$ emissions in the short- and long-term. Financial development’s impact on CO$_2$ emissions is found to be neutral. Başarır and Çakır [89] study the interactions between CO$_2$ emissions, financial development, energy, and tourism for France, Spain, Italy, Greece, and Turkey, for the period between 1995 and 2010. The findings show that a 1% increase in energy consumption boosts CO$_2$ emissions by 3.02%, and a 1% increase in financial development and the number of visitors decrease CO$_2$ emissions by 0.12% and 0.11%, respectively. Moreover, the causality analysis found a one-way causal relationship between the number of visitors and financial development, and a two-way interaction between CO$_2$ emissions, financial development, energy, and visitors. Ziaei [90] analyzes the impact of financial development on energy consumption and CO$_2$ emissions, finding that, despite bearing different coefficients, CO$_2$ emissions and energy consumption have significant explanatory power concerning each other’s deviation.
Additionally, even though the shocks of energy consumption and CO$_2$ emissions on financial indicators, such as private sector credit, are not very pronounced, the impact of an energy consumption shock on the return to stocks is greater in Europe than in East Asia and Oceania. It is also found that shocks to return stocks have a long-term impact on energy consumption, especially in East Asian and Oceanian countries. Shahbaz et al. [91] investigate the effect of financial development on CO$_2$ emissions for Malaysia, revealing a long-term interaction between CO$_2$ emissions, financial development, economic growth, and energy consumption. The study also asserts that financial development hinders CO$_2$ emissions. Moreover, Granger causality tests put forward that two-way causalities exist between financial development and CO$_2$ emissions, energy consumption and CO$_2$ emissions, and CO$_2$ emissions and economic growth. Shahbaz et al. [92] investigate the interaction between economic growth, energy consumption, financial development, international trade, and CO$_2$ emissions for Indonesia. They conclude that while economic growth and energy consumption boosts CO$_2$ emissions, financial development and trade openness have an inverse effect on the dependent variable.

2.6. Urban Population

The urban population is the collection of people that reside in cities or areas that bear urban characteristics, irrespective of the magnitude of the total population. The interaction between the urban population and carbon emissions can be simplified as the effect of living in the cities on the environment. Higher urbanization is believed to cause pollution through the misuse of resources, but it is also argued that an efficient urbanization process can mitigate CO$_2$ emissions with the effective utilization of resources. The literature covered within the context of this study is presented below.

Anwar, Younis, and Ullah [93] investigate the main determinants of CO$_2$ emissions in Asian countries between 1980 and 2017, concluding that economic growth and trade openness have significant explanatory power for CO$_2$ emissions. Urbanization is revealed to have a positive effect on CO$_2$ emissions. In addition, a higher level of urbanization is shown to have severe impacts on CO$_2$ emissions and poses a threat to public health. Mosikari and Eita [94] assess the effect of the urban population, energy consumption, and economic growth on carbon emissions in African countries spanning 2005 to 2019, obtaining results that validate the environmental Kuznets curve. They propose that, while energy consumption positively impacts carbon emissions, growth in the urban population has an inverse relationship with the explained variable. Ali, Bakhsh, and Yasin [95] assess the impact of urbanization on CO$_2$ emissions in Pakistan between 1972 and 2014. The findings suggest that urbanization increases carbon emissions both in the short- and long-term, and that a one-way causality is prevalent from the former to the latter. Bai et al. [96] scrutinize the influence of urbanization on carbon emissions for 64 cities in China, from 2006 to 2013. A positive correlation of statistical significance is identified between the variables, and the urban population growth’s adverse impact on the environment via its facilitation of CO$_2$ emissions is emphasized. In their research undertaken in China, Liu and Bae [97] evaluate the interdependencies between CO$_2$ emissions, energy density, economic growth, industrialization, urbanization, and the share of renewable energy usage. The findings and the long-term parameters’ forecasts suggest that a 1% increase in energy density, real GDP, industrialization, and urbanization increases CO$_2$ emissions by 1.1%, 0.6%, 0.3%, and 1%, respectively.

