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Demography, Human Capital, and Environmental Impact: Evidence on Income Growth from OECD Countries

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A R T I C L E I N F O

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A B S T R A C T

The most important issue of the day is global warming. People think that the greenhouse gases that people put into the air are the main reason for the warming. Most of it comes from burning fossil fuels. The primary sources of CO_2 emissions from burning fossil fuels are economic and population growth. The study is determinant to explore the impact of working-age people, population, higher education and carbon emission on the economic growth of OECD countries. The world temperature growing day by day is alarming due to the increase in the amount of Carbon emission. The results found a positive and significant relationship between the Population, working-age People and carbon emission on the per capita income. These results imply that more education, population, working-age people and carbon emissions may cause an increment in per capita income of OECD countries. It is suggested that these countries pay attention to creating more jobs for working-age people. This will increase per capita income. This study also suggests that carbon emissions should be minimized to reduce the world temperature.

Introduction

The deterioration of the environment stands as the foremost issue for policymakers across the globe. The increase in carbon emissions resulting from elevated economic activities is viewed as the primary factor contributing to the degradation of ecosystems. Global warming is a vital problem of the 21st century. The average world surface temperature rose by about 1.5°C during the period 1945-2024 (IPCC, 2023, Zhao, W, et al. 2025). It is believed that human-generated greenhouse gas (GHG) emissions are the primary cause of the warming that has been occurring since the mid-1900s. (IPCC, 2023, Sumabat et al 2016). Carbon dioxide (CO_2) is the main greenhouse gas that people generate. It is mostly produced when fossil fuels are burnt. Economic and population development are the main factors that are probably going to continue boosting up CO_2 emissions from burning fossil fuels. (Guan et al. 2008, Feng K et al. 2015).

There are two major shifts in living standards that are occurring in societies across the globe. One is environmental deviations, particularly in relation to the global climate. The demographic change is another variable affecting the world environment. Because of carbon dioxide and other "greenhouse gas" releases into the atmosphere, average temperatures will rise in the future, and the way temperatures and rainfall are across regions and countries will change. (Parry, and Martin L., 2007) A demographic transition involves adjustments to the population's size, age distribution, and life expectancy in addition to other factors (Chesnais, and Jean-Claude 1992). An ageing population is a defining feature of both the current and future phases of the demographic change in both developed and developing countries. We need to fully understand how changes in income and population affect carbon emission and enhance the level of global warming. We should make good rules and regulations about climate change (Liddle B, 2015). Global warming is increasing natural disasters. This increases global climate security economic challenges. An increase in global warming by 1°C has led to harsh weather, increasing sea levels, and decreased Arctic Sea ice, among other things. (Munir et al, 2018).

It's now important for everyone to take action to control greenhouse gas pollution. The Paris Agreement, which 178 countries signed in 2015, tried to keep the rise in average world temperature to 1.5°C or less and no more than 2°C above pre-industrial levels by the end of the 21st century. Even though everyone is trying to cut down on greenhouse gas emissions, they have gone up since the Paris Agreement was signed, with the exception of a small drop in 2020 because of the Covid-19 Pandemic (Zhang et al 2022). Along with fast social and economic growth, the world's population has grown up because birth rates have gone up and deaths are going down. Japan is the world's fastest-ageing country, with 28.7% of its people 65 or older as of 2021. Italy comes in second with 23.6%, and Portugal comes in third with 23.1%. Around 16% of the world's population, or 6.4 billion people, will be 65 or older by 2050 (Sachs, Jeffrey, et al. 2022).

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The ageing of the population is now another big problem for the progress of society (Li et al., 2023). There will be significant shifts in socioeconomic production and consumption due to the rising number of elderly individuals (Yamasaki et al 1997, Zhang and Tan, 2016). Many studies have examined the connection between global ageing and carbon emissions, as consumption and production play a significant role in carbon emissions. Consumption patterns are particularly influenced by the age structure of the population. In a study conducted by (Dalton, 2008), it was suggested that population ageing had a positive impact on the long-term carbon emissions of U.S. households. On the other hand, (Menz and Welsch, 2012) discovered that a rise in working-age people resulted in an increase in carbon emissions in OECD countries. Several studies have shown that the relationship between ageing and carbon emissions is not straightforward. As the ageing population grows, carbon emissions per capita tend to increase and then decrease, according to various scholars (Okada, Yukinori, et al 2012, Estiri and Zagheni 2019). Is there a point at which population ageing will have a significant impact on carbon emissions? Can we explain the ways and mechanisms that lead to this effect? Our study aims to address these questions.

The current literature explored how changes in population, level of higher education, and carbon emission affect the economy using panel data. To be more specific, the study aims to look at how the percentage of people aged 15-65 affects Gross Domestic Product and Carbon Emission levels of OECD Countries. It also emphasizes the connection between the share of people with and without higher education and their income and learns how education affects the economic growth rate and Carbon Emission levels of OECD Countries. It investigates the relationship between the amount of carbon dioxide emission per person and their income. Also, look into the trade-offs that exist between industry operations and protecting the environment.

The study hoped to show how changes in population, education policies, and climate change affect economic results as a whole by looking at these goals. The results are destined to help policymakers, educators, and environmental planners understand how these factors affect each other in complicated ways. This will help them come up with ways to boost economic growth and sustainability. A lot of study has been done on the factors that affect income, but we still don't fully understand how the growing population, higher education, and carbon emissions affect income in the OECD. Which are 36 major and minor economies of the world. Previous research has mostly investigated these factors in the context of a single country. It hasn't always taken into account the unique economic processes and comparison lessons that could be found in a cross-country analysis. Also, there aren't many panel data studies that can properly take into account changes over time and effects that are unique to each country. These are important for figuring out long-term trends and policy impacts. This study aims to fill this gap by using a panel data approach to examine and compare how OECD countries are affected. This will give us a better and more complete picture of how the economies of these 36 countries are affected.

Literature Review

Here is some previous literature shared to highlight this main issue for this specific region. Liu, et al, (2023) investigated Humanity faces two fundamental challenges: population ageing and climate change induced by greenhouse gas emissions. This paper uses panel data from 63 countries from 2000 to 2020 to empirically identify and explore the threshold effects of population ageing on carbon emissions and tests in a causal inference framework the mediating effect mechanism through industrial structure and consumption. The threshold effects vary by country, but carbon emissions from industrial construction and home consumption are dramatically decreased when the senior population is greater than 14.5%. In lower-middle-income nations, the threshold effect is unknown, indicating that population ageing has less impact on carbon emissions.

Huang et al., (2020) observed how changes in population and improvements in schooling have affected the economies of the USA and China. They talk about the different steps of economic growth and how each country's government has responded, which suggests that these factors have a complex effect on income. Wang and Zhao (2015) found that China must address carbon emissions and the ageing issue to maintain economic development. This article used the STIRPAT model with Chinese province panel data to examine demographic variables and carbon emissions at the national and regional levels, including the effects of population ageing. Nationally, population ageing and quality are positively connected with China's carbon emissions. Living standards affect carbon emissions differently in urban and rural areas. Regional disparities exist in how population ageing affects carbon emissions.

Liu et al., (2016) investigated Global attention has focused on CO_2 and other greenhouse gas buildup as global warming escalates. However, the impact of demographic considerations on carbon emissions, especially in China, remains unclear. A revised STIRPAT model was used to evaluate the influence of population and income changes on China's energy-related CO_2 emissions at national and regional levels, utilising balanced province panel data from 1990-2012. Most earlier studies of emission–population/wealth elasticity in China have generated broad estimates, but this research found that income rather than demographic change has driven China's CO_2 emissions. Urbanisation increases energy use and emissions, except in western China. Age structure changes have not significantly affected energy usage but have led to higher national emissions, mainly in eastern China. Reducing home size did not decrease energy usage or emissions, suggesting that improving domestic energy efficiency may do so.

Mitigating the environmental effect of human activities in China may require changing the old economic development model, reducing urbanisation, boosting energy efficiency, and upgrading industrial structures. Cai and Cheng (2014) talked about how China's quickly growing population hurts its economic growth because fewer people are of working age, which lowers income and output. They said that the economic load of an older population could get worse if pension plans and job markets aren't changed. Zhang et al., (2017) studied the complicated link between China's carbon emissions and income, pointing out that the country's fast development has caused a lot of emissions. But they also found proof that higher incomes can lead to investments in green technologies that are better for the earth.

Li et al., (2013) explored the benefits of higher education in China and found that it had big good effects on income. Their study showed how important education is in changing an economy from one based on industry to one based on services and new ideas. Stern (2010) looked at the environmental Kuznets curve in the USA and suggested that higher incomes caused more resources to be put into better technologies and lower emissions at first, but over time, higher incomes lead to lower carbon emissions. Goldin and Katz (2008) investigated the connection between higher education and economic growth in the US. They show that making it easier for people to go to college raises their own wages and helps the economy grow by creating new jobs and skills. Baltagi (2005) talked about the benefits of using panel data for economic study, like how it took into account how different people are and how interactions change over time. This way is especially useful for looking at how ageing, schooling, and pollution affect income over time in a variety of settings. Munnell and Chen (2016) communicated about how an older population can make people less likely to work, which can slow down economic growth and lower incomes. They stressed how hard it is on social security systems and how policies need to be changed to lessen the effects on the economy.

