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Energy, domestic investment and economic growth in OECD countries: a second-generation panel cointegration analysis (1990–2025)

Bahi Ouafa [1]
1 Laboratory of Sustainable Economic Business Management El oued University, (Algeria)
bahi-ouafa@univ-eloued.dz

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Abstract:
This study examines the relationship between renewable energy consumption and economic growth in OECD countries during the period 1990–2025 using second-generation panel data. The analysis employs the CIPS unit root test, the Westerlund cointegration test, and the CS-ARDL model within the framework of co-correlated effects (CCE). The results show a long-term equilibrium relationship between the variables. Energy consumption and domestic investment positively influence economic growth, while renewable energy has no effect. The error correction model confirms a rapid adjustment toward long-term equilibrium. The findings indicate that OECD economies remain primarily dependent on traditional growth drivers, particularly energy use and investment.

Keywords Economic growth; renewable energy; energy consumption; domestic investment; Panel data; CS-ARDL; OECD countries
Jel Classification Codes : C23, O47, Q42, Q43, E22

Corresponding author: Bahi Ouafa, e-mail: **bahi-ouafa@univ-eloued.dz**

1. INTRODUCTION

The energy sector is one of the pillars of economic growth, providing the essential basis for productive activity and fostering industrial and technological development. With the increasing global awareness of environmental issues and climate change, the significance of the transition to renewable energy sources has emerged as a strategic choice for sustainable development, particularly for OECD countries aiming to balance economic development with environmental protection

In this context, the analysis regarding the relationship between energy and economic growth is no longer limited to traditional energy consumption, but has expanded to include renewable energy, as well as other important factors such as domestic investment – one of the most important determinants of long term productive capacity – and carbon dioxide emissions, which reflect the environmental cost of economic growth.

Many studies have been conducted to examine the relationship between energy and economic growth, but the results have been mixed especially on the role of renewable energy to support economic growth. Moreover, many of these studies have used traditional (first generation) econometric techniques which assume cross-section independence, a not realistic assumption given that OECD countries are economically and financially interdependent.
Hence, the present study tries to fill this gap by applying second-generation panel techniques that enable to account for cross-sectional dependence to investigate the short- and long-run relationship between energy consumption (conventional and renewable), domestic investment, carbon dioxide emissions and economic growth over the period 1990–2025.

Research Question:

From the above the following research question is deduced:
How do short and long run effects of energy consumption, domestic investment and carbon

emissions on economic growth differ across OECD countries?
This research question also raises a number of sub-questions:
• Is there a long run relationship between these variables?
• What is the impact of renewable energy on economic growth?
• What is the role of domestic investment in promoting economic growth?
• Do carbon emissions drive or slow growth?
This study has a great practical significance because it provides empirical evidence that can help policymakers to develop better energy and investment policies, which bring a balance between economic growth and environmental sustainability.
The following hypotheses can be formulated based on the research question and sub-questions:
• Total energy consumption has positive and significant effect on economic growth in the short and long run.
• The impact of renewable energy consumption on economic growth is statistically significant.
• Domestic investment (gross fixed capital formation) has positive and significant effect on economic growth.
• Carbon dioxide emissions have a significant impact on economic growth.

2. Literature Review:

2.1. Study of (Apergis & Payne, 2010): This study investigates the relationship between renewable energy consumption and economic growth in 13 Eurasian countries over the period 1992–2007 using multivariate panel data. Cointegration tests and error correction model were used to investigate the dynamic relationship among variables in the study. The findings showed a long term eq”Ilib’Ium relationship between GDP, renewable energy consumption, fixed capital formation and labor. The results validated the bidirectional causal relationship between renewable energy consumption and economic growth in the short and long-term.
Regarding the present study, these results are consistent with the theoretical framework that postulates a positive relationship between renewable energy and economic growth; however, our results partially differed, as renewable energy consumption did not present a significant effect in the long run, which could be due to the difference in the sample of OECD countries or the standard methodology adopted (second-generation techniques).

2.2. Research (Wang & Wang, 2020): investigated the nonlinear relationship between renewable energy consumption and economic growth in OECD countries by using panel threshold models. The set of control variables used in the study includes non-renewable energy intensity, urbanization level, and per capita income.

The results indicated that renewable energy consumption has a positive effect on economic growth. However, the effect of renewable energy consumption on economic growth is nonlinear, as its magnitude and direction differ over threshold levels. This means that the role of renewable energy in promoting growth depends on the level of economic development and energy structure of a country.

The results are consistent with the present study concerning the complexity of the relationship renewable energy and growth, and they partially explain the insignificance of the variable in our model, as its effect might be conditional on structural factors not included in our mode.

2.3. Study of (Chakraborty & Mazzanti, 2021): This paper investigates the long-run relationship between renewable electricity consumption and economic growth for a group of countries over the period 1971–2015, employing panel data techniques to address heterogeneity and cross-sectional dependence across countries.

The results showed further a positive and statistically significant long run relationship between renewable electricity and economic growth. However, the causality test did not show a direct causal relationship between the two variables whereas economic growth was found to be a cause of electricity consumption.

These results are partially consistent with the present study, especially regarding the lack of a direct or strong effect for renewable energy. They support the notion that the link between renewable energy and growth may be indirect or contingent on other factors.

2.4. Study (Mili, Bengana, Aouini, & Hezla, 2025) : This study investigates the effect of renewable energy consumption and investment in environmental research and development on green growth in OECD countries using the Augmented Mean Group (AMG) approach that takes into account cross-sectional dependence and heterogeneity.

The results showed that renewable ”nerg’ consumption had a positive and statistically significant effect on green growth while the spending on environmental R&D did not have a statistically significant effect, implying that the efficiency of environmental policies depends more on mechanisms of implementation than on the volume of spending.

These results are in line with the current study regarding the importance of renewable energy in achieving sustainability goals, but they differ in terms of its impact on conventional economic growth, as it was not significant in our model. This reflects the different nature of the dependent variable (economic growth versus green growth).

2.5. (Liang, Weng, & Sun, 2026) research: this study constitutes a strategic analysis of the investment in energy infrastructures in the context of the transition to a low-carbon economy, based on panel data of 15 countries for the period 2010-2023, case studies and simulations of future scenarios.

The results Indicated that Investment In renewable energy Is positively associated with economic growth and helps reduce carbon emissions after controlling the time and country effects. This supports the key role of energy investment for promoting sustainable development.

Our results confirmed that domestic investment is one of the most important determinants of growth and these results are certainly consistent with the results of the current study regarding the positive role of investment (GDI) in the promotion of economic growth. However, there is a difference in the impact of renewable energy which was not significant in our study, probably reflecting the impact of energy crises or differences in the statistical methodology.

In general, the majority of the previous studies have confirmed the existence of a positive relationship between renewable energy and economic growth, but the nature of this relationship depends on the methodologies and the samples studied, with some studies proposing a non-linear or indirect relationship. The literature also points to the vital role of investment in aiding economic growth. These results partially confirm the current study, especially in terms of the importance of investment, but differ in terms of the impact of renewable energy, which highlights the need to apply advanced econometric models taking into account cross-sectional dependence and heterogeneity across countries.

3. Tools and methodology

3.1. Sample of study:

The sample consists of 22 OECD countries selected on the basis of data availability and completeness over the study period. Countries with substantial missing observations were excluded to ensure a balanced panel structure.

Data were collected from the World Bank and OECD databases. For a limited number of missing observations across some countries and years, linear interpolation and extrapolation techniques (using the Stata command "epolate") were employed to complete the dataset and preserve panel balance.

3.2. Variables of the research are: in this study, the dependent variable is economic growth, and the explanatory variables are renewable energy, energy consumption, carbon dioxide emissions and domestic investment. The source and definition of each indicator is provided in the following table

Table (1) Study Variables and Data Sources

Variable	Symbol	Description	Unit of Measurement	Source
Economic Growth	GDPp	Real GDP per capita	Fixed Dollar	World Bank
Renewable Energy	Renew	Percentage of renewable energy consumption in total energy	%	World Bank / International Energy Agency
Power Consumption	Energy	Primary energy consumption per capita	Kg Oil Equivalent	World Bank
CO2 emissions	CO2	Carbon dioxide emissions per capita	Metric Ton	World Bank
Local Investment	GDI	Total Fixed Capital Composition	% of GDP	World Bank

Source: Prepared by the researcher based on databases

3.4. Standard methods and tests:

Standard tests were carried out and the appropriate model was estimated using STATA 17 software.

The model adopted in this study will be estimated according to the following equation:

GDPp = f(Renew, Energy, CO2, GDI)

- Standardized testing:

In the study we employ a set of modern 445tandardized tests for panel data, which allows us to be confident in the accuracy of the results in the presence of cross-sectional dependence between countries. The tests can be arranged as follows:

-**Test of cross-sectional dependence**: The first test of the existence of cross-sectional dependence between units was the Pesaran CD test which is one of the most important second-generation tests in panel data. This test is used to test the degree of correlation between countries in the sample because ignoring this dependence can lead to misleading results. (Pesaran. H., 2004)

- Unit Root Test: Cross-Sectionally Augmented IPS (CIPS) Test: In the case of the cross-section dependence, the second generation unit root test was used, which was developed by (Pesaran M. H., (2007)) What distinguishes this test is its focus on common effects across countries.

- Panel Cointegration Test: After confirming the variables have the same order of integration, the presence of a long-run equilibrium relationship was tested by using the Cointegration Test (Westerlund, 2007) This test is characterized by its capability of dealing with cross-sectional dependence and testing the presence of an error correction mechanism

- Estimation of the Error Correction Model (CS-ECM) Short- and long-term dynamics were analysed using the following model:

Cross-Sectional Augmented Error Correction Model (CS-ECM) an extension of the CCE methodology (Chudik & Pesaran, (2015)) This model provides for:

• short-term and long-term analysis
• estimation of the speed of adjustment to equilibrium
• cross-sectional dependence treatment

- Estimation of the CS-ARDL model within the CCE framework:

The Common Correlated Effects (CCE) methodology proposed by (Pesaran & M, (2006)) was used due to the existence of cross-sectional dependence. This approach has the following features:

• Dealing with cross-sectional dependence
• Incorporating cross-sectional averages
• Delivering unbiased estimates

Estimation of the CS-ARDL model by the Common Correlated Effects (CCE) methodology reduces the need for a number of traditional post-estimation tests used in first-generation panel models. This methodology is designed primarily to address the issue of cross-sectional dependence resulting from unobserved common factors by including cross-sectional averages of the variables in the estimation equation. (Pesaran M. , 2006) proved that CCE estimators provide consistent estimates in the presence of strong cross-sectional dependence arising from a multi-factor structure. (Chaudik & Peasaran, 2015) argued that dynamic models based on the above framework preserve their desired statistical properties in the presence of unobserved common factors and heterogeneity across cross sectional units. In this sense, some traditional post-estimation tests are not a fundamental methodological requirement when using the CS-ARDL model, if the conditions for the application of the methodology have been verified in advance. However, some studies may resort to additional diagnostic tests to verify robustness of the results for enhancing reliability.

4. Results:

4.1. Descriptive statistics of the variables used in the study model.

Table 2: Descriptive statistics for the study variables

Variable		Mean	Std. dev.	Min	Max	Observations
GDPp	overall	44739.5	19510.62	14593.27	112417.9	N = 792
	between		18281.83	18923.47	96307.96	n = 22
	within		7824.822	14458.61	89323.1	T = 36
Renew	overall	20.80821	18.35117	.6	82.9	N = 792
	between		17.77994	4.261111	68.95833	n = 22
	within		5.884464	4.149874	46.11654	T = 36
Energy	overall	4747.091	2672.668	1659.74	18212.73	N = 792
	between		2565.543	2109.395	13446.19	n = 22
	within		923.2441	-782.2145	9513.637	T = 36
CO2	overall	9.754173	4.642364	3.11287	32.19406	N = 792
	between		4.311145	5.049695	20.44984	n = 22
	within		1.946268	-.2795728	21.49839	T = 36
GDI	overall	22.15463	3.701532	9.807758	53.21066	N = 792
	between		2.242283	18.38949	27.12357	n = 22
	within		2.982612	8.29472	51.69763	T = 36

Source: Stata Statistical Software Version 17

Table 2 provides the descriptive statistics of the basic characteristics of the study variables for 22 countries of the Organisation for Economic Co-operation and Development (OECD) for the period 1990–2025 with a total of 792 observations. This is a balanced panel data used in the study.The result shows that the mean real gross domestic product per capita (GDPp) was about $44,739.5 with a relatively high standard deviation of 19,510.62, indicating a clear divergence in the levels of economic growth across the countries in the sample. The values ranged from a minimum of 14,593.27 to a maximum of 112,417.9, indicating different levels of economic development in the countries included in the study. Regarding the consumption of renewable energy (Renew), the average was around 20.81% and showed a large variability among countries, from 0.6% to 82.9%. This suggests a different reliance on renewable energy sources in OECD countries, influenced by different energy policies and economic structures. In terms of the total energy consumption (energy), the average was about 4,747.09 with a relatively large standard deviation, which reflects the significant differences in the level of energy consumption among countries due to the differences in the scale of economic activity and industrial development.The results also showed that average carbon dioxide (CO2) was around 9.75 metric tons per capita. There was a large variation between countries, where the values varied from 3.11 to 32.19, reflecting differences in pollution levels and emissions due to economic activity and energy consumption.The average for the domestic investment variable, Domestic investment, proxied by Gross Fixed Capital Formation (GFCF) as a percentage of GDP, recorded an average value of 22.15%. The relatively low standard deviation suggests limited dispersion around the mean, reflecting a relatively stable pattern of investment activity among the OECD countries included in the sample.

4.2. Cross-section independence tests: Table (3) shows the cross-section independence tests for the panel (Pesaran, 2004).

Table (3): Cross-sectional independence test for model variables

Variables	CD Statistic	p-value
GDPp	82.08	0.000
Renew	71.14	0.000
Energy	54.89	0.000
CO2	70.65	0.000
GDI	14.41	0.000

Source: Output from Stata version 17

The results of the test for null hypothesis are shown in Table (3). The null hypothesis has been rejected. This implies that the cross sections of all variables are not independent. Panel data unit root tests:

The results of the previous tests of cross-sectional dependence indicate the use of second-generation

4.3. unit root tests for panel data:

Table (4) presents the outcomes of the Pesaran CIPS unit root tests for the study variables.

Table (4) : Pesaran CIPS unit root tests for the study variables

Variable	Level (C)	Decision	Level (C+T)	Decision	First Difference (C)	Decision	First Difference (C+T)	Decision	Degree of integration
GDPp	-1.576	Unstable	-1.987	Unstable	-4.160	Stable	-4.160	Stable	I(1)
Renew	-1.194	Unstable	-1.588	Unstable	-4.834	Stable	-5.384	Stable	I(1)
Energy	-1.516	Unstable	-2.603	Unstable	-5.218	Stable	-5.389	Stable	I(1)
CO2	-1.922	Unstable	-2.571	Unstable	-5.563	Stable	-5.807	Stable	I(1)
GDI	-2.275	Stable	-2.872	Stable	-4.728	Stable	-4.779	Stable	I(0) / I(1)*

Source: Prepared by the researcher based on output from the statistical software Stata 17

The CIPS test results reveal that most of the variables are not level stationary as the test statistics does not exceed the critical values at 5% level; however, all the variables became stationary after the first differencing. Therefore, all variables are of the first order integrated (I (1)) except for the GDI variable, which was stationary at the level. This does not affect the validity of the CS-ARDL approach, which can accommodate a combination of I(0) and I(1) variables provided that none of the variables is integrated of order two.