3. Materials and Methods

3.1. Data

This study assesses the effect of economic growth, energy consumption, financial development, trade openness, and the urban population on CO$_2$ emissions for 17 OECD countries (Australia, Austria, Belgium, France, Denmark, Finland, the Netherlands, the United Kingdom, Ireland, Spain, Sweden, Switzerland, Italy, Japan, Iceland, Norway, and New Zealand) that rank highest in the Environmental Performance Index, from 1990 to
2014. First, a panel unit root test is undertaken, and the hypothesis on the stationarity of the first difference of the series is accepted. Then the effect of unit/time is investigated via LR test, and it is acknowledged that the panel data model is the one-way unit effects model, where the Hausman test is conducted and reveals the unit effects to be fixed. After testing the hypotheses, the model is seen to contain heteroscedasticity, autocorrelation, and correlation between units. Therefore, the Driscoll-Kraay robust standard estimator was used to overcome these issues. Finally, the Dumitrescu-Hurlin panel causality test is done. In the test, one two-way causality is detected between energy consumption and CO$_2$ emissions.

Moreover, interrelations where CO$_2$ emissions cause trade openness, and the urban population is an explanatory variable of the former, are discovered [33]. The period spanned is determined by taking into consideration the availability of the data. The model used in this work is constructed through the literature reviewed and is presented in the Equation (1) below. Variables used are in logarithmic form.

$$\ln CO_{2it} = \alpha_{it} + \beta_1 \ln GDP_{it} + \beta_2 \ln EC_{it} + \beta_3 \ln TO_{it} + \beta_4 \ln FIN_{it} + \beta_5 \ln UR + \epsilon_{it}$$  

(1)

In Equation (1), $i = 1, \ldots, N$ represents each of the 17 countries in the sample, while $t = 1, \ldots, T$ is a notation indicating the specific year between 1990 and 2014. Moreover, CO$_2$ is the carbon dioxide emissions per capita, GDP is the gross domestic product per capita (normalized by 2010 prices), FIN represents the percentage of private sector credits vis-à-vis the GDP; EU stands for the energy consumption per capita, TO is trade openness, and UR indicates the urban population. A detailed description of the variables used is presented in Table 1 below, and relevant data is collected from the World Bank database [98].

| Variables | Definition | Source |
|-----------|------------|--------|
| CO$_2$    | Carbon Dioxide Emissions (metric tons per capita) | World Development Indicators (WDI) |
| EC        | Energy Consumption (kg of oil equivalents per capita) | |
| GDP       | Economic Growth (GDP per capita constant USD at 2010 prices) | |
| TO        | Trade Openness (% of GDP) | |
| FIN       | Financial Development, Domestic Credit to the Private Sector (% of GDP) | |
| UR        | Urban Population | |

3.2. Methodology

As in Im, Peseran, and Shin [99], we commence the panel unit root test by identifying a specific ADF (augmented Dickey-Fuller test) for each of the cross-sections. The hypotheses of this test are:

$$\Delta \tilde{y}_{it} = \alpha_{it-1} + \sum_{j=1}^{p} \beta_{ij} \Delta y_{it-j} + \chi_{it} \delta + \epsilon_{it}$$  

(2)

$$H_0 = \alpha_i = 0 \ (\text{All } i\text{'s have unit root})$$

$$H_0 = \alpha_i < 0 \ (\text{At least one } i \text{ has unit root})$$

In Fisher-type tests (Fisher ADF and Fisher PP), a null hypothesis on the prevalence of the individual unit root is tested. First, a unit root test for each unit is conducted, and then the $p$ values obtained from these tests are used to produce the whole test. The Fisher ADF test uses the classical ADF test, whereas the Fisher-Philips and Perron tests use the
classical Philips and Perron test for each unit for the time series. The statistics for each of
these tests are listed, respectively, below:

\[ \lambda = -2 \sum_{i=1}^{N} \ln(\rho_i) \rightarrow X^2_{2N} \]  

(3)

and

\[ Z = \frac{1}{2\sqrt{N}} \sum_{i=1}^{N} (-2 \ln(\rho_i - 2)) \rightarrow N(0, 1) \]  

(4)

Here \( \rho_i \) is the probability value of the unit root test for cross section \( i \).

It is crucial to investigate the unit/time, or either the unit or time effects in the
panel regression model. If the unit/time effects fail to be found in a forecasted panel
regression model, one can safely state that the classical model is valid, and forecasting can
be conducted by pooling. If unit/time impacts are prevalent, then a likelihood ration (LR)
test is undertaken.

In this test, the \( H_0 \) hypothesis is constructed to test whether the classical model is
validated.

During the calculation of LR test statistics, both the random effects model and the
classical model are estimated through maximum likelihood estimation, and the resulting
log-probability values are used. The LR test statistics are presented below [100].

\[ LR = 2[1(\text{Restricted}) - (\text{Unrestricted})] \]  

(5)

The LR test statistics’ \( q \) (the number of restrictions) and the degrees of freedom fit the
\( X^2 \) distribution. If the hypothesis is rejected, it can be deduced that unit, root, or either unit
or root effects exist, and therefore the classical model is no longer valid [100].

Three different statistics are calculated, and three different hypotheses are tested
within the LR test. First, the classical model is tested against the panel data model, which
bears both unit and time impacts, where the main hypothesis argues that no such impacts
exist. The decision to reject the hypothesis depends on the calculated probability value.
In the case of rejection, it is deduced that at least one of the unit or time effects, or both,
are prevalent in the model. In the second step, the classical model is tested against the
one-way model, which includes unit effects. The main hypothesis argues that unit effects
do not exist (thus, the classical model prevails). The calculated probability value rejects
the hypothesis and shows that the model incorporates unit effects. Lastly, the classical
model is tested against the panel data model featuring time impacts. The main hypothesis
suggests that the classical model is valid (therefore, no time impact exists), and based on
the calculated probability value, the hypothesis cannot be rejected.

Following the identification of unit and/or time effects via the LR test, one should
assess whether these impacts are fixed or are the results of coincidence. Within this context,
the Hausman test is commonly conducted to choose among estimators. One of the most
emphasized differences between fixed and random effects models is the correlation between
unit impacts and independent variables. If no such correlation exists, random effects can
be put forward as a more appropriate model.

In the Hausman test:

\( H_0 = \) No correlation exists between explanatory variables and unit effects. Therefore, a random
effect estimator can more appropriately estimate the phenomena in question.

\( H_A = \) A correlation is present between explanatory variables and unit effects. The result is
consistent with the fixed-effect model, and it should be preferred.

In the fixed-effects model, the existence of heteroscedasticity with respect to the units
in residuals is tested by the modified Wald test. The \( H_0 \) hypothesis constructed as \( \varphi^2 i = \varphi^2 \)
is rejected, and the variance is shown to vary by units \((\varphi^2_i \neq \varphi^2)\), proving the existence of heteroscedasticity. The modified Wald statistic is defined as follows [100]:

\[
W = \sum_{i=1}^{N} \frac{(\varphi^2_i - \varphi^2)^2}{V_i} \tag{6}
\]

Pesaran [101] has developed the CD test to test for correlation among units, where the CD test statistic is presented below [100]:

\[
CD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \rho_{ij} \right) \tag{7}
\]

The test statistic developed by Friedman (1937) to test for correlation between units is calculated as [100]:

\[
FR = \left[ (T-1) (N-1) R_{AVE} + 1 \right] \tag{8}
\]

The FR statistic has an asymptotic \(\chi^2\) distribution with \((T-1)\) degrees of freedom, and \(R_{AVE}\) in the equation stands for the Spearman correlation coefficient.

The basic hypotheses tested in modified Durbin-Watson tests by Bhargava et al. are [100]:

\[ H_0: \rho = 0 \] (There is no autocorrelation) and the alternative hypothesis is: \( H_a: |\rho| < 1 \).

In the Baltagi-Wu local best invariant test, the main hypothesis is constructed as \( H_0: \rho = 0 \) and is tested against the alternative hypotheses \( H_{a1}: \rho > 0 \) or \( H_{a2}: \rho < 0 \).

The causality between variables can be investigated via the Dumitrescu-Hurlin panel test, whose model can be defined as follows for stationary \( y \) and \( x \) variables [33]:

\[
x_{it} = \alpha_i + \sum_{k=1}^{k} \gamma_{i(k)} x_{i,t-k} + \sum_{k=1}^{k} \beta_{i(k)} y_{i,t-k} + e_{it} \tag{9}
\]

\[
y_{it} = \alpha_i + \sum_{k=1}^{k} \gamma_{i(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_{i(k)} x_{i,t-k} + e_{it} \tag{10}
\]

In the Dumitrescu and Hurlin [33] method, the following hypotheses are tested:

\[ H_0: y \] is not causal for \( x \) for all units.

\[ H_1: y \] is causal for \( x \) for some units.

