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The Link between Economic Growth and Ecological Footprint: What Future Prospects for the G7 Countries: PMG-ARDL

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Abstract

Given the need to achieve economic development while preserving environmental quality, our main objective in this article is to study the impact of economic growth on the ecological footprint in the G7 countries (Italy, France, Canada, the United States, United Kingdom, Japan, Germany) over the period 1961-2018. By studying the environmental Kuznets curve (EKC) using the dynamic ARDL panel, we found that the relationship between EFP (ecological footprint) and GDP is N-shaped. In the renewable Kuznets curve (RKC), we found a U-shaped relationship. The international investment position and debt then contribute to pollution, and the consumption of renewable energy reduces CO2 emissions. However, additional efforts are needed to promote renewable energy in the countries analyzed.

Keywords: *Growth, Ecological Footprint, renewable energy, PMG-ARDL.*

1. Introduction

Generally speaking, the growth in the production of goods and services is revealed by economic growth over a certain period of time. The link between economic development and environmental quality is linked to Sustainable Development Goals drive economic development and environmental quality because economic activities could increase pollution., which constitutes an obstacle on the path to sustainable development (Shahzad, U. et al. 2021). According to Sannigrahi, S. (2020), a serious risk is represented by environmental degradation in the health sector, where we see major negative effects on the ecosystem. A nonlinear and inverse U-shaped connection between economic growth and environmental pollution, based on the environmental Kuznets curve, has been the subject of many previous studies (Kaika, D.(2013), Gill, A.R (2018), Apergis, N.; Payne, J.E. (2012)).

This problem is essential for economists, they have debated the impact of environmental degradation on economic growth on a national scale for quite some time, resulting in some high impact publications (Sarkodie & Strezov, 2019; Boufateh & Saadaoui, 2020; Ike et al., 2020). Additionally, the increase in consumer demand associated with economic growth creates increased pressure on the ecological footprint from the expansion of trade, globalization and other factors. (Ansari et al., 2020, Marques, A.C. and Caetano, R. T., 2012).

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According to Gill, A.R. et al. (2018), most EKC-related articles have focused on describing the evolution of CO2 emmisions. However, the impact of fossil energy consumption on pollution has been revealed positive in all studies. Consumption of renewable energies could therefore be a solution to improve the quality of the environment. So, our analysis focuses on traditional EKC then improved model by adding other relevant predictors and RKC. The independent variables of the EKC include debt and international investment position.The consumption of renewable energy and its essential role in economic growth has been analyzed and confirmed by several previous works (Yao, S.; Zhang, S.; Zhang, X., (2018), Bhattacharya, M . et al. (2017), Tugcu, C.T., et al. (2012), Apergis, N.; P., (2012)). Moreover, the significant impact of renewable energy consumption and its capacity to reduce CO2 emissions was verified by Tugcu et al. (2012) and Apergis and Payne (2012) by observing a bidirectional causal link between economic growth and renewable energy consumption.

According to the EKC, environmental degradation increases with per capita income at first. However, as the economy grows, the demand for environmental quality results in less degradation of the environment (Lacheheb et al., 2015). (Xu et al., 2020) showed that if the EKC is inverted U-shaped, economic growth will eventually lead to significant improvements.

According to Ahmad et al., (2021), approximately 30 and 25% of global energy consumption is caused by these countries, respectively. Additionally, G7 countries have a direct relationship with non-renewable energy supplies domestically and internationally. Thus we can say that the majority of G7 countries import non-renewable energy to meet their energy needs. Japan, Germany and Italy import approximately 96%, 84% and 64% of their total primary energy supplies. As a result, these figures highlight the G7 countries' dilemma regarding dependence on dirty fuels. These figures explain why, despite their economic prosperity, these countries have mostly failed to limit the degradation of their environmental protection.

Against this environmental bravado, the objective of this study is to estimate the result of economic development on the ecological footprint in the Japan, Italy, France, United Kingdom, United States , Canada and Germany during the period 1961-2018. In addition to the revised EKC, the article offers an examination to hold up the hypothesis that the consumption of renewable energy could replace the consumption of energy based on orthodox sources that have pessimistic environmental consequences. The biliographie come up with the evidence of the result of economic growth and other elements on the ecological footprint in G7. After describing the methodology and presenting the empirical results, the hindmost section of our article prepare conclusions and recommendations for attaining sustainable development.

2. Literature review:

The G7 countries are among the most economically advanced nations in the world. However, alongside such hang economic growth in the G7, environmental states in these countries have worsen, raising important concerns among stakeholders. Therefore, we examine the result of economic growth, international position of investment and renewable energy consumption on the ecological footprint in G7 countries.

The connection between economic growth, international investment and ecological footprint is a controversial issue with many viewpoints. As stated in many research, natural resources may assist resource-rich countries swell their economies between increasing commerce and production. According to Baz et al., (2020), in examining the impacts of economic growth and natural resources on the religious footprint of Pakistan from 1970 to 2014, confirm the inverted U-shaped association between the economic growth and ecological footprint. They found that economic growth and natural resources had a positive effect on the ecological footprint.

Conceptuel and observe syntheses were provided to describe the need to learning EKC. We start with Grossman and Krueger (1991) who manifested that plate and technological effects could spell out the link between contamination and growth. The enlargement of economic activities control a lamella effect which results in increased contamination. Changes in the economy generate a constructional effect. Nevertheless, according to Panayotou, T. (2003), technological progress based on innovation and investment presupposes the use of less polluting technologies. Furthermore, Martini, C. (2014) and Ghalwash, T. et al. (2007) show that the quality of environment can be considered as normal good or luxury good. In this view, EKC is an effect of variations in income elasticity in order to improve environmental quality. Pollution has a pessimist result on the quality of life of populations, which requires appropriate policies in the environmental field. From this perspective, based on the study by Lucas, R.E. et al. (1992), weak rules in developing countries favor improvements in pollution, but additional attempts in this direction could reduce environmental degradation Dasgupta, S. et al. (2002).

Many other studies have tested the role that economic globalization plays on the ecological footprint. citing the example of Yilanci & Gorus, (2020) who found that globalization has a positive impact on the ecological footprint and contributes to reducing environmental quality in the MENA region for the period 1980-1916. Similarly, Du & Zhang (2018) assessed the factors influencing carbon discharge in Chinese regions and found an N-shaped relationship between the growth and CO2 emissions. However, the education also confirmed that the causal link between economic globalization and environmental quality exist. Contrary to previous findings (Ahmed et al., 2019) communicated that globalization had least effect on Malaysia's environmental footprint.

Several methodologies have been puted in to estimate the relationship between economic growth and ecological footprint. For example, (Sabir & Gorus, 2019) applied the ARDL method to study how economic development holds the ecological footprint. In the long term, their results confirmed that economic development harms the environmental footprint in the case of the ASIAN region. However, the study corroborates the Kuznets environmental curve hypothesis and shows that the link between economic development and ecological footprint is inverted U-shaped.

Additionally, a medium-sized group technique examined the link between renewable energy, economic development and ecological footprint. Empirical results indicate that economic development presents a negative impact on renewable energies and the ecological footprint, while Ike et al., 2020 showed that the ecological footprint is caused by renewable energies. renewables in the short term and by economic development in the long term (Ansari et al., 2021).

Generally, the importance of renewable energy cannot be overemphasized as it varies from country to country. However, the positive or negative effects of renewable energy are determined by the extent of extraction and management of such resources. Similarly, each nation has its own set of rules and laws to deal with the effects of economic globalization. In examining the correlation between globalization and carbon emissions in MINT nations from 1995 to 2018 (Aziz et al., 2020), globalization and CO2 emissions were characterized as having an inverted U-shaped.

However, the link between environmental quality and economic growth has an inverted U shape according to the synthesis of the Economic Growth and Environmental Degradation Association (Grossman and Krueger, 1991). The environmental N-shaped Kuznets curve indicates that habituel EKC theory will fail the test. Instead, increasing money could restore a positive link between economic expansion and environmental quality (Murshed et al., 2020). The N-shaped relationship arises if the influence of scale outweighs structure and technical impacts (Balsalobre-Lorente et al., 2018), this may result from inadequate opportunities to improve the distribution of industry or insufficient resources.

The phenomenon of N-shaped EKC is relatively new as it was identified in the 1990s when an N-shaped relatedness between economic development and element dioxide emissions (Grossman & Krueger, 1991) and is at the end of the dataset, the N-shape has been removed in both occurence. Furthermore, according to the study of Balsalobre-Lorente et al., (2018), the EKC is N-shaped using the fixed effect test and cross-sectional OLS combined. Additionally, they showed that globalization, renewable energy and environmental quality are inextricably linked. This is attributable to various factors, namely national resource extraction policies and management mechanisms.

Three classes of methods can explain, analyze and verify the EKC hypothesis according to the types of data. First we find the time series models, then the panel data models, and finally the time domain and frequency domain. In our analysis, we focus on G7 countries, which assumes panel data. Our model ensures control of individual heterogeneity and better coefficients in terms of efficiency. We find studies that estimated panel data models and described focusing on the environmental pollution indicator and the main results for developing countries. Regional studies were not considered in this research, since the empirical analysis focuses only on countries and not their subregions.

Few studies have worked on developing countries while there are several that have worked on the largest groups of states. Almost all of them found a bell shape, but that doesn't prevent other articles from finding other models. We start with Lazar et al. (2019) who estimated a monotonic increasing trend for a sample of 11 central and eastern European countries whose aim is to explain CO2 emissions and the ecological footprint over a period spanning between 1996 and 2015. The rest focused on cointegration methods based on MG-FMOLS, MG and AMG. We find that some of the countries analyzed by Lazăr et al. (2019) are the subject of our problem. A U-shaped relationship was estimated by Hove and Tursoy (2019) in the case of 24 emerging economies over a period from 2000 to 2017 using a GMM for CO2 releases. In addition, several studies on emerging countries have found an N-shaped trend using a multiple regression model.Based on the existing literature above, the proposed hypotheses are:

H1. The EKC hypothesis indicated that environmental pressures increase as income level increases at the initial stage of economic development, but these pressures then decrease with income level.

H2. The second hypothesis, called the Renewable Energy Environmental Kuznets Curve (RKC), describes the U-shaped relationship between EFP and GDP per capita when considering renewable energy.

This research, however, examines not only the long-term relationship between economic globalization, natural resources, and ecological footprint but also the extent to which the G7 countries can balance economic growth and environmental preservation. Furthermore, this study introduces an interaction term between EFP and the relationship between economic growth per-capita cube and economic growth per-capita square to assess the existence of the EKC hypothesis with an N-shaped in the context of economic globalization, contrary to previous studies that used the globalization variable, which has several dimensions. On the other hand, the analysis of previous studies depends on the relationship between emissions and the square of economic growth, which constitutes a relationship between economic growth per capita and the ecological footprint in a U shape, and this does not has not become sufficient in the context of globalization and growth in the income of members of society. To this end, we introduce a new step in which we use the economic growth cube per capita as an N-shaped relationship.

3. Empirical Methodology

3.1. PMG-ARDL

The environmental inferences of profusess factors have been examined recently by several studies such as the work of Sharma et al. 2020, 2021c and Sharma et al. 2021b. This study therefore extends this by examining the dynamic impact of economic growth, international position of investment, debt and renewable energy on EFP (ecological footpint) which is examined by the distributed lag approach autoregressive (ARDL) by the pooled mean group (PMG) estimators developed by Pesaran et al. (1999).

The writing of our heterogeneous panel model is as follows:

$$y_{it} = \mu_i + \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij}\, X_{i,t-j} + \varepsilon_{it} \quad (1)$$

In Eq. (1), i= 1…, N represents units of cross-sectional, t= 1…, T executes the annual periods, j performs the time lags number, p manifests dependent variable lag, and q give away independent variables lag. μ_i disclosed the fxed efect, y betrays the dependent variable, and X evinces the vector of the independent variables.

$$\Delta y_{it} = \mu_i + \phi_i y_{it} + \beta_i X_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*}\, \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*}\, \Delta X_{i,t-j} + \varepsilon_{it} \quad (2)$$

Where ϕ_i=-(1-$\sum_{j=1}^{p-1} \lambda_{ij}$) , $\beta_i = \sum_{j=0}^{q-1} \delta_{ij}\, X_{i,t-j}$, $\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im}$, j=1,2,…,p-1 , $\delta_{ij}^{*} =$ -$\sum_{m=j+1}^{q} \delta_{ij}$, j=1…,q-1.

Eq. (2) is rewritten as an error correction equation by grouping more variables at the level

$$\Delta y_{it} = \mu_i + \phi_i (y_{it} + \theta_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^{*}\, \Delta y_{i,t-j} + \sum_{j=0}^{q=1} \delta_{ij}^{*}\, \Delta X_{i,t-j} + \varepsilon_{it} \quad (3)$$

In Eq. (3), we find first the long-run equilibrium appositeness between $y_{i,t}$ and $X_{i,t}$ defned by ($\theta_i = \beta_i / \phi_i$). δ_{ij}^{*} and λ_{ij}^{*} associate growth to other determinants past values and the short-run coefcients. Finally, ϕ_i, which is the error-correction coefficient, indicates the speed at which y it is adjusted toward the long run following t$X_{i,t}$ change. Moreover, ϕ_i must be pessimist and between zero and one. Therefore, the estimate will be as follows:

$$\hat{\theta}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\theta}}{N} \quad , \quad \hat{\beta}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\beta}}{N} \quad , \quad \hat{\lambda}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\lambda}}{N} \quad , \quad \text{and} \quad \hat{\gamma}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\gamma}}{N}$$
(4)

Where j=0,…,q and $\hat{\theta}_{PMG} = \tilde{\theta}$

Since our PMG-ARDL considers adequate lag of all variables, the existence of endogeneity bias and serial correlation is eliminated. The PMG estimator imposes heterogeneity in the short run and homogeneity in the long run (Boufateh and Saadaoui 2020).

3.2. Data description

This study considers economic growth per capita (GDP), International investment Position (IIP), debt assets (Debt) and renewable energy consumption (REC) as determinants of ecological footprint for the G7 countries using yearly data starting from 1961 to 2018. These countries include United States, Japan, Germany, France, Italy, United Kingdom, Canada. The periods selection is based on the availability of the data. We included data from the World Bank database (WDI) for economic growth per capita, renewable energy consumption and debt assets. Ecological footprint data are extracted from Footprint Network. International Investment Positin (IIP) are extracted from The External Wealth of Nations Database (EWN). To eliminate issues of heterogeneity, the variables were also converted into a natural logarithm. The proxies and sources of the variables utilized in this study are listed in Table 1.

Table1. Variable description

Variables	Symbols	Definition's	Sources
Ecological footprint	EFP	Ecological footprint per capita	Footprint network
Economics growth per capita	GDP	Constant 2010 USD	WDI
International Investment Position	IIP	Ratio of net IIP excluding gold to GDP (values converted to domestic currency)	EWN
Debt assets	Debt	Sum of the stocks of portfolio debt claims and other investment claims on nonresidents	WDI
Renewable energy consumption	REC	It is the share of renewable energy in final energy consumption of that country.	WDI

3.3. Empirical Results and discussions

Table 2 describe study variables in the natural logarithm. The average EFP in the G7 is 3.45 with a standard deviation of 5.66. So the standard deviation of renawlable energy consumptiont is the highest, and the lowest value of it is related to debt assets. If the skewness value of a series is 0 and its kurtosis value is 3, the latter has a normal distribution (Mensah et al. 2019). Specifcally, REC and Debt have been pessimistly skewed. Which means that the mentioned series tend to the left, contrasted with a normal distribution. The skewness values of EFP, GDP and IIP are more than zero and inclined to the right. Moreover, the kurtosis of trade openness is less than 3, indicating that the distribution of this serie is platykurtic. Moreover, the kurtosis values of EFP, GDP, IIP, DEBT and REC are greater than the normal value, and their distribution is leptokurtic. Thus, none of the variables has a normal distribution, according to the kurtosis and skewness values presented in Table 2 which showed that none of the variables satisfies the conditions required for the normal distribution. The normality of the distributed series was proved by the test of Jarque Bera because the null hypothesis of normality is rejected.

Table. 2. Descriptive statistic

	EFP	GDP	IIP	DEBT	REC
Mean	3.452978	1.0822981	11.30662	13.25515	9.138551
Median	1.693417	1.404509	11.20525	13.54751	7.260000
Maximum	21.81640	5.869636	15.04529	16.06825	22.67000
Minimum	1.443841	-5.711508	6.724333	8.915701	0.610000
Std. Dev.	5.660436	1.818991	2.030878	1.735880	6.552319
Skewness	2.927042	-1.339235	0.076120	-0.304773	0.787356
Kurtosis	9.578779	6.485542	2.232195	2.022459	2.466577
Jarque-Bera	445.9161	111.1084	3.548565	18.96694	23.84175
Probability	0.000000	0.000000	0.000000	0.000076	0.000007
Sum	476.5110	149.4514	1571.620	4546.518	1891.680
Sum Sq. Dev.	4389.553	453.2956	569.1761	1030.542	8844.174

If we focus on cross-sectional dependence, heterogeneity and the presence of unit root, we find them verified in our data using appropriate tests. The cross-sectional dependence is explained by the fact that these countries have the same membership in the same economic system before 1990. By focusing on the CD Pesaran test, we find that there is a cross-sectional dependence for all the variables, already the p- value is always less than 5% (see Table 3). The heterogeneity is explained by the spatial location, climatic characteristics, different environmental regulations and policies aimed at strengthening economic growth.

Table. 3. The results of CD Pesaran's test for cross-sectional dependence

Variable	Statistic	P-Value
EFP	12.01823	0.0000
GDP	12.02966	0.0000
IIP	-2.076856	0.0378
Debt	30.41988	0.0000
REC	13.99609	0.0000

Source: own calculations in Eviews 12.

First of all, the fluctuation of the variables around a constant mean is ensured to criticize the use of panel data. Thus, the results of the regression will not be reliable without evaluating the stationarity of the variables. We used Breitung panel unit root test are extensively considered to examine the stationary of the studies variables.

Ensuring that our variables fluctuate around a constant mean is essential in this work to be able to use panel data. Thus, we start by evaluating the stationarity of the variables, because our results would not be reliable if the variables were not stationary. Prior to application of the given cointegration models, we initially establish the variables being cointegrated of Order I(1). The Hadri, Breitung, Levin-LinChu (LLC), Im-Pesaran-Shin (IPS) and Fisher panel unit root tests are implied by the first generation panel unit root tests which are used to treat the stationary of variables .

In this regard we apply Breitung Panel Unit Root Test ascertain the stationarity of the data in order to avoid spurious regression and misleading results.

Data in Table 4 indicate that the variables examined are stationery, especially with the use of putting the constant and trend into consideration. This implies that the variables are integrated. The variables include ecological footprint, IIP, Debt, REC and growth per capita. We find that the GDP data series is level stationary, using the Breitung test, while all other panel data are first difference stationary (see Table 4). Our variables were considered in logarithmic form to know how to interpret our results in terms of elasticities.

Table. 4. Stationarity test result

UNIT ROOT TEST IN PANEL DATA (Breitung 1961-2018)

	Statistic with Constant & Trend (No lag) Data in level	Statistic with Constant & Trend (One lag) Data in level	Statistic with Constant & Trend (No lag) Data in the First Difference	Statistic with Constant & Trend (No lag) Data in the First Difference
EFP				
t-Statistic	2.25239	2.84547	-9.93607***	-12.3763***
Prob.	0.9879	0.9978	0.0000	0.0000
GDPP				
t-Statistic	-2.89955***	-3.25132***	-4.15239***	-1.32096*
Prob.	0.0019	0.0006	0.0000	0.0933
Debt				
t-Statistic	5.67968	3.24506	-11.0568***	-8.61594***
Prob.	1.0000	0.9994	0.0000	0.0000
REC				
t-Statistic	3.12078	5.53189	-7.45604***	-7.31010***
Prob.	0.9991	1.0000	0.0000	0.0000
IIP				
t-Statistic	6.11554	5.34011	7.06453***	1.61205***
Prob.	1.0000	1.0000	0.0022	0.0000

The next step is to validate the long-run connection among selected variables, through the Pedroni cointegration test (Table 5). Inspecting the cointegration test is primordial in econometrics. Also, the presence of cointegration is essential among variables for estimate the panel ARDL. So the existence of cointegration makes the model's results more reliable (Uzar 2020). Referring to the Pedroni (1999) who is a cointegration test and it has become widely used in studies. The null hypothesis of this test is the absence of cointegration in sets of panel data. However, this cointegration test have been criticized, and it has been stated that this test consider cointegrated vectors to be homogeneous across units of cross-sectional. The outcomes of the Pedroni test reveal the existence of the cointegration relationship between the study variables (Table 5). According to the Pedroni test, there is a cointegration relationship between the EFP and other variables: GDP, IIP, REC, Debt at the 5% significance level.

Table 5: Pedroni Cointegration Test

Series: EFP GDP IIP REC Debt

	Panel-PP	Panel-ADF	Group-PP	Group-ADF
Pedroni cointegration	-1.248751	1.142975	-2.066018	1.200211

Probability values	0.3750	0.5522	0.2194	0.7250

*,** and *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.
Source : Current Research

Firsty, we supply estimates using PMG-ARDL for the first model, then we check robustness with the second model who has additional variables. According to our results presented in Table 7, the models converge toward a long-run relationship. The results describe a long-term and short-term relationship between the variables.

So, the long and short impact between variables can be estimated afterwards in the cointegration analysis. After determining the long-run linkage between the variables, the paper further employs the panel ARDL with PMG estimator. Table 6 demonstrates the panel ARDL results.

The error correction term (ECT) coefcient describes whether or not the model will approach the equilibrium level in the long term. In our work, it converges towards the long-term equilibrium level if the ECT coefcient is between 0 and −1 (Uzar 2020). Based on our results, the value of the ECT coefcient is −0.21, so it satisfes this condition and is also statistically significant. We provided estimates using models with main variables and one using other variables in the models. According to our model estimates in Table 6, the models converge toward a long-run relationship. The results only indicate a long-term relationship between the variables, the highest speed of adjustment was recorded by RKC.

Table 6: Panel ARDL estimation results (2,1,1,1,1)

Dependent Variable: EFP

Sample: 1961 2018

	EKC		RKC	
	Long-run results		Long-run results	
Variables	Coefficients	t-statistic	Coefficients	t-statistic
GDP	0.017004	1.244695***	0.079518	2.674497***
GDP^2	-0.455200	-1.455200***	-0.256985	-3.256982***
GDP^3	0.560055	2.486900***	---------	---------
Debt	1.050000	4.274430***	---------	---------
IIP	-1.440000	-6.250787***	---------	---------
REC	-0.024495	-7.380138***	-0.041225	-4.946933***
	Short-run		Short-run results	

	results			
Variables	Coefficients	t-statistic	Coefficients	t-statistic
ECT(-1)	-0.216328	-2.312217**	-0.199847	-3.025244***
GDP ******	0.006281	1.265486***	0.026217	0.055862***
GDP^2	-0.089659	-1.869522***	-0.015986	-2.056256***
GDP^3	0.022569	2.659856***	0.000326	3.026598***
D(IIP)	-6.040000	-1.488406		
D(REC)	-0.012701	-2.227579**	0.000765	0.133916
D(Debt(-1))	-1.430000	-1.195764	--------	--------
C	0.384240	2.016942*	0.694682	2.560896**

*,** and *** denote statistically significant at the 10%, 5%, and 1% levels, respectively. Source: Current Research

The results appeared in Table 6 corroborate a non-linear association between GDP and the ecological footprint. We can observe how in the long term, firstly, the EFP rises along with climbing per capita income (GDP) and after we show that EFP decrease. The of GDP is always significant in all polynomial specifications, hence a relevant effect of GDP on VET is observed in the analyzed countries (see Table 6). The optimist effect for the linear term and cubic and the pessimist effect for the square term indicate that theassociation between EFP and GDP is N-shaped.

So a final stage confirms that the N-shaped connection is verified between economic growth and the ecological footprint in our results. This finding is in line with the bibliography (Al-Mulali, 2011; Sahli and Ben Reje, 2015; ; Farhani et al., 2014; Abdallh and Abugamos, 2017). Environmental deterioration, for an N-shaped EKC, begins at the beginning of the development phase, and it increases with income growth, but it begins to decrease as soon as the income level is reached. and finally its last phase is characterized by high development and a low growth rate where the level of pollution begins to increase again due to technological obsolescence (Álvarez et al., 2017). So, in the last stage, environmental enrichment begins to gradually decrease, while the scale effect begins to prevail again (Shahbaz et al., 2018; Balsalobre et al., 2018). This final stage is then at the origin of the additional sustainable development reforms that economic systems must carry out, namely the delay of technological obsolescence when the technical effects are exceeded by the effect of scale (Balsalobre and Álvarez, 2016).

These econometric results confirm the EKC empirical proof in the G7 are consistent with previous literature. Génesis-Carolina et al. (2021) validate the presence of the EKC hypothesis in South America.

Otherwise, our results also represnent that for the linear term, IIP negatively and directly affects EFP, validating the contamination haven hypothesis in the G7 (Udemba and Yalçıntaş, 2021). The observative evidence validates that IIP reduced EFP in the G7. This brand new evidence curbs relevant policy perspectives for the G7. In this sense, we consider that this interaction corroborates the negative influences of IIP over the energy sector in the G7 due to the desirability of industry with more well organized energy usage in the G7. For this reason, the G7 should promote the desirability of cleaner and high-tech industry aimed to reduce its environmental force. This evidence indicates that, in the presence of stringent environmental treaty for violates at this stage of economic development for the G7, IIP one of the major catalysts of pollution (He, 2006; Liang, 2006; Neequaye and Oladi, 2015). Therefore, the international investment position largely depends on contamination so it is necessary to invest in clean industries so that service sectors will increase environmental regulation and decrease ecological fortification (Managi, 2012).

We can also say that the relationship between the international position of investment, debt and the ecological footprint requires progression towards clean economic sectors and above all supported by foreign investment. In addition, political and economic decision-makers must encourage non-polluting investors to restructure trade policies.

However, to reduce environmental pressure we must resort to renewable energies. This requires an improvement in the administrative structure, to have a certain effectiveness of the liberalization of the capital account and the inflow of FDI. Therefore, we must act against corruption and focus on good governance to strengthen policies and improve environmental aspects (Abdouli et al., 2018).

Finally, we consider that an climbing economic cycle lessen the dampening impact of fossil sources on the environmental degradation process (Grimm, N. B., et al. (2008)). Under an climbing economic trend, an economic system's advancements in energy efficiency lead to a decline in environmental degradation (Kasperowicz, 2015; Sinha et al., 2020). Our results confirm that the effectiveness of the contamination control policy will reduce PEF through the use of renewable energy (Bilgili, 2012; Lin and Moubarak, 2014; Adewuyi and Awodumi, 2017).

Therefore, environmental degradation can be caused by long-term global trade. On the other hand, the development of trade between nations requires adherence with environmental standards. Therefore, trade openness pushes countries to be technologically advanced and less carbon-intensive in the long term. Our results are similar to the results of the study by Wang and Zhang (2021) which was conducted for upper-middle-income and high-income countries. Furthermore, our results are justified and verified by the studies of Adebayo et al. (2022), Zhang et al. (2017) and Khan et al. (2022).

4. Discussion and Conclusion

One of the major human concerns is environmental degradation, where we find an absence of regulations that can cause catastrophic damage to the economy and the survival of the planet. For this we thought of solving this problem and proposing effective policies through this study, using data from 1961 to 2018 on the G7, to examine the impact of economic growth on the indicators of widely used environmental degradation (ecological footprint) in the short and long term. In addition, the impacts of internation position of investment, debt, and the renawlable energy consumption on EFP are also considered. The panel ARDL approach was used to determine the impact of study variables on EFP.

The stimulation of non-pollution through economic development is verified in the G7 states using the theoretical review of the revised Kuznets environmental curves. The implementation of appropriate policies that aim to reduce VET is among the practical implications linked to the end, the objective here is to mitigate climate challenges. Our results have implications for environmental policies in these countries. Furthermore, the assessment of the degree of sustainability of economic and environmental policies was justified by the analysis of the EKC assumptions.

However, specific policy recommendations should be made for each country according to actual environmental issues. G7 members should work with industry to establish agreed measurement standards for near-zero emissions. This is essential for establishing policy and production guidelines. Additionally, G7 economies must put in place mechanisms to recognize the use of interim technologies that significantly reduce emissions but do not go far enough to be considered close to zero emissions.

The U-shaped connection in the RKC was confirmed for the sampled countries. Renewable energy consumption is part of the G7 Green Deal, but additional efforts are needed for these sample countries to achieve the required targets (Aye, G.C. and Edoja, P.E, 2017). On the other hand, if renewable energies are encouraged too quickly, economic progress is less (Sinha, A.; Shahbaz, M. and Sengupta, T., 2018). The need for eco-innovative developments must be verified for improved use of renewable energy sources. Thus, the reduction in renewable energy production costs could be justified by the use of these innovations. These innovations could reduce the costs of producing renewable energy and eliminate pollution caused by non-renewable resources. In developed countries, more investments are devoted to eco-innovation and the stage of this type of innovation in these countries is more advanced than in developing countries. The model observed in developed countries should be followed by emerging economies through more investments. The use of renewable energy in these G7 countries guarantees a balanced climate and sustainable economic development. Economic growth contributes to energy consumption and environmental pollution. Therefore, environmental policies should promote sustainability through policy goals related to environmentally friendly technology, clean energy use, and higher consumption of non-renewable energy sources. Developed countries have already achieved environmental benefits in electricity markets from renewable energy. The weight of renewable energy consumption in total consumption is therefore expected to increase further in developing countries.

Through this study, political and economic implications can help governments and decision makers to improve the environmental situation in the long and short term, in particular, the consumption of clean energy sources which is recommended for the reduction of pollution and the increase of consumption of renewable energy which determines the quality of the environment and can also provide the energy necessary for the economic growth of these countries. Since the objective is to reduce environmental pollution over a short period of time, particular attention must be paid to this. Thus, the use of clean energy by economic institutions and compliance with environmental standards can stabilize the impact associated with sustainable development.

Similarly, technological progress and improvement in the energy sector is important for controlling environmental degradation. Therefore, environmental sustainability can be achieved by increasing green investments. Another suggestion is to design green credit mechanisms to allow for variable interest rates for industries based on their role in environmental degradation and carbon emissions, which will force polluted industries to innovate in the production of green or renewable energy at their potential level. Similarly, industries that follow environmental standards should be incentivized with tax exemptions and importers of green energy products can benefit from subsidies. These suggestions show the collaboration of three Sustainable Development Goals (SDGs), which are increasing economic growth (SDG-8), addressing the problem of environmental degradation and improving ecological quality (SDG-13) and ultimately to provide masses of affordable green energy (SDG 7). We cannot deny the role of renewable energy in environmental sustainability. Thus, there is a need to increase green investments to improve techniques for producing green energy. Therefore, the volume of green finance and the production of renewable energy should be expanded in the G7.

In addition, it is strongly recommended that low-income groups receive an increase in income as long as they comply with environmental regulations and standards. Thus, it is necessary to use less carbon-intensive and equipped technologies that will positively affect the quality of the environment to capture the world market. In addition, care must be taken to conduct effective and transparent economic policies in order to be able to analyze and diagnose the economic disease and treat it correctly. So, governments should focus on controlling economic policy uncertainty to stimulate renewable energy and energy-efficient technological innovations. Particular attention should be given to improving environmental quality to health levels. Thus, by adopting all the policies of health and environmental standards, the quality of the environment and the rate of economic growth will improve successively. Finally, we consider that a particular focus on finding the threshold of fiscal decentralization could be an advantage for future studies to optimize economic growth with sustainable environmental objectives, which is the soul of the SDGs. Furthermore, this research study paves the way for future researchers to dissect the role of energy consumption in improving the ecological footprint with particular reference to economic policy uncertainty.

References

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy economics, 34(3), 733-738.

Apergis, N., & Payne, J. E. (2012). The electricity consumption-growth nexus: renewable versus non-renewable electricity in Central America. Energy Sources, Part B: Economics, Planning, and Policy, 7(4), 423-431

Atkeson, A., & Lucas Jr, R. E. (1992). On efficient distribution with private information. The Review of Economic Studies, 59(3), 427-453.

Al-Mulali, U. (2011). Oil consumption, CO2 emission and economic growth in MENA countries. Energy, 36(10), 6165-6171.

Abdallh, A. A., & Abugamos, H. (2017). A semi-parametric panel data analysis on the urbanisation-carbon emissions nexus for the MENA countries. Renewable and Sustainable Energy Reviews, 78, 1350-1356.

Alvarez-Herranz, A., Balsalobre-Lorente, D., Shahbaz, M., & Cantos, J. M. (2017). Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy policy, 105, 386-397.

Álvarez-Herránz, A., Balsalobre, D., Cantos, J. M., & Shahbaz, M. (2017). Energy innovations-GHG emissions nexus: fresh empirical evidence from OECD countries. Energy Policy, 101, 90-100.

Abdouli, M., Kamoun, O., & Hamdi, B. (2018). The impact of economic growth, population density, and FDI inflows on CO 2 emissions in BRICTS countries: Does the Kuznets curve exist?. Empirical Economics, 54(4), 1717-1742.

Adewuyi, A. O., & Awodumi, O. B. (2017). Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. Renewable and Sustainable Energy Reviews, 69, 275-291.

Adebayo, T. S. (2022). Renewable energy consumption and environmental sustainability in Canada: does political stability make a difference?. Environmental Science and Pollution Research, 29(40), 61307-61322.

Al-Mulali, U., Ozturk, I., & Lean, