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Testing the Environmental Kuznets Curve Hypothesis within the Context of Industrial Development through NARDL Model: The Case of France

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ABSTRACT

Energy is one of the necessary and vital factors for the economic development of countries and the increase in living standards. The limited availability of conventional energy resources, in parallel with the rapid increase in energy consumption due to industrialization activities and technological developments, has encouraged countries to change their energy production policies and use alternative energy sources. For this purpose, in the study, the relationship and direction of the relationship between industrial production, CO_2 emissions, energy use and economic growth in France are examined with the carrying out of the ADF, PP, KPSS unit root and the NARDL test for the period 1990–2023. The analysis findings reveal that the variables are cointegrated in the long-run and a 1% unit raise in energy consumption would trigger CO_2 emissions by 0.46%. The increase in energy consumption in the long term affects both negatively and positively in the long term. While a 1% increase in energy consumption reduces carbon emissions by 0.48%, a 1% decrease causes a 0.35 decrease in carbon emissions. The positive increase in economic growth and the negative increase in energy consumption trigger environmental pollution by causing an increase in carbon dioxide emissions. There is interdependence between economic activities and environmental pollution. Policy makers need to adopt a strategic approach in solving the rapid industrialization phenomenon and the accompanying magnitude of energy consumption, the pressure on natural resources and the environmental pollution problems resulting from them. In this respect, it is an inevitable necessity for countries to continue multilateral negotiations in which the public sector, business world, academia and non-governmental organizations will take part in solving environmental problems.

Keywords: Industrial Production, CO_2 Emissions, Energy Consumption, Economic Growth, Kuznets Curve
JEL Classifications: O14, O13, Q4, O47, C22

1. INTRODUCTION

Global interest in the environment has increased due to the increasing emergence of environmental problems around the world in recent years and the threat to the living spaces of future generations. Deterioration in the environment has become more visible, especially after the industrial revolution. These developments have accelerated the industrialization process of countries and contributed bring about economic growth and development in countries that can easily adapt to this process and follow technology closely (Altan, 2021). As countries increase their production for the purpose of growth and development, it becomes necessary for them to increase their energy use. Energy is considered one of the most important production inputs required to ensure sustainability in the production process. For this reason, it is of great importance for the realization of the economic and social development of countries (Aydin, 2020).

Energy, which is present in every period of our lives and increases its impact day by day, is an important factor in a country's growth level, industrialization, raising the standard of living and ensuring social development. The increasing demand for goods and services with industrialization has brought about an increase in industrial production. Environmental pollution that occurs during production and consumption as a result of the increasing use of raw materials and energy due to production has become an important problem. Because a significant part of the energy demand is based on energy obtained from fossil fuels that largely pollute the environment. Energy, which is an indispensable part of economic life, participates in the production process, and as the national income of countries increases, their energy consumption, especially electrical energy consumption increases as well (Ergun and Polat, 2017).

Globalization and the economic activities it brings with it, rapid and uncontrolled economic growth in both industrialized and industrializing countries, have also brought environmental effects. While industrialization has caused radical changes in the economic, social and cultural lives of societies, it has also caused rapid change and pollution of the natural environment in a noticeable way since the 20th century. Because industrialization was not planned, only industrialization was targeted, and the environmental factor was ignored. Since the industrial revolution, greenhouse gas emissions and deforestation movements created first by developed countries and then by developing countries with rapidly increasing industrialization processes have caused global warming to reach dangerous levels today. The development processes of the world countries and the environmental problems that develop in parallel with them become more evident day by day, making it necessary to address these problems with a holistic approach (Sancar and Polat, 2018).

All world leaders gathered on a common platform to discuss environmental problems, identified the problems and then made efforts to solve these problems. The declaration published at the end of the meeting reminded us again how valuable the environment is and showed that this problem is not just a problem of a few countries but of the whole world. A road map on environmental protection was drawn for the United Nations, and not only states but also individuals were warned to be sensitive about this issue, as environmental pollution increases as the world population and industrialization increases (Altunbas, 2003, p.103-105).

One of the most important factors in the economic development of a country is the development of the industrial volume. In other words, development in industrial production is considered the greatest precursor of the country's economic development (Liu et al., 2018).

As a result of the increase in the production volume of companies in the country, there may be an increase in the export figures of that country. If this industrial production is based on high value-added goods (capital intensive), economic development in this country becomes long-term and permanent (Dincer et al., 2018).

On the other hand, a development in industrial production will also contribute to reducing the unemployment rate in the country. With the industrial revolution, mass production increased and consumption needs began to be met rapidly. In direct proportion to this increase, there has also been an increase in environmental pollution. Toxic gases and pollutants released from factories have mixed into the air, water and soil, causing serious pollution (Ahmad and Zhao, 2018).

It is known that especially toxic gases mixed into the air cause global warming and climate change. Global warming and climate change are among the biggest problems the world has faced recently due to their devastating effects on human life. The most important cause of global warming is greenhouse gas emissions (Shahbaz et al., 2019).

A large part of greenhouse gases consists of carbon (CO_2) emissions. CO_2 emission is included in the literature as a measure of environmental pollution. The main reason for CO_2 emissions is economic growth. The relationship between economic growth and environmental pollution is depicted as an inverted U-shaped connection (Grossman and Krueger, 1991).

This hypothesis, called the environmental Kuznets curve (EKC), states that countries, especially developing economies, encounter environmental problems in the early stages of development. This is because at the beginning of economic growth, countries use polluting sources that have the potential to have a negative impact on the environment. This continues until higher income levels, where the development structure is changed to include environmentally friendly resources such as renewable energies and innovative production processes (Dauda et al., 2021).

The main purpose of this paper is to conduce to the energy and environment literature by determining the macroeconomic factors influencing the aggregate of CO_2 emissions, which has been oftenly inspected through several academicians in the France, and to comprehend the connection by employing special econometric tests. In this frame, when the contributions and novelties of this research to the literature are examined, the outcome of the research are significant that it will apperceive to the attain of the road map of the France in action plans in which decisions on environmental problems will be taken in terms of industrial production. In the first section of the manuscript, the subject is discussed through general framework which includes EKC hypothesis and industrial issues. In the second section of the research, the recent literature regarding the relevant subject is provided in detail. Besides, econometric techniques are practised and the existence of the EKC hypothesis is tested in terms of industrial production in the third part of the research. Finally, in the last part, empirical outcomes are reviewed and interpreted within the frame of industrial development-induced EKC hypothesis and some recommendations are given to French policy makers as well.

2. LITERATURE REVIEW

Generally, developed countries focus on sustainable development rather than economic growth. Sustainable development requires attention to the environment. There are many studies in the literature examining the relationship between economic growth and environmental degradation within the scope of the EKC hypothesis. Studies conducted on this subject and the results of the studies are included in this section. In the studies conducted, the amount of CO_2 emissions, which has the highest share in greenhouse gas emissions and represents greenhouse gases, is generally used as the dependent variable, and economic growth, energy consumption and industrial production were used as independent variables. Variables are mostly considered as amounts per capita. In this study, differently, the validity of the EKC hypothesis is examined for the manufacturing industry.

The relationship between economic growth and environmental pollution is the first subject to studies by Grossman and Krueger (1995), Shafik and Bandyopadhyay (1992). In these studies, an inverted-U-shaped relationship is found between the variables, but no reference was made to the EKC hypothesis. The first study to consider the inverted-U-shaped relationship as the EKC hypothesis is the study by Panayotou (1993). The literature examining the relationship between environmental pollution and economic growth can be divided into two groups: Empirical studies that support and do not support the EKC hypothesis. These studies can be examined in distinction between studies whose samples consist of country groups and studies conducted for EU countries.

In the recent academic literature, it can be concluded that there are several research which tests the EKC hypothesis in many economies in terms of different income groups. Bese and Kalayci (2021a), Bese and Kalayci (2021b), Ozturk and Acaravci (2013), Apergis and Ozturk (2015), Ozturk et al. (2016), Kalayci (2017), Ozkan et al. (2019), Kalayci (2021), Kalayci and Ozden (2021), Sarigul and Apak (2024), Tarazkar et al. (2021), and Yazici (2022) analyze the viability of the EKC hypothesis in lots of country groups. In this sense, conducting the research in terms of the EKC hypothesis regarding a sectoral basis is so significant as well. Bese and Kalayci (2021a; 2021b) discuss in detail the EKC hypothesis by considering 3 developed countries, containing Denmark, the United Kingdom, and Spain, from 1960 to 2014 by supposing the elements such as GDP, CO_2 and energy usage. In this context, Toda and Yamamoto Granger non-causality, ARDL bounds, VAR granger causality/block exogeneity Wald, and the Johansen cointegration tests are performed. According to empirical findings, the EKC hypothesis is not verified for Denmark, the United Kingdom, and Spain. Unidirectional causality running from energy consumption to CO_2 is confirmed for Denmark, and unidirectional causality running from CO_2 to energy usage is obtained for the United Kingdom.

There are many studies in the literature on testing the validity of the EKC hypothesis in terms of industrial production. For instance, Salim et al. (2014) examine the dynamic relationship between renewable and non-renewable energy consumption and industrial production and GDP growth in OECD countries during the 1980-2011 periods. The panel cointegration technique, which allows structural breaks, is used in the study and it is concluded that there is a long-term balance relationship between non-renewable and renewable energy sources, industrial production and economic growth.

In addition, panel causality analysis reveals that there is a unidirectional causality between GDP growth and renewable energy consumption. Yildirim and Cevik (2017) perform the Johansen cointegration method to analyze energy prices and industrial production index data covering the period between 2005-M1 and 2015-M1 to investigate the impact of the trans-anatolian natural gas pipeline project on industrial production in Türkiye. The result of the analysis shows that the decline in energy prices positively affects the industrial production index, which is considered a basic sign of economic growth. Accordingly, it has been proven that prices of gas had a significant impact on industrial production in the Turkish economy in the relevant periods.

Unluoğlu and Dagdemir (2023) state that there is no inverted-U relationship between Turkey's manufacturing industry production and CO_2 emission amounts from the manufacturing industry in the 1998-2018 period, as predicted by the ÇKE hypothesis. In addition to manufacturing industry production, manufacturing industry energy demand is also a determinant of CO_2 emissions from the manufacturing industry. Increasing pollutant emissions due to the increase in manufacturing industry production do not seem to decrease in the long term, following a natural path with the effect of new dynamics that will emerge with the increase in production, as predicted by the EKC hypothesis. The findings of their research are meaningful in that they emphasize the importance of regulatory environmental policies for the industrial and energy sectors. To sum up, the importance of developing environmental protection policies covering the manufacturing industry, which is one of the major causes of greenhouse gas emissions is more increasing day by day.

3. DATA AND METHODOLOGY

In this study, a topic covering the annual periods between 1990 and 2023 with variables such as economic growth (GDP), energy consumption, CO_2 emissions and industrial production in France is discussed. It is known that EKC hypothesis consist of 3 variables including GDP, energy usage and CO_2 emissions. The industrial production is added to the EKC model in order to test the validity of the hypothesis. CO_2 is determined as depependent variable and rest of them are determined as independent variables including industrial production, GDP, energy consumption. The annual data of variables containing energy use, CO_2, GDP and industrial prodution are collected from Our World in Data (2024a; 2024b), World Bank (2024), OECD (2024) and respectively.

The dataset is gathered more than 30 which cover 1990–2023 periods in order to make the econometric time series analyzes as parametric tests. Dataset symbols and explanations for the variables are given in detail in Table 1 below. For instance, "CO_2"

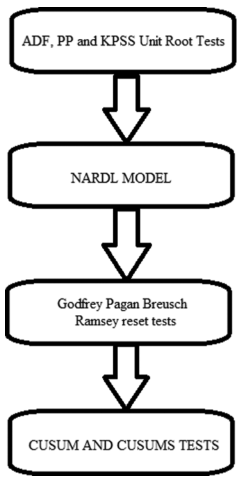
Table 1: Data descriptions

Variables	Description
Carbon dioxide emissions	Carbon dioxide emissions from fossil fuels and industry. Land-use change is not included
Industry (IP)	Includes production, sales, work started and orders
Gross domestic product	Gross domestic product (Current US$) It refers to the total goods and services produced by a country in a year
Energy use	Energy use (measured in terawatt-hours of primary energy consumption)

refers carbon dioxide emissions from fossil fuels and industry. "IP" includes production, sales, work started and orders. "GDP" refers to the total goods and services produced by a country in a year. "EU" refers energy use (measured in terawatt-hours of primary energy consumption).

Figure 1 shows the methodological chronology of this research. According to this chronology, ADF, PP, and KPSS unit root tests are employed to comprehend the structure stationarity of series. After determination of all series' stationarity at I(1) at Table 2, NARDL test is performed to designate the positive and negative long-run influence of industrial production, energy use and GDP on CO_2 emissions for France from 1990 to 2023.

Figure 1: Methodology flowchart of the study



In this sense, according to empirical findings majority of independent varibles affect the CO_2 emissions at Table 3 both negative and positively which confirms the EKC hypothesis. Afterwards, various methods such as Godfrey Pagan Breusch and Ramsey reset are used to verify the NARDL method in Tables 4 and 5. The P-value of all tests is more than 0.05 which affirms the NARDL model of France. Furthermore, CUSUM and CUSUMS tests applied in Figures 2 and 3 below, the blue line remained within the desired interval, confirming the NARDL model empirically.

A time series is stationary if its variance and mean do not change over time and if the common variance between two periods depends only on the distance between the two periods and not on the period in which this common variance is calculated (Gujarati, 2021). In empirical analyzes using time series, it is first necessary to test whether the series used in the model are stationary or whether there is a unit root. In studies, the Augmented Dickey-Fuller (ADF) test is generally used to test the stationarity of variables. The ADF test includes the lagged values of the dependent variable into the model as an independent variable. Thus, in the autocorrelated error term, autocorrelation is eliminated with the lagged values of the time series. The number of lags is selected according to Akaike and Schwarz information criterion. The following

Table 2: ADF, PP and KPSS unit root test results

Findings	Region	Variables	ADF test at I (0)	ADF test at I (1)
I (1)		CO_2	−0.1044	−7.7047*
			−2.9571	−2.9571
I (1)	France	Industrial pro	1.9165	−5.9622*
			−2.9540	−2.9571
I (1)		Energy cons	−1.2895	−9.1872*
			−2.9571	−2.9571
I (1)		GDP	−1.0615	−5.0428*
			−2.9540	−2.9571

ADF: Augmented Dickey-Fuller, CO_2: Carbon dioxide. Thick numerals refer ADF test findings. "*" and "**" terms show the unit root test of the all variables which is conducted in the estimation period, 1 and 5% importance levels

Findings	Region	Variables	PP test at I (0)	PP test at I (1)
I (1)		CO_2	−0.1346	−7.6523*
			−2.9540	−2.9571
I (1)	France	Industrial pro	−1.9062	−5.9622*
			−2.9540	−2.9571
I (1)		Energy cons	−0.5829	−8.3467*
			−2.9540	−2.9571
I (1)		GDP	−1.0632	−5.0500*
			−2.9540	−2.9571

PP: Phillips Perron, CO_2: Carbon dioxide, GDP: Gross domestic product. Thick numerals refer PP test outcomes. "*" and "**" symbols show the unit root test of the series which is employed in the estimation period, 1 and 5% importance levels

France	At level intercept	I (0)	At first difference intercept	I (1)
Variables	Frequency (k)	FKPSS stats.	Frequency (k)	FKPSS stats.
CO_2	1	0.6162	1	0.0016
Industrial pro	1	0.2066	1	0.0014
Energy cons	1	0.3999	1	0.0015
GDP	1	0.6055	1	0.0063

CO_2: Carbon dioxide GDP: Gross domestic product, KPSS: Kwiatkowski-Phillips-Schmidt-Shin. Notes: * indicatess significance at 1% level. The critical values of the FKPSS; test are 0.269 at 1%

Table 3: NARDL model estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
$CO_2$1 (-1)	−0.177455	0.139177	−1.275031	0.2246
$CO_2$1 (-2)	−0.132274	0.115760	−1.142660	0.2738
ENERGY_C1_POS	0.634687	0.178183	3.561996	0.0035
ENERGY_C1_NEG	0.470330	0.151722	3.099951	0.0084
GDP1_POS	0.494777	0.114884	4.306746	0.0009
GDP1_POS (-1)	−0.104644	0.128058	−0.817165	0.4286
GDP1_POS (-2)	−0.215789	0.085565	−2.521929	0.0255
GDP1_NEG	−0.371401	0.073607	−5.045715	0.0002
GDP1_NEG (-1)	0.253272	0.103189	2.454443	0.0290
GDP1_NEG (-2)	0.181344	0.082814	2.189772	0.0474
INDUSTRIAL_P1_POS	0.549383	0.246392	2.229710	0.0440
INDUSTRIAL_P1_POS (-1)	0.105920	0.229253	0.462022	0.6517
INDUSTRIAL_P1_POS (-2)	0.212973	0.122870	1.733317	0.1067
INDUSTRIAL_P1_NEG	0.237934	0.173752	1.369387	0.1941
INDUSTRIAL_P1_NEG (-1)	0.514156	0.352336	1.459280	0.1682
INDUSTRIAL_P1_NEG (-2)	0.521566	0.300075	1.738122	0.1058
C	−0.086320	0.027341	−3.157149	0.0076
Number of models evaluated:	1458	Dependent	Varible: CO_2	
Sample: 1994 2023, Inc ob: 30		Dependent lags: 2		
Mean dep var−0.010960		ARDL (2,0,0,2,2,2,2)		
CUSUM: STEADY		CUSUMS: STEADY		

Table 4: Godfrey Pagan Breusch test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic	0.970592	Prob. F (6,24)	0.4660
Obs*R-squared	6.053273	Prob. Chi-Square (6)	0.4172
Scaled explained SS	2.767779	Prob. Chi-Square (6)	0.8374
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	0.758524	Prob. F (3,10) 0.5425	
Obs*R-squared	5.561222	Prob. Chi-Square (3) 0.1350	

Table 5: Ramsey reset test of France

Ramsey reset test			
Equation: NARDL			
Test Statistics	**Value**	**df**	**Probability**
F-statistic	0.730869	(3.10)	0.5568
Likelihood ratio	5.947338	3	0.1142
F-test summary			
Test Statistics	**Sum of Square**	**df**	**Mean Squares**
Test SSR	0.000414	3	0.000138
Restricted SSR	0.002301	13	0.000177
Unrestricted SSR	0.001887	10	0.000189
LR test summary			
Test Statistics	**Value**		
Restricted LogL	99.56709		
Unrestricted LogL	102.5408		

NARDL: Nonlinear Autoregressive Distributed Lag

equations are used in the augmented Dickey Fuller (ADF) unit root test.

Equation without constant;

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-j} + \varepsilon_t \quad (1)$$

Figure 2: CUSUM test

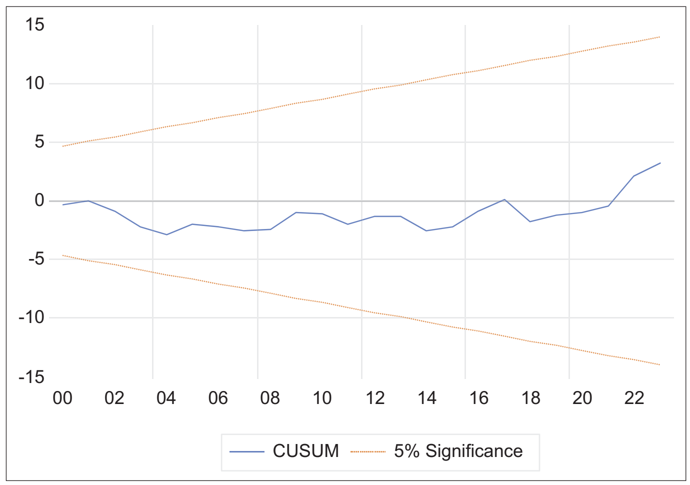
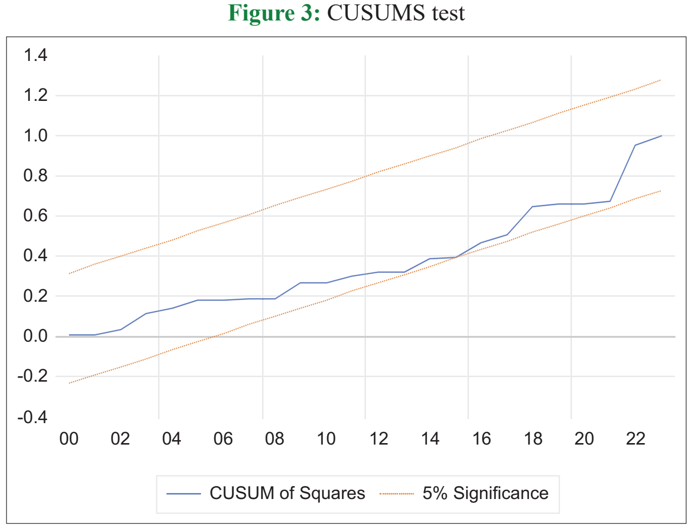


Figure 3: CUSUMS test



Equation with constant and no trend;

$$\Delta Y_t = \mu + \delta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-j} + \varepsilon_t \quad (2)$$

Constant-trend equation;

$$\Delta Y_{\ddot{u}\ddot{u}\bar{\ddot{u}}} = \mu + \beta \; + \delta Y_{-1} + \sum_{i=1}^{p} \delta \, \Delta Y_{-} \; + \varepsilon \quad (3)$$

In the equations, (Δ) represents the first difference, (Y_t) represents the time series in period t, (μ) represents the constant term of the series, ε_t represents the error term, β_t represents the time trend and (p) represents the lag length. In the ADF test; if the value of the ordinary least squares method estimation result is sufficiently negative or the (t^δ) value is smaller than the critical values, H0 is rejected and the series becomes stationary.

The hypotheses of the augmented Dickey Fuller (ADF) unit root test are as follows;

- H0: δ = 0 (There is a unit root, the series is not stationary)
- H1: δ < 0 (There is no unit root, the series is stationary).

Table 6: F and t statistics test

Null hypothesis: No levels relationship
Number of cointegrating variables: 6
Trend type: Unrest. constant (Case 3)
Sample size: 30

Test Statistic	Value
F-statistic	12.087495
t-statistic	−6.089234

Table 7: F bound test

Sample size	10%		5%		1%	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
	F-statistic					
30	2.457	3.797	2.970	4.499	4.270	6.211
Asymptotic	2.120	3.230	2.450	3.610	3.150	4.430
	t-statistic					
Asymptotic	−2.570	−4.040	−2.860	−4.380	−3.430	−4.990

*I (0) and I (1) are respectively the stationary and nonstationary bounds

Phillips and Perron (1988) is another unit root test. Phillips and Perron used nonparametric statistical methods to eliminate the autocorrelation problem in error terms. In this test, the statistics are transformed to remove the effect of autocorrelation on the asymptotic distribution of the test statistics. Critical values used in the DF test are also used in the PP test. The model developed by Phillips and Peron allows the error terms to be weakly dependent and heterogeneously distributed. Unlike the Phillips Perron ADF test, no lagged values of the dependent variable are included in any equation. In unit root tests, a stationary series subject to a structural break may appear to be non-stationary. This may cause the null hypothesis to be incorrectly rejected in unit root tests where structural breaks are not taken into account. For this reason, Perron (1989) developed a unit root test that can be applied under the assumption of a single structural break known to be exogenous. Perron unit root test is based on adding the correction factor suggested by Perron (1989) into the ADF process. It differs from the ADF test in terms of the error terms are not statistically independent, there is weak dependence between them, and those have heterogeneous distribution instead of homogeneous distribution. The equations included in the PP model are demonstrated below:

$$Y_{t-}\alpha_0 + \beta_1 Y_{t-1} + \varepsilon_t \quad (4)$$

$$Y_{t-}\alpha_0 + \beta_1 Y_{t-1} + \beta_2 (t - T/2) + \varepsilon_t \quad (5)$$

Equations (4) and (5) above refer constant and constant-trend models, respectively. Y_t is the tested variable, α_0 constant term, *t* is the trend which shows all the observations and the error term. Furthermore, it is the coefficient of value to be analyzed in this model. It is specified whether the series is stationary or not with comparing the value found in the ADF method through the MacKinnon critical table value.

The following hypotheses are used in the PP test;

- H0: δ = 0 (There is a unit root, the series is not stationary)
- H1: δ < 0 (There is no unit root, the series is stationary).

The last unit root test used in the study is Kwiatkowski et al. (1992). It is aimed to make the series stationary by purifying the deterministic trend in the series observed in the Kwiatkowski et al. (1992) unit root test. In the KPSS test, H0 means that the series is stationary and H1

Table 8: Long-term NARDL estimation results

Variable*	Coef	Standard Error	t-Stat	Probability
ENERGY_C1_POS	0.484594	0.155756	3.111249	0.0048
ENERGY_C1_NEG	0.359105	0.143148	2.508626	0.0193
GDP1_POS (-1)	0.133115	0.063540	2.094969	0.0469
GDP1_NEG (-1)	0.048266	0.067132	0.718966	0.4791
INDUSTRIAL_P1_POS (-1)	0.662943	0.290250	2.284043	0.0315
INDUSTRIAL_P1_NEG (-1)	0.972458	0.258543	3.761300	0.0010

*Coefficients derived from the CEC regression
Deterministics: Unrest. constant (Case 3)
CE=$CO_2$1 (-1)-(0.484594*ENERGY_C1_POS+0.359105
*ENERGY_C1_NEG+0.133115*GDP1_POS (-1)+0.048266
*GDP1_NEG (-1)+0.662943*INDUSTRIAL_P1_POS (-1)+0.972458 *INDUSTRIAL_P1_NEG (-1)

means that there is a unit root in the series. In the test, the stationarity in the null hypothesis is basically trend stationarity because the series are detrended. The absence of a unit root in the trend-free series indicates trend stationarity of the series. Since the null hypothesis in the KPSS test indicates trend stationarity, the variance of the random walk hypothesis should be zero.

Assuming that there is a normal clean sequence in the normal and stationary errors of the random walk, one-sided LM-statistics can be perceived as local best invariance for the trend stationary hypothesis. The formation of the LM statistic is important because the KPSS Test is determined in a similar way to the LMc test. In the LM test, the null hypothesis consists of the sum of the deterministic trend, random walk and stationary errors of the series, assuming that the random walk has zero variance.

$$Y_t = \beta_t + w_t + \varepsilon_t \quad (6)$$

$$w_t = w_{t-1} + u_t \quad (7)$$

w_t in the equations represents the random walk of the model, ε_t represents stationary errors and t represents the deterministic trend. The stationarity hypothesis assumes that the variance of u_t is zero. Hypotheses to be created for KPSS test; H0 means that the series is trend stationary, that is, there is no unit root in the series, and H1 means that the time series is not stationary, there is a unit root in the series.

- H0: There is no unit root, the series is stationary.
- H1: There is a unit root, the series is not stationary.

According to the 3 unit root analyzes including ADF, PP, and KPSS in Table 2 above, it is understood that the undifferentiated series are not stationary. As a result of the tests, one of the two reasons why the series are not stationary is that the P-values are not below 0.05, and the other reason is that the t-statistic value is not in the optimal range. The first differences of the series where logarithm is performed but not the difference are taken and tested again. The first differences of series such as GDP, energy consumption, carbon emissions and industrial production are taken and empirically it is observed that all of them stagnated in France, between 1990 and 2023.

The nonlinear/asymmetric model to be estimated based on the specifications produced by Shin et al. (2014) regarding NARDL's equation is presented in equation 8 below: The "Δ" difference operator in equation 4 above, the "*ln*" natural logarithms at the beginning of the variables, "μ_t" the error term, "β0" the constant term, "β1, β2 and β3" the short-term coefficients "α1, α2 and α3" refers to the long-term coefficients and "k, l, m" refers to the lag lengths.

$$\Delta Y_t = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta \; Y_{-} + \sum_{i=0}^{l} \beta_2 \Delta \; X_{1-}^{+} + \sum_{i=0}^{m} \beta \Delta X_{t-i}^{-} + \alpha \; Y_{t-} + \alpha \; X_{t-}^{+} + \alpha_3 \ln X_{1t-1}^{-} + \mu_t \quad (8)$$

F-bounds and t-bounds test" boundary tests are used to test cointegration in the nonlinear-ARDL method at Tables 6 and 7. As it is seen in Table 6, the F-bounds test value is 12.087495. In Table 7, this value is compared with the I(0) and I(1) limit values. For 1000 observation values, this value is greater than the upper limit value of 6.36 at the 1% significance level. Therefore, the model created according to the F-bounds test result is asymmetrically cointegrated at the 1% significance level. The number of observations in the study is 34. Since the data is annual, the maximum lag length is determined as 2 and the most appropriate model was determined to be NARDL (2, 0, 0, 2, 2, 2, 2). Therefore, after deducting the lag lengths, the actual number of observations of the study turns out to be 30. As seen in Table 6, the value of 12.087495 for 30 observation values is greater than the upper limit value of 6.853 at the 1% significance level. Therefore, the model created according to the F-bounds test result is asymmetrically cointegrated at the 1% significance level for the limited observation value.

According to NARDL test of Table 8 the increase in energy consumption in the long term affects both negatively and positively in the long term in France. While a 1% increase in energy consumption reduces carbon emissions by 0.48%, a 1% decrease causes a 0.35 decrease in carbon emissions. The positive increase in economic growth and the negative increase in energy consumption trigger environmental pollution by causing an increase in carbon emissions in Table 8.

4. DISCUSSION AND CONCLUSION

When the empirical findings in Table 8 are interpreted, the increase in energy consumption in the long term affects both negatively and positively in the long term. While a 1% increase in energy consumption reduces carbon emissions by 0.48%, a 1% decrease causes a 0.35 decrease in carbon emissions. The positive increase in economic growth and the negative increase in energy consumption trigger environmental pollution by causing an increase in carbon emissions. The issue of the source from energy, which is among the important raw material inputs with industrialization, will be obtained and determining the usage rates form the basis of the energy policies of countries. In this sense, the trend of change from fossil fuels, which constitute conventional resources, to renewable energy sources is becoming more popular day by day. France, like other developed countries, is a country whose energy needs are rapidly increasing and which is dependent on foreign sources for energy resources. In addition, the fact that the necessary saving measures regarding energy consumption have not been taken at a sufficient level shows that energy is used inefficiently in France. These problems necessitated the determination of a new energy policy based on the use of domestic resources that will cause the least harm to the environment and provide maximum contribution to the economy. France's focus on domestic energy sources that are renewable and have the least harmful environmental impacts will reduce its external dependence on energy consumption and the current account deficit.

As a result, the significance of developing environmental protection policies covering the manufacturing industry, which is one of the main sources of greenhouse gas emissions, is increasing as well. Increasing GDP per capita shows that social support for these regulations is also building. Within the scope of these policies, it may be suggested that a production planning should be carried out to reduce the share of the manufacturing industry's industries with high pollutant intensity in total production. At the same time, there is an obligation to prioritize investments that will realize technological transformation that will reduce pollution levels in manufacturing industry production. For sustainable growth and clean production, the transition to renewable energy sources instead of fossil fuel-based energy can be encouraged in the manufacturing industry. It is also possible to reduce polluting greenhouse gas emissions by ensuring energy efficiency, which means producing with the same quality using less energy. For this purpose, energy policies as well as industrial policies need to be transformed in line with this purpose. Bidirectional causality relations between GDP and energy consumption, which show increases in the production scale of the economy, as well as between GDP and CO_2 emissions, demonstrate that environmentally friendly policies are not sufficiently implemented in developed G7 countries, despite environmental agreements accepted at the global level. There is an interdependence between economic activities and environmental pollution. Policy makers need to adopt a strategic approach in solving the rapid industrialization phenomenon and the accompanying magnitude of energy consumption, the pressure on natural resources and the environmental pollution problems resulting from them. In this respect, it is an inevitable necessity for countries to continue multilateral negotiations in which the public sector, business world, academia and non-governmental organizations will take part in solving environmental problems. Another policy recommendation based on the results of this study is to prioritize the increase in energy efficiency in terms of technology, to develop cleaner production sources and to use joint action plans in environmentally friendly policies. It is necessary to observe the effects of environmental reforms in the long term. For this reason, it is important to review environmental policies frequently and make environmentally friendly improvements. Additionally, environmental policies need to be designed on a country-specific basis.

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