4. Results and Discussion

Table 2 shows the descriptive statistics of the variables used in the model proposed, where the mean, standard deviation, minimum, and maximum values are presented. In this regard, the mean of the CO\(_2\) emissions is 8.75, and the ratio varies between a minimum of 4.35 and a maximum of 18.20. The average per capita income of the 17 countries studied is 44,206.71 USD, where the highest and lowest values are 91,565.73 USD and 22,512.76 USD, respectively. Energy consumption has a mean of 4721.348, and it varies between a minimum of 2317.477 and a maximum of 18,178.14. The average trade openness is calculated to be 76.08, where the highest and lowest values are 201.99 and 16.01, respectively. The financial development variable has a mean of 104.27 and varies between a minimum of 30.26 and a maximum of 308.97. Lastly, the average urban population is 20,500,000, and the lowest and highest values are 231,255 and 116,000,000, respectively.

The descriptive correlation matrix of the variables is shown in Table 3. While there is a positive correlation between CO\(_2\) emissions and economic growth (GDP), energy consumption, and the urban population, the sign is inversed when the correlation between CO\(_2\) emissions and trade openness and financial development is studied. Moreover, GDP positively correlates with energy consumption, financial development, and trade openness, but negatively interacts with the urban population. Even though there is a positive correlation between energy consumption and trade openness, the former variable is
shown to have a negative correlation with financial development and the urban population. A positive correlation exists between financial development and the urban population. Moreover, the results of the correlation matrix show that no high correlation is prevalent between variables, therefore rejecting the hypothesis of a multicollinearity problem.

Table 2. Descriptive statistics.

| Variable | Number of Observations | Mean     | Standard Deviation | Minimum  | Maximum  |
|----------|------------------------|----------|--------------------|----------|----------|
| $\text{CO}_2$ | 425 | 8.756242 | 2.770796 | 4.35724 | 18.20018 |
| GDP      | 425 | 44.206.71| 13.983.28 | 22.512.76 | 91.565.73 |
| EC       | 425 | 4721.348 | 35.9319 | 16.01388 | 201.9903 |
| TO       | 425 | 76.08257 | 44.2784 | 30.26377 | 308.9784 |
| FIN      | 425 | 20,500,000| 2,660,000 | 231,255 | 116,000,000 |

Note: Data presented in the table are original observations.

Table 3. Correlation matrix.

|      | $\text{CO}_2$ | GDP | EC     | TO     | FIN     | UR     |
|------|---------------|-----|--------|--------|---------|--------|
| $\text{CO}_2$ | 1             |     |        |        |         |        |
| GDP   | 0.0351        | 1   |        |        |         |        |
| EC    | 0.2121        | 0.2079 | 1    |        |         |        |
| TO    | −0.1345       | 0.1718 | 0.0061 | 1    |         |        |
| FIN   | −0.1364       | 0.2890 | −0.1088 | −0.0906 | 1 |        |
| UR    | 0.0299        | −0.1906 | −0.5791 | −0.4464 | 0.1899 | 1 |

Note: The logarithms of the variables used in the model are taken.

The variables used in panel data analyses need to be stationary. If a series is stationary, its mean, variance, and covariance between two periods do not change over time. Considering this, Im, Pesaran, and Shin W-Stat, ADF-Fisher Chi-Square, and PP-Fisher Chi-Square tests are conducted. As presented in Table 4, as a result of the first generation unit root tests, the variables used in the model are proposed to demonstrate non-stationarity at level [I(0)] but are stationary when their first difference is taken [I(1)]. Therefore all variables are [I(1)].