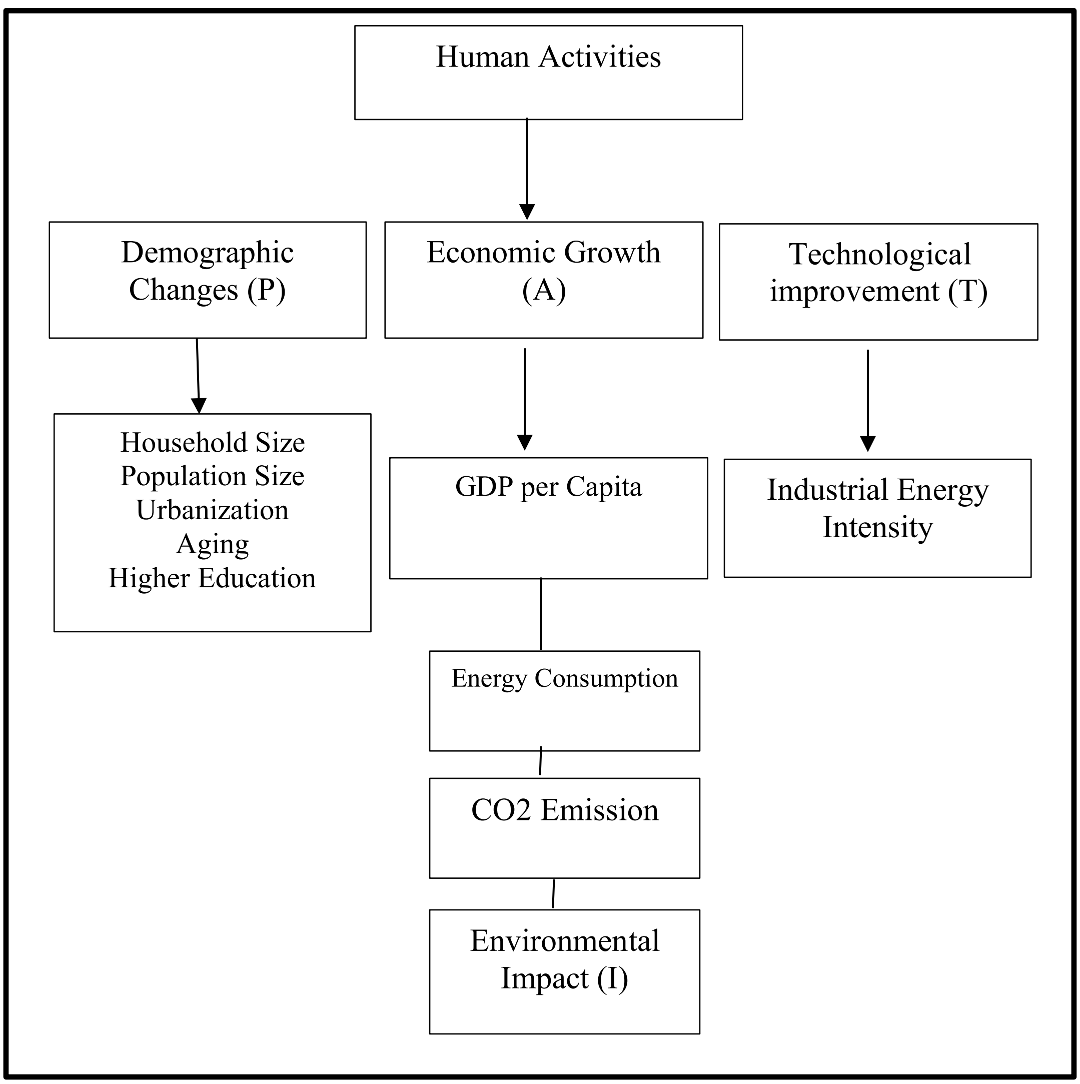
This review of the literature shows how important it is to look at a lot of different things together to see how they affect income as a whole. Individual studies are helpful for learning more about certain connections, but we need more in-depth studies that use panel data to show how changing factors like older populations, better education, and carbon emissions affect income. In order to fill this gap, this study will compare and contrast the USA and China using the benefits of panel data analysis to give a fuller and more complex picture of these important economic connections.