4.5. Panel dat cointegration tests:

Table (5) reports the results of second generation cointegration tests (Westerlund, 2007)

Table (5): Cointegration tests (Westerlund, 2007)

```
Westerlund test for cointegration
------------------------------------------------------------------------------
H0: No cointegration                        Number of panels      =      22
Ha: Some panels are cointegrated            Number of periods     =      36

Cointegrating vector: Panel specific
Panel means:          Included
Time trend:           Not included
AR parameter:         Panel specific
------------------------------------------------------------------------------
                                             Statistic      p-value
------------------------------------------------------------------------------
 Variance ratio                                3.6000       0.0002
------------------------------------------------------------------------------
```

Source: Output from Stata version 17

In the panel data framework, the existence of a cointegration relationship between the study variables was tested using the Westerlund (2007) test. The results showed that the test statistic (variance ratio) was 3.6000 and the p-value was 0.0002 which is less than 5% significance level which leads to the reject of the null hypothesis that there is no

cointegration. Therefore, it can be concluded that there is a long run equilibrium relationship between the variables under study which implies that they move together in the long run despite their instability in level. This result supports the use of dynamic models such as CS-ARDL in analysing short- and long run relationships

4.6. Estimation Technique: because of the existence of cross-sectional dependence among countries, the Common Correlated Effects (CCE) methodology developed by M. Hashem Pesaran (2006) was used to treat common shocks by including the cross-sectional means of the variables in the model. The CS-ARDL (cross-section enhanced distributed lag autoregressive model) proposed by Alexander Chudik and M. Hashem Pesaran (2015) was used because of the heterogeneous and dynamic nature of the data. The CS-ARDL combines the features of ARDL models with the ability of the CCE methodology to handle cross-sectional dependence.

This model permits estimating short- and long-term relationships between variables, the inclusion of variables with different orders of integration, and the ability to handle heterogeneity across units. The Westerlund test was conducted to confirm the presence of cointegration between the variables. An Error Correction Model (ECM) was developed within the CCE framework to examine the speed of adjustment towards long-run equilibrium.

This standard framework is one of the newest methods used in the analysis of panel data, integrating standard accuracy with the capacity to tackle frequent problems like cross-sectional dependence and heterogeneity, thus producing more trustworthy estimates.

Table (6). Results of the estimation of the dynamic error correction model (CS-ECM) by the common effects (CCE) approach with the mean group method.

(Dynamic) Common Correlated Effects Estimator - Mean Group

Panel Variable (i): **country**		Number of obs	= 770
Time Variable (t): **year**		Number of groups	= 22
Degrees of freedom per group:		Obs per group:	
without cross-sectional avg. min	= 29	min	= 35
max	= 29	avg	= 35
with cross-sectional avg. min	= 24	max	= 35
max	= 24		
Number of		F(242, 528)	= 2.27
cross-sectional lags	0 to 0	Prob > F	= 0.00
variables in mean group regression	= 110	R-squared	= 0.49
variables partialled out	= 132	R-squared (MG)	= 0.49
		Root MSE	= 950.23

D.GDPp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean Group:						
L.res	-.7169527	.1165523	-6.15	0.000	-.9453911	-.4885144
D.Renew	126.8223	141.6669	0.90	0.371	-150.8397	404.4844
D.Energy	2.721675	.8891367	3.06	0.002	.9789989	4.464351
D.CO2	193.5582	210.1923	0.92	0.357	-218.411	605.5275
D.GDI	408.7685	70.29351	5.82	0.000	270.9958	546.5413

Mean Group Variables: L.res D.Renew D.Energy D.CO2 D.GDI
Cross Sectional Averaged Variables: GDPp Renew Energy CO2 GDI
Heterogenous constant partialled out.