Table 4. Panel unit root test.

| Variables | Level | First Difference |
|-----------|-------|------------------|
|           | Lm, Pesaran and Shin W-Stat | ADF-Chi-Square | PP-Fisher Chi-Square | Lm, Pesaran and Shin W-Stat | ADF-Chi-Square | PP-Fisher Chi-Square |
| $\text{CO}_2$ | 4.88210 (1.000) | 15.1077 (0.9979) | 15.4269 (0.9974) | −7.65424 (0.0000) | 128.797 (0.0000) | 294.653 (0.0000) |
| GDP       | −0.34272 (0.3659) | 30.3520 (0.6471) | 26.8936 (0.8018) | −6.49877 (0.0000) | 105.664 (0.0000) | 131.517 (0.0000) |
| EC        | 3.38560 (0.9996) | 14.4133 (0.9987) | 19.9779 (0.9732) | −6.71934 (0.0000) | 111.857 (0.0000) | 284.172 (0.0000) |
| TO        | −0.42724 (0.3346) | 42.7564 (0.1442) | 31.1905 (0.6060) | −9.32435 (0.0000) | 152.632 (0.0000) | 271.637 (0.0000) |
| FIN       | −0.05923 (0.4764) | 31.7128 (0.5802) | 17.0958 (0.9930) | −5.17169 (0.0000) | 90.9452 (0.0000) | 162.474 (0.0000) |
| UR        | 6.44991 (1.000) | 21.9342 (0.9453) | 13.7147 (0.9992) | −2.19583 (0.0141) | 52.6358 (0.0216) | 49.6858 (0.0402) |

Note: Numbers shown in brackets are probability values. *, **, *** indicate significance levels of 1%, 5%, and 10%, respectively.
Following the unit root test, the presence of unit/time impacts in the model is investigated via the LR test, and the results are summarized in Table 5. Based on the results obtained, after identifying the unit time effect, the impacts of time and unit are tested separately, concluding that only unit impact prevails in the model. Therefore, it is safe to state that the model is one-way. In other words, the panel data model proposed in this study is a one-way unit effects model (that does not contain time effects).

### Table 5. Unit and time effects LR test.

| Model                  | Test Used     | Results                      |
|------------------------|---------------|------------------------------|
| Unit Effect and Time Effect | LR Test      | $\chi^2(2) = 899.38$        |
|                        |               | Prob > $\chi^2 = 0.0000$    |
| Unit Effect            | LR Test       | $\chi^2(01) = 899.38$       |
|                        |               | Prob $\geq \chi^2 = 0.0000$|
| Time Effect            | LR Test       | $\chi^2(01) = 0.00$         |
|                        |               | Prob $\geq \chi^2 = 1.0000$|

As seen in Table 6, while the fixed effects estimator is consistent and effective, the random effects estimator is not. To put it differently, the Hausman test shows that the unit effect is fixed, concluding that the model proposed is a one-way fixed effects model.

### Table 6. Hausman test.

| Hausman Test Results |
|----------------------|
| $X^2$ Statistics     | 25.23            |
| Probability          | 0.0001           |

First, the regression model shown in Equation (1) is estimated, and within this context, information regarding the proposed model is given. Before scrutinizing the coefficient estimations, it is also crucial to determine whether the hypotheses are accepted. Therefore, the study also presents the test results of the hypotheses. Lastly, an estimator that can produce standard errors and is resilient against deviations from hypotheses is obtained, and the final model is run.

Table 7 presents the estimation results of the one-way (fixed) effects model. Even though the F-statistic posits that the model is statistically significant, a thorough evaluation cannot be made since the model has not yet been examined via diagnostic tests.

### Table 7. One-way (fixed) effects model estimate.

| Independent Variables | Coefficient | Standard Error | t-Statistic | Probability |
|-----------------------|-------------|----------------|-------------|-------------|
| GDP                   | 0.2733954   | 0.0640919      | 4.27        | 0.000       |
| EC                    | 0.4837542   | 0.0462651      | 10.46       | 0.000       |
| TO                    | -0.176593   | 0.0359941      | -4.91       | 0.000       |
| FIN                   | -0.871256   | 0.0161148      | -5.41       | 0.000       |
| UR                    | -0.4364375  | 0.1012588      | -4.30       | 0.000       |
| FIXED                 | 3.299264    | 1.338914       | 2.46        | 0.014       |

The model can prove to be valid, and therefore interpretable, if it lacks autocorrelation, heteroscedasticity, and multicollinearity. If at least one of those attributes is prevalent, estimators that produce resilient standard errors should be incorporated. To comply with this structure, the study then tests the hypotheses put forward.
As seen in Table 7, in the fixed effects model, the $H_0$ hypothesis that heteroskedasticity exists in residual units is rejected via the modified Wald test. The variance is shown to differ with units, and it is concluded that heteroskedasticity vis-a-vis units is prevalent.