Method and Material

Theoretical Framework

The IPAT model (I = PAT), which was first put forward by Ehrlich PR, Holdren JP (1971), is the main idea behind how human actions affect the world. The IPAT equation shows how human activities affect the atmosphere (I) based on population (P), wealth, and technology. The IPAT model has flaws because it only changes one factor at a time. This means that changes in one factor have equal effects on the dependent variable (Shi, 2003, Cong and Shen, 2013). To address these problems, (Shi , 2003) changed the IPAT model into a random model called STRIRPAT. This model can use statistics to look at how moving forces affect the environment in ways that aren't linear or proportional. Here is the model specification: -

Figure1. Demographic changes, economic growth, technological improvement and environmental impact



Mathematical Model Specification

The STIRPAT model has been shown to be an effective tool for analyzing how driving factors affect different environmental consequences (York, Rosa, and Dietz, 2003, Poumanyvong and Kaneko, 2010, Zhou et al., 2015, Liu et al., 2015, Pesaran et al., 1999, Zhao et al., 2025) . Equation for the STIRPAT model is as follows:

$$I_{it} = a \quad b\, P_{it} c\, A_{it}\; d\; T_{it}$$

Taking logarithms, The model assumes the following shape:

$$Ln\, I_{it} = a + bLn\, P_{it} + cLn\, A_{it} + dLn\, T_{it} + \varepsilon_{it}$$

In this case, the suffixes i and t stand for countries and years, respectively; P represents population size; A is real GDP per capita; T is technology; and I is the dependent variable. The error term is ei, the constant term is a, and the coefficients of P, A, and T are, respectively, b, c, and d. Additional elements may be included in the STIRPAT model to investigate their impact on environmental parameters. Factors P, A, and T are decomposable in the STIRPAT model (York, Rosa, and Dietz, 2003).

In order to comprehensive study the effects of income and population on energy consumption and CO_2 emissions in the OECD, the STIRPAT model was extended to account for urbanization, ageing, Higher Education and household size. In this research, technological advancement was quantified using the industrial energy intensity and real GDP share of the added values of the industry sector, in accordance with the methodology of (York, Rosa, and Dietz, 2003).The STIRPAT model was modified in the following ways:

Empirical Models

In this study, three empirical models were used for estimation.

GDP = f (Pop, Ageing, Urban, EC, Edu, CO2) Model - 1

CO_2 = f (Pop, Ageing, Urban, EC, Edu, GDPp) Model - 2

EC = f (Pop, Ageing, Urban, EC, Edu, GDPp) Model - 3

GDPP = β0 + β1 Pop + β2 URBAN + β3 Ageing + β4 HED + β5 CO2 + β6 EC + μi ----Eq -1

$CO_2 = \alpha_0 + \alpha_1$ Pop + α_2 URBAN + α_3 Ageing + α_4 HED + α_5 GDPP + β_6 EC + ε_i --------Eq - 2

EC = ¥0 + ¥1 Pop + ¥2 URBAN + ¥3 Ageing + ¥4 HED + ¥5 GDPP + β6 EDU + εi -- Eq – 3

In this context, POP refers to the total population, URBAN indicates the level of urbanization, Ageing represents the share of the working-age population (ages 15–65), GDPp signifies the real per capita GDP, and CO2 denotes both total energy consumption and CO2 emissions. EC is the total energy consumed by people. HED is Higher Education level.

Results and Discussion

In this section, empirical results are shown. We applied multiple estimation techniques to highlight the impact of the explanatory variable over the regressor. Table 1 illustrated the descriptive states of the given variable and data series. The mean value of GDP per capita income, population, Ageing, urbanization, Education, CO_2 and Energy usage is 39849.24, 34326539, 162224.4, 75.86812, 212.9739, 1.89 and 4525.48 respectively. It means that the Per Real Capita income of the 36 OECD countries is $39849.24 per year for the base year 2015, Average total population of 34326539 million in the countries. The average population having ages below 15 years and above 65 years is calculated to be to be 162224.4 of the total population. It also showed that urbanization has affectedest 75.86 per cent the total population of OECD Countries which is also a big problem which creates various issues for these countries. Carbon Emission has an average value of 1.89 percent of al pollution. The usage of energy (kg of oil equivalent per capita) has an average value of 4525.48 for these countries. The standard deviation value of all variables is very high,, which is an indication of big variations in these variables.

Table 2 showed that there is no multicollinearity issue with this set of data's underlying variables. Because there isn't much of a link between the variables. What it means is that there is no link between the separate factors. So, it is decided that there is no multicollinearity exit in our independent variables. Our study implied Augmented Dickey Fuller (ADF) meted for the detection of unit root properties of the data. The results of this technique is posted in Table 3. It is showing the results of ADF test. It showed that CO2 Emission, Energy Consumption and Ageing are stationary at level and GDP per capita, Education, Population and Urbanization are stationary at first difference. T-statistics are -22.2701, -18.3204, -16.7779, -02.2432, -10.7514, -01.4776, -03.4740 respectively. They are significant at 1% and 5% level.

When the data found stationary at different levels not more than first difference, we can apply Autoregressive Distributive Lag Model (ARDL) for empirical estimation. As above results witnessed that our variable found stationary at level and first difference. So, we applied the Pesaran, M.H.; Shin, Y.; Smith 1999 presented ARDL test on all three models. For the selection of lags, we use Akaike Information Criterion (AIC).