Source: Output from Stata version 17

The results of the Dynamic Error Correction Model (CS-ECM) show that the error correction coefficient is negative and statistically significant at 1% level with a value of (-0.716), confirming the existence of long-run equilibrium relationship between the variables and a high speed of adjustment towards equilibrium, with about 71% of imbalances being corrected within a single time.In the short term, the results showed a positive and statistically significant effect of both total energy consumption and domestic investment on economic growth, reflecting the vital role of these two variables in supporting economic activity. On the other hand, consumption of renewable energy and carbon dioxide emissions had no significant impact, implying that the effect may be indirect or in the long run.Overall these results suggest the importance of energy and investment as crucial drivers of economic growth, particularly in the light of the global economic conditions and volatility in energy markets.Results of the CS-ARDL model estimation by using the Common-Coefficient Estimation (CCE) method with the mean group approach-Long-run estimatesThe long-run relationship was estimated using the cross-sectional enhanced distributed autoregressive model (CS-ARDL) within the common-effects methodology (CCE) framework because it yields long-run estimates that account for cross-sectional dependence and heterogeneity across countries. The results presented are the long-run coefficients derived from this model.

The long-run estimation results show a positive and statistically significant effect of both total energy consumption and domestic investment on the economic growth which implies the importance of these two variables in facilitating the economic activity in the long-run. On the other hand, renewable energy consumption and carbon dioxide emissions were not significant, however the signs of the coefficients were positive which means that the effect of these variables could be indirect or dependent on other structural factors.

The findings also confirm that domestic investment is the most influential factor for the achievement of economic growth which shows the importance of capital formation for productivity and economic

methodology with the mean group method – long-term estimates.

Table 7 shows the results of the CS-ARDL model estimation using the combined effects (CCE)

(Dynamic) Common Correlated Effects Estimator - Mean Group

Panel Variable (i): **country**		Number of obs	= 792
Time Variable (t): **year**		Number of groups	= 22
Degrees of freedom per group:		Obs per group (T)	= 36
without cross-sectional averages	= 31		
with cross-sectional averages	= 26		
Number of		F(220, 572)	= 2.26
cross-sectional lags	0 to 0	Prob > F	= 0.00
variables in mean group regression	= 88	R-squared	= 0.54
variables partialled out	= 132	R-squared (MG)	= 0.99
		Root MSE	= 812.12

GDPp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Mean Group:						
Renew	175.3275	115.5221	1.52	0.129	-51.09172	401.7468
Energy	1.826116	.9096669	2.01	0.045	.0432014	3.60903
CO2	133.4838	238.4546	0.56	0.576	-333.8788	600.8463
GDI	279.7397	39.51444	7.08	0.000	202.2928	357.1866

Mean Group Variables: Renew Energy CO2 GDI
Cross Sectional Averaged Variables: GDPp Renew Energy CO2 GDI
Heterogenous constant partialled out.

Source: Output from Stata version 17

expansion. Overall, these results seem to suggest that economic growth in OECD countries still relies more on traditional factors such as investment and energy rather than renewable energy, whose economic impact may take longer to materialise.

5. Analysis and interpretation of results:

- Total Energy Use: the results revealed that total energy consumption has a positive and statistically significant effect on economic growth in the short and long run. Such result is in line with the classical economic theory that considers energy as one of the most important inputs in the production process, so that the increase of its consumption leads to a greater industrial and productive activity and hence economic growth. The finding supports the findings of many previous studies that have confirmed a positive relationship between energy consumption and economic growth . This is particularly true in industrialised countries where these economies depend heavily on energy to power various productive sectors.

This result can be read also in the context of the present geopolitical situation, where the tensions in the global energy markets, particularly in the Middle East, have highlighted the importance of securing energy sources as a strategic priority. Countries confronted with such crises tend to increase the use of conventional energy to ensure the continuity of economic activity, which reinforces the role of total energy as a key driver of growth.

Renewable Energy (Renew): The empirical results showed that in the study period, the use of renewable energy did not significantly affect economic growth in OECD countries. This does not necessarily imply that renewable energy is not important economically but rather that its contribution to economic growth may be indirect, gradual or subject to factors unique to a particular nation. One reason is that renewable energy technologies often require large initial investments, infrastructure development and regulatory support before their economic benefits are fully reflected in aggregate output.

In addition, the minor coefficient may reflect the diversity of the OECD economies that differ greatly in the share of renewable energy, efficiency and technological development. This interpretation is consistent with previous research which also indicates the possibility of a nonlinear relationship between renewable energy and economic growth in the form of threshold levels of economic development, technological progress or energy transition. Thus, there is no meaningful average effect in the current model that would rule out beneficial effects in some countries or under some economic conditions.

The result can also suggest that conventional energy sources still prevail in production and economic activity in many OECD economies, despite the growing use of renewable energy. Thus, the economic benefits of renewable energy may accrue over a longer time horizon, through improvements to energy security, technical innovation, and environmental sustainability, rather than through an immediate boost to economic growth.

- Domestic Investment (Gross Fixed Capital Formation – GDI): the results indicated that the domestic investment has positive and significant impact on economic growth both in the short and long run. This is consistent with economic theory, as investment is one of the main drivers of growth by increasing productive capacity, improving infrastructure and promoting technological progress.

This is also consistent with a large number of empirical studies which have shown that fixed capital formation plays a vital role in achieving sustainable growth especially in advanced economies.

For all these reasons, the importance of domestic investment tends to be particularly evident from a geopolitical point of view in times of crisis, when countries seek to increase their reliance on internal sources and to reduce their vulnerability to external shocks. Infrastructure investment, particularly in the energy sector, is a key tool for promoting economic stability in the context of turmoil in the world's energy markets.

- Carbon Emissions (CO_2): The results show that carbon dioxide emissions do not statistically influence economic growth in OECD countries during the study period. This finding implies that the direct effect of environmental pressure on economic growth is rather weak in the sample. One explanation may be that OECD economies have gradually implemented cleaner technologies of production, stricter environmental regulations and more energy efficient production processes, which may reduce the direct economic effects of carbon emissions.

Moreover, the trivial coefficient might be indicative of the heterogeneous economic and environmental structures across OECD countries. Some economies remain relatively carbon intensive but others have managed to decouple economic growth and carbon emissions significantly. Thus, the model may be capturing an average effect that is statistically insignificant. However, this result should not be interpreted as evidence supporting the Environmental Kuznets Curve hypothesis because testing such a hypothesis requires the specification of a nonlinear model and the inclusion of additional terms to capture potential threshold effects.

- Error Correction Term (ECT): the results obtained from the error correction model also indicated the coefficient of correction to be negative and statistically significant, which is indicative of a long run equilibrium relationship between the variables. The relatively high value of the coefficient also indicates a fast adjustment rate, with a significant percent of imbalances being corrected quickly.

This result illustrates the speed with which OECD economies can adjust to shocks, especially foreign shocks associated with international energy markets. These factors include development of economic institutions, flexibility of economic policies and diversification of investments and energy sources.

6. CONCLUSION

The study attempts to investigate the linkage between energy consumption (conventional and renewable), domestic investment (total fixed capital formation), carbon dioxide emissions, and economic growth in the Organization for Economic Co-operation and Development (OECD) countries for the period 1990–2025, by employing second generation longitudinal data techniques that take into consideration the cross-sectional dependence problem.

The unit root test results revealed that domestic investment (GDI) is stationary at level, whereas the remaining variables are integrated of order one, integration.The results of joint integration test also confirmed the presence of long-term equilibrium relationship among the variables. The results of the error correction model showed the existence of a negative and statistically significant coefficient, which indicates a high speed of return of the system to the long-term equilibrium after shocks .

Regarding the impact of the explanatory variables, it was found that total energy consumption and domestic investment are important variables in explaining the increase in economic growth, as they showed a positive and moral impact in the short and long term. On the other hand, both renewable energy consumption and carbon dioxide emissions had no significant impact on economic growth, which reflects the gradual character of the energy transition process, in addition to the impact of structural factors and economic and geopolitical conditions.

The results suggest that aggregate energy consumption is still the main driver of growth in OECD economies, whereas the role of renewable energy has not yet reached a level that can directly influence long-term economic performance. The strong role of domestic investment also highlights the importance of policies that support capital accumulation and improve infrastructure.

-Limitations and Future Research

Although the study provides strong evidence on the long-run relationship between energy consumption, renewable energy, domestic investment, carbon emissions and economic growth in OECD countries, some limitations have to be highlighted. The analysis mainly focuses on long-run equilibrium relationships and adjustment dynamics in the CS-ARDL framework. Future research may extend the analysis by employing panel causality techniques such as the Dumitrescu–Hurlin causality test to determine the direction of causality among the variables and to provide deeper insights into the energy-growth nexus. Furthermore, future studies can investigate the possible nonlinear relationship between carbon emissions and economic growth by applying the Environmental Kuznets Curve hypothesis in a second-generation panel setting.

-Recommendations:

Based on the findings, the following recommendations can be made:

- ✓ **Promotion of energy efficiency**: Countries should aim at improving energy efficiency, especially in productive sectors, in order to achieve economic growth without excessive dependence on traditional energy sources.
- ✓ **Supporting the transition to renewable energy:** Although renewable energy was not found to exert a statistically significant direct effect on economic growth, policymakers should continue supporting the transition toward renewable energy because of its contribution to environmental sustainability, energy diversification, technological innovation, and long-term energy security.
- ✓ **Promoting local investment: The study recommends that: Given the positive role of local investment, the study suggests that**:

• Enhancing the business environment
• Backing productive projects
• directing investments to strategic sectors, especially the energy sector;

- ✓ **Growth and Environmental Sustainability Balance Decision makers should seek to:**

• Reduce emissions without compromising growth
• Implement progressive and effective environmental policies
• Embedding the environmental dimension in economic policies

This research confirms that for greater competitiveness and long-term economic stability, the OECD countries need a balanced combination of energy and investment policies to achieve sustainable economic growth, taking the environmental challenges and changing geopolitical conditions into account.

7. Bibliography

- Apergis, N., & Payne, J. E. (2010, Volume 32, Issue 6, November). Renewable energy consumption and growth in Eurasia. *Energy Economics*, pp. 1392-1397.
- Chakraborty, S. K., & Mazzanti, M. (2021, Volume 59, December). Renewable electricity and economic growth relationship in the long run: Panel data econometric evidence from the OECD. *Structural Change and Economic Dynamics*, pp. 330-341.
- Chudik, A., & Pesaran, M. H. ((2015), 188(2)). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, pp. 393–420.
- Liang, Y., Weng, X., & Sun, T. (2026). Policy, Technology, and Economic Efficiency of Infrastructure Energy Investment: A Strategic Analysis for a Low-Carbon Future. *econ.GN*.
- Mili, K., Bengana, I., Aouini, S., & Hezla, M. (2025, Volume 14, December). Threshold effects of renewable energy and environmental R&D on green growth: A dynamic panel analysis of OECD countries. *Energy Reports*, pp. 2368-2383.
- Pesaran, & M, H. ((2006), 74(4)). *Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica*, pp. 967–1012.
- Pesaran, M. H. ((2007) , 22(2)). A simple panel unit root test in the presence of cross-section dependence . *Journal of Applied Econometrics*, pp. 265–312.
- Pesaran. H., M. (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics*.
- Wang, Q., & Wang, L. (2020, Volume 207, 15 September 2020, 118200). Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. *Energy*.
- Westerlund, J. (2007). Testing for error correction in panel data. *Oxf Bull Econ Stat, 69*, pp. 709–748. doi:10.1111/j.1468-0084.2007.