To test for the presence of autocorrelation in the model, the Durbin-Watson test proposed by Bhargava, Franzini, and Narendranathan, and the locally best invariant test proposed by Baltagi-Wu, are undertaken. Both tests conducted examine the hypothesis that the autocorrelation coefficient is equal to zero ($p = 0$). Both tests conducted for this purpose demonstrate the values being lower than 2, therefore one can deduce that autocorrelation is present in the fixed effects model, in line with the existing literature suggesting that if the test statistics are lower than 2, autocorrelation is significantly prevalent.

The Friedman test and the Pesaran test are undertaken to test for multicollinearity in the fixed-effects model. As presented in Table 8, the $H_0$ hypothesis is rejected and an outcome attesting multicollinearity is deduced.

### Table 8. Hypotheses test results.

| Test Type                  | Method                  | Statistics       | Probability |
|----------------------------|-------------------------|------------------|-------------|
| Heteroskedasticity Test    | Modified Wald Test      | $\chi^2 = 1828.96$ | 0.0000      |
| Multicollinearity Test     | Pesaran Test            | 8.064            | 0.000       |
|                            | Friedman Test           | 61.635           | 0.000       |
| Autocorrelation Test       | Modified Bhargava et al. Durbin-Watson Test | 0.28529871 |           |
|                            | Baltagi-Wu LBI Test     | 0.47077123       |             |

Therefore, it can be inferred that a model that bears heteroscedasticity, autocorrelation, and multicollinearity should be re-estimated using estimators and methods that are resilient against the aforementioned problems. Within this context, the Driscoll-Kraay estimator is used to eliminate these issues.

It can be inferred that, from a detailed evaluation of Table 9, which depicts the analysis results, economic growth, energy consumption, and the urban population all have a positive and significant effect on CO$_2$ emissions. On the other hand, financial development is shown to have a significant and negative impact on CO$_2$ emissions, and no significant relationship is found between trade openness and the dependent variable in question.

The coefficients of the variables can be interpreted as follows: A 1% increase in economic growth triggers CO$_2$ emissions by 0.07%, while this effect increases to 25% when the impact of energy consumption is considered. Consequently, one can state that energy consumption is noteworthy in its contribution to emission density in OECD countries. The elasticity of CO$_2$ emissions to financial development is $-0.11\%$, so it can be inferred that financial developments could trigger R&D investments that would facilitate the expansion of high-tech, eco-friendly energy investments, which can obstruct carbon emissions. A 1% increase in the urban population results in a 0.04% rise in carbon emissions, reaffirming the lemma that urban areas engage in more emissions than their rural counterparts. This phenomenon can be explained by various factors, such as the growth in production activities to cater to the increasing needs of the urban dwellers and high traffic congestion. The model fails to find a significant relationship between trade openness and CO$_2$ emissions.

The causality between variables used in the model is investigated via a Dumitrescu-Hurlin panel causality test. As demonstrated in Table 10, a two-way causality exists between energy consumption and CO$_2$ emissions. Moreover, one-way causality is prevalent from CO$_2$ emissions to trade openness, and from the urban population to CO$_2$ emissions.
Therefore, it can be inferred that a model that bears heteroscedasticity, autocorrelation and multicollinearity should be reestimated using estimators and methods that are free of these issues. As demonstrated in Table 10, the Dumitrescu-Hurlin estimators are employed to investigate causality. The results are summarized in Table 10.

Table 10. Dumitrescu-Hurlin causality test.

| Direction of Causality | w-Stat    | Zbar-Stat | Prob     | Decision           |
|------------------------|-----------|-----------|----------|--------------------|
| ∆EC → ∆CO₂             | 3.50040   | 1.96248   | 0.0497 **| Causality Exists   |
| ∆CO₂ → ∆EC             | 4.58100   | 3.68138   | 0.0002 * | Causality Exists   |
| ∆GDP → ∆CO₂            | 3.28749   | 1.62382   | 0.1044   | Causality Does Not Exist |
| ∆CO₂ → ∆GDP            | 1.71934   | −0.87062  | 0.3840   | Causality Does Not Exist |
| ∆CO₂ → ∆FIN            | 2.56621   | 0.47648   | 0.6337   | Causality Does Not Exist |
| ∆FIN → ∆CO₂            | 2.18162   | −0.13528  | 0.8924   | Causality Does Not Exist |
| ∆TO → ∆CO₂             | 2.40572   | 0.22119   | 0.8249   | Causality Does Not Exist |
| ∆CO₂ → ∆TO             | 0.90428   | −2.16712  | 0.0302 **| Causality Exists   |
| ∆UR → ∆CO₂             | 3.80447   | 2.44616   | 0.0144 **| Causality Exists   |
| ∆CO₂ → ∆UR             | 1.86137   | −0.64470  | 0.5191   | Causality Does Not Exist |

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

5. Conclusions

The effective and efficient utilization of environmental resources is vital for sustainable economic growth. Considering this, the depletion of natural resources and the worsening environmental crisis have resulted in research efforts aiming to explain CO₂ emissions, since this phenomenon is a vital factor in the determination of the Environmental Performance Index. This study, likewise, assesses the impact of economic growth, energy consumption, financial development, trade openness, and the urban population on CO₂ emissions for OECD countries ranking high in the 2020 Environmental Performance Index, by utilizing the panel data method for a dataset spanning 1990 to 2014. This analysis finds a strong positive correlation between economic growth and CO₂ emissions. It can be argued that an increased output production is highly likely to result in energy consumption, which leads to carbon emissions. This outcome bears similarities with the findings of studies conducted by Leitao [69], Koengkan, Fuinhas, and Silva [70], Leitao and Lorente [74], Koengkan and Fuinhas [75], Bouznit and Romero [76], Kasperowicz [77], and Stolyarova [78]. Moreover, in line
with the findings of Salari, Javid, and Noghanibeambari [53], Khan, Teng, and Khan [58], Nordin and Sek [59], Saidi and Hammami [60], Al-Mulali and Sheau-Ting [61], Papiez [62], Arouri et al. [63] and Paul and Bhattacharya [64], energy consumption’s impact on CO\textsubscript{2} emissions is found to be positive. Moreover, the magnitude of the independent variable’s impact on the explained factor is demonstrated to be higher than that of the other explanatory variables introduced into the model. It is also put forward that a negative correlation exists between financial development and CO\textsubscript{2} emissions. To explain this relationship, one can argue that financial development contributes to the usage of clean and green technologies in the energy sector, therefore hampering the usage of conventional production methods that contribute to environmental pollution. In summary, financial development is demonstrated to facilitate environmental quality. Similarly, it can also be inferred that the financial sector in the countries studied gives the necessary efficient support to green sectors and technologies. Godil et al. [87], Başarır and Çakır [89], Shahbaz et al. [91], and Shahbaz et al. [92] could be listed as some of the work conducted in this area. Urban population growth is another triggering factor for CO\textsubscript{2} emissions, an outcome that was also found in Anwar, Younis, and Ullah [93], Ali, Bakhsh, and Yasin [95], Bai et al. [96], and Liu and Bae [97]. Lastly, a negative but statistically significant relationship is found to exist between trade openness and carbon emissions. In the Dumitrescu-Hurlin panel causality tests conducted, a two-way causality between energy consumption and CO\textsubscript{2} emissions and a one-way causality from CO\textsubscript{2} emissions to trade openness, and the urban population to CO\textsubscript{2} emissions, are found.

In conclusion, energy plays a prominent role in reducing poverty and, essentially, developing a country. While pursuing economic growth, a high level of energy consumption poses a material threat to the environment. It is of material importance to adopt clean production technologies to hamper ecological degradation. Therefore, it is expected that countries will formulate energy development programs, reduce their fossil fuel footprint, and improve their environmental quality by transitioning to clean and renewable energy consumption. In addition, it is proposed that countries focus on clean energy production projects to facilitate renewable energy consumption [102]. Similarly, environmentally aware planning during the investment phase of production activities, and the effective implementation of environmental taxes, is thought to prove valuable in reducing countries’ carbon footprints resulting from industrial production.

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