	GDP Per Capita	Population	Ageing	Urban Population	Education	CO2	Energy use
Mean	39849.24	34326539	162224.4	75.86812	212.9739	1.894284	4525.480
Median	41190.45	10214714	66.84556	78.35850	4.571367	0.229025	3873.382
Maximum	112417.9	3.21E+08	10892413	98.15300	3673.293	61.34100	18178.14
Minimum	7862.871	303782.0	60.95921	18.19600	0.000000	0.056214	0.000000
Std. Dev.	20874.40	65633185	1021905.	14.57333	821.4341	9.739495	2873.914
Skewness	0.744035	3.320486	7.466317	-1.403354	3.707012	5.885076	1.845535
Kurtosis	4.029165	13.42094	66.45772	6.807382	14.78386	35.64746	9.399974
Jarque-Bera	56.46840 (0.00)	2634.051 (0.00)	73310.18 (0.00)	385.9474 (0.00)	3343.517 (0.00)	20775.78 (0.00)	941.5683 (0.00)
Observations	414	414	414	414	414	414	414

Table 1 Descriptive Statistics

Table 2 Correlogram for Multicollinearity in Explanatory Variables

	GDP	Population	Ageing	Urban Pop	Education	CO2	Energy Use
GDP	1.000	0.034	-0.003	0.339	0.427	-0.231	0.374
Population		1.000	-0.067	0.016	-0.103	0.013	0.169
Ageing			1.000	-0.097	-0.041	-0.028	-0.048
Urban Population				1.000	-0.039	-0.169	0.394
Education					1.000	-0.045	-0.044
CO2						1.000	-0.254
Energy Use							1.000

Table 3 Panel Unit Root Analysis

Variable	**Coefficients (t-Stats)**	**Stationarity Level**	**Variable**	**Coefficients (t-Stats)**	**Stationarity Level**
CO_2 Emission	-22.2701 [0.0000]	I (0)	Ageing	-02.2432 [0.0125]	I (0)
Energy Consume	-18.3204 [0.0000]	I (0)	Education	-10.7514 [0.0000]	I (1)
GDP Per Capita	-16.7779 [0.0000]	I (1)	Population	-01.4776 [0.0697]	I (1)
Urbanization	-03.4740 [0.0003]	I (1)			

Table 4 Autoregressive Distributive Lag Analysis (Model-1)

Regressor	Coefficients	T-Statistics	Probability
GDP (-1)	0.9758	50.7533	[0.0000]*
Population	0.0008	12.8240	[0.0000]*
Population (-1)	-0.0008	-12.3462	[0.0000]*
Ageing	19.8124	1.2057	[0.2300]
Urbanization	109.2688	5.4292	[0.0000]*
Urbanization (-1)	-111.0697	-5.4606	[0.0000]*
Education	476.0231	2.6910	[0.0080]*
Education (-1)	-434.4857	-2.4385	[0.0160]*
CO_2	-33571.2	-6.6702	[0.0000]*
CO^2 (-1)	34419.8	7.1707	[0.0000]*
Energy Consume	0.7667	1.2861	[0.2010]
Energy Consume (-1)	-1.0460	-1.7493	[0.083]***
R-Squared	**0.9848**	**Adjusted R-Squared**	**0.9833**
DW Statistics	**2.32**		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

The ARDL data for Model 1 were shown in Table 4. The dependent variable was GDP per capita income for OECD countries. It showed that the lag value of GDP per capita income has a big and good effect on GDP per capita income. Number of people living in cities, cities getting older, getting a college degree, and energy. In OECD countries, consumption has a positive and significant effect on GDP per capita. The only other factor that has a positive but not very significant effect on GDP per capita is ageing. There is a negative and significant effect on GDPp from carbon emissions, but a positive and very significant effect on GDP per capita income from those emissions. The values of the coefficients are 0.9758, 0.0008, 19.8124, 109.2688, 476.0231, 0.7667, and 34419.8. It's important to note that all of them are important at the 1% level, except for energy use, which is important at the 10% level. Liu, Yansui, Bin Yan, and Yang Zhou, 2016

The output of the ARDL technique in model - 1 showed that One person increase in population will increase 0.0008 dollars in per capita income of the OECD region. In the same way one person increase working age people cause 19.8124 dollars in GDP per capita increase in this region. The rate of urbanization is high 109.26 and positive correlated to GDP per capita which states that one percent increase in urbanization tends to 109.26 dollar increase in GDP per capita in OECD economies. The carbon emission increase by 1 percent caused 34419.8 dollar in GDP per capita income while 1 percent increase in Energy Consumption caused 0.7667 percent enhance in per capita GDP of OECD countries. The number of R-square is 98.48%, which means that the model fits right. On the other hand, the adjusted R-Squared number is 98.33%, which shows that this model captures a 98.33% effect. The fact that the DW Statistics is close to two shows that Autocorrelation is not a problem in the model.

Table 5 Diagnostic Tests on a Panel for Model-1

Applicable Tests	CHSQ	Prob
Lagrange factor for serial correlation	3.9713	[0.146]
Ramsey's restart test for functional forms	1.8975	[0.168]
Test of Normality for Skewness and Kurtosis	136.2421	[0.000] *
White Test for Heteroscedasticity	0.9837	[0.321]

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

In the aforementioned table, 5 diagnostic tests were implemented, and the results indicated that no econometric issues, such as autocorrelation or conflict with the normal distribution, existed. In the same vein, there was no bias in the model specification with respect to functional form, and there is no indication of heteroscedasticity in the model.

The serial correlation in the data was verified using the Lagrange multiplies test of residual correlation, which yielded an insignificant result. It demonstrated that the data set does not contain any serial correlation. The Ramsey's RESET test, which utilized the square of the fitted values, indicated that the functional form of the model in question is accurate. A skewness and kurtosis test of residuals was implemented as the third test. Ultimately, the white test was implemented to evaluate the issue of heteroscedasticity, and it was determined that the model did not exhibit any heteroscedasticity.

Table 6 Panel Error Correction Mechanism Analysis for Model-1

Variable	Coefficients	T-Statistics	Probabilities
dPopulation	0.0008	12.8240	[0.000]*
dAgeing	19.8124	1.2057	[0.230]
dUrbanization	109.2688	5.4292	[0.000]*
dEducation	476.0231	2.6910	[0.008]*
dCO_2	-33571.2	-6.6702	[0.000]*
dEnergy Consume	0.7667	1.2861	[0.201]
Ecm(-1)	-0.2414	-1.2557	[0.021]
R Squared	**0.9892**	**Adjusted R^2**	**0.9214**
DW Statistics	**2.3228**		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

Error Correction Mechanism Analysis showed population, Urbanization, and CO2 emission have significant impact on GDP per capita income. The coefficient values of these 0.0008, 109.2688, -33571.2 respectively. Energy consumption, and Ageing have insignificant impact in short turn. The Error Correction Mechanism was developed by integrating the long-term and short-term behavior of economic variables. The ECM (-1) represents the one-period delayed value of the error terms acquired from the long-turn relationship, while the error correction term captures the adjustment toward the long-turn equilibrium. ECM coefficient (-1) indicated the degree to which the short-term imbalance would be resolved in the long term. Both statistical significance and a negative result for the error correction term ECM(-1) are justified. The ECM term coefficient suggests a medium adjustment process, as evidenced by a 24.14% change from the previous year to the current one.

Table 7 Autoregressive Distributive Lag Analysis (Model-2)

Regressor	Coefficients	T-Statistics	Probability
CO2 (-1)	0.9436	55.1728	[0.0000]*
Population	0.8665E-8	6.4255	[0.0000]*
Population (-1)	-.6761E-8	-4.7952	[0.0000]*
Ageing	0.0388	4.1666	[0.0000]*
Ageing (-1)	-0.03803	-4.1113	[0.0000]*
Urbanization	0.0027	4.6807	[0.0000]*
Urbanization (-1)	-0.00224	-4.1607	[0.0000]*
Education	0.0145	-5.9696	[0.0000]*
Education (-1)	0.0135	6.0339	[0.0000]*
Energy Consume	0.000028	3.2474	[0.0002]*
Energy Consume (-1)	.0000399	-4.9047	[0.0000]*
GDP	0.0000067	-5.5024	[0.0000]*
GDP (-1)	0.0000059	4.5888	[0.0000]*
R-Squared	0.9949	Adjusted R Squared	0.9944
DW Statistics	2.18		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

Table 7 presented the ARDL results of Model -2, with the dependent variable Carbon Emission for OECD countries. It showed that there is the lag value of Carbon Emission has positive and significant impact on Carbon Emission. The population, Ageing Urbanization, attaining of Higher Education and Energy Consumption have positive and Significant impact on GDP per capita in in OECD countries except Ageing which is positive but insignificant impact over GDP per capita income. Carbon Emission has negative and significant impact on GDPp but its lag value has positive and highly significant impact on GDP per capita income. The Coefficient values are 0.8665E-8, 0.038, 0.0027, 0.0145, 0.000028, and 0.000059 respectively. They all are significant at 1% level of significance except Energy consumption which is significant at 10% level of significance. Liu, Yansui, Bin Yan, and Yang Zhou, (2016)

The analysis of the ARDL technique in model - 2 showed that One person increase in population will increase 0.8665E-8 dollars increase in CO2 emission of the OECD region. One person increases working age people cause 0.038 percent increase in this region. The rate of urbanization has also positive correlation with coefficient 0.0027 which states that one percent increase in urbanization tends to 0.0027 percent increase in carbon emission in OECD economies. The higher education level increase by 1 percent caused 0.0145 percent in carbon emission on the other hand 1 percent increase in Energy Consumption caused 0.000399 percent enhance in per capita GDP of OECD countries. GDP per capita increase by one percent make sure 0.0000399 percent increment in carbon emission of this region. The goodness fit of the model is indicated by the value of R-square, which is 98.48%. In contrast, the Adjusted R-Squared value is 98.33%, which indicates that the 98.33% effect was incorporated in this model. The DW Statistics is closed to two, indicating that the model does not have any issues with autocorrelation.

Table 8 Diagnostic Tests on a Panel for Model-2

Applicable Tests	CHSQ	Probabilities
Lagrange factor for serial correlation	03.8297	[0.150]
Ramsey's restart test for functional forms	19.3374	[0.120]
Test of Normality for Skewness and Kurtosis	12.3190	[0.200]
White Test for Heteroscedasticity	0.5018	[0.048]**

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

The previous table 8 contained diagnostic tests, and the results indicated that no econometric issues, such as autocorrelation or conflict with the normal distribution, were present. In the same vein, there was no bias in the model specification with respect to functional form, and there is no indication of heteroscedasticity in the model. The serial correlation in the data was examined using the Lagrange multiplies test of residual correlation; however, the results were not statistically significant. It demonstrated that the data set lacks any series connection. The functional form of the model in question was determined to be accurate by employing Ramsey's RESET test with the square of the fitted values. Use of the third test was determined by a skewness and kurtosis of residuals test. Lastly, the white test was implemented to determine whether heteroscedasticity was an issue. It was determined that the model did not contain any such issues.

Table 9 Panel Error Correction Mechanism Analysis for Model-2

Variable	Coefficients	T-Statistics	Probabilities
dPopulation	0.8665E-8	0.1348E-8	[0.0000]*
dAgeing	0.8665E-8	0.009319	[0.0000]*
dUrbanization	0.00267	0.5701E-3	[0.0000]*
vdEducation	-0.01447	0.002424	[0.0000]*
dEnergy Consume	.2773E-4	0.8538E-5	[0.0020]*
dGDP	-.6754E-5	0.122tE-5	[0.0000]*
Ecm(-1)	-0.05644	0.01710	[0.0010]*
R Squared	**0.9675**	**Adjusted R Squared**	**0.9642**
DW Statistics	**2.18**		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

In second model Error Correction Mechanism analysis showed that Population, Ageing, urbanization, and Education, Energy Consumption, and GDP per Capita have significant impact over the carbon emission. These have coefficients of 0.8665E-8, 0.8665E-8, -0.01447, 0.2773E-4, and -0.6754E- respectively. The Error Correction Mechanism was developed by integrating the long-term and short-term behavior of economic variables. The ECM (-1) represents the one-period delayed value of the error terms acquired from the long-turn relationship, while the error correction term captures the adjustment toward the long-turn equilibrium. ECM coefficient (-1) indicated the degree to which the short-term imbalance would be resolved in the long term. Both statistical significance and a negative result for the error correction term ECM (-1) are justified. The ECM term coefficient suggests a very low adjustment process, as evidenced by the 5% change from the previous year to the current one.

ARDL results of Model -3 is resented in Table 10, with the dependent variable Energy Consumption for OECD countries. It showed that the lag value of Energy consumption has positive and significant impact on Carbon Emission. The population, CO2 and GDP per Capita income have positive impact on Energy Consumption in OECD countries except Ageing, Education and Urbanization which is positive but insignificant impact over Energy Consumption. The Coefficient values are 0.9369, 0.0000517, 3.8681, 0.9459, 8.9485, 3196.8 and 0.02822 respectively. They all are significant at 1% level of significance except Energy consumption which is significant at 10% level of significance. Estiri H, Zagheni E (2019) Liu, Yansui, Bin Yan, and Yang Zhou, (2016), (Hafeez et al., 2024).

The third model indicated that the lagged value of energy consumption has a positive correlation with its dependent variable. An increase in population of one percent results in a 0.0000517 percent increase in energy consumption. A 1% increase in the number of individuals in the working age group may result in a 3.8681 percent increase in energy consumption. In next step, results also showed that one percent increase in level of higher education will increase 0.9485 percent rise in energy consumption while 1 percent rise in CO2 emission may cause 3196.8 kg in energy consumption in said region. If the GDP per capita rise by 1 dollar it will 0.0282 kg increase in energy consumption in OECD region. The goodness fit of the model is indicated by the value of R-square, which is 99.18%. The Adjusted R-Squared value is 98.33%, which indicates that the model captured a 99.11% effect. The DW Statistics is closed to two, indicating that the model does not have any issues with autocorrelation.

Table 10 Autoregressive Distributive Lag Analysis (Model-3)

Regressor	Coefficients	T-Statistics	Probability
EC (-1)	0.9369	27.9925	[0.0000]*
Population	0.0000517	3.5739	[0.0010]*
Population (-1)	-0.0000459	-3.2108	[0.0020]*
Ageing	3.8681	1.5311	[0.1280]
Urbanization	0.9459	0.7370	[0.4630]
Education	8.9485	1.1526	[0.2510]
Education (-1)	3563.9	5.9733	[0.0000]*
CO_2	3196.8	-5.5363	[0.0000]*
CO_2 (-1)	-3196.8	2.2693	[0.0000]*
GDP	0.02822	-2.8628	[0.0025]*
GDP (-1)	-0.03462		[0.0050]*
R-Squared	**0.9918**	**Adjusted R Squared**	**0.9911**
DW Statistics	**2.17**		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

Table 11 Diagnostic Tests on a Panel for Model-3

Applicable Tests	CHSQ	Probabilities
Lagrange factor for serial correlation	1.4240	[0.233]
Ramsey's restart test for functional forms	1.3318	[0.248]
Test of Normality for Skewness and Kurtosis	97.3617	[0.000]*
White Test for Heteroscedasticity	6.1078	[0.013]*

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

Table 12 Panel Error Correction Mechanism Analysis for Model-3

Variable	Coefficients	T-Statistics	Probabilities
dPopulation	0.5168E-5	3.5739	[0.001]*
dAgeing	3.8681	1.5311	[0.128]
dUrbanization	0.9459	0.7371	[0.463]
dEducation	8.9485	1.1526	[0.251]
dCO2	3563.9	5.9733	[0.000]*
dGDP	0.02821	2.2693	[0.025]*
Ecm(-1)	-0.063	-1.8848	[0.062]**
R Squared	**0.80**	**Adjusted R Squared**	**0.78**
DW Statistics	**2.17**		

(*), (**), and (***) show that the value is significant at 1%, 5%, and 10%, respectively.

Diagnostic tests were implemented in Table 11, and the results indicated that no econometric issue, including autocorrelation or conflict with the normal distribution, existed. In the same vein, there was no bias in the model specification with respect to functional form, and there is no indication of heteroscedasticity in the model (Ahmad & Ali, 2024).

We used the Lagrange multiplies test of residual correlation to look for serial correlation in the data, but the results were not significant. No series connection was found in the data set, as shown. The Ramsey's RESET test, which employs the square of the fitted values, demonstrated that the functional form of the model in question is accurate. The third test was based on a measurement of residual skewness and kurtosis. Heteroscedasticity issues were ultimately identified through the utilization of the white test. No heteroscedasticity issues were identified in the model. In third model Error Correction Mechanism analysis showed that Population, CO2 and GDP per Capita have significant impact over the Energy Consumption. These have coefficients of 0.5168E-5, 3563.9 and 0.02821respectively.

The Error Correction Mechanism was developed by integrating the long-term and short-term behavior of economic variables. The ECM (-1) represents the one-period delayed value of the error terms acquired from the long-turn relationship, while the error correction term captures the adjustment toward the long-turn equilibrium. ECM coefficient (-1) indicated the degree to which the short-term imbalance would be resolved in the long term. Both statistical significance and a negative result for the error correction term ECM (-1) are justified. The ECM term coefficient suggests a very low adjustment process, as evidenced by the 6% change from the previous year to the current one.

Conclusion

OECD countries are mixed (Developed and Developing) economic region. The OECD economies have a lot of issues. In the same way as in the rest of the world, there are now two big changes happening in the living standards of people in OECD countries. The first is changes in the environments, mostly in reference to the temperature of the world. Changes in population are another factor that affects the environment across the world. Because of carbon dioxide and other "greenhouse gas" releases into the atmosphere, average temperatures will rise in the future. In this way temperatures and rain fall across regions and countries will change Parry, Martin L. (2007).

A demographic shift includes changes to the size fo population, age distribution (Working age people), and life expectancy of the community, among other things Chesnais, Jean-Claude. (1992). In both rich and emerging countries, the present and future stages of demographic change will be marked by an ageing population. It is also important to recognize that education has a significant impact on all the factors that are dependent on it, such as energy use, carbon emissions, and GDP per capita.

This study was conducted to check the impact of working age population, total population carbon emission and level of higher education on per capita income of OECD countries mainly. We found the impact of these variables on carbon emission and energy consumption level. It found direct relationship between the Population, working age People and carbon emission on the per capita income. It is suggested that these countries put attention to creates more job for working age people. This will increase per capita income. This study also suggest that carbon emission should be minimize to reduce the world temperature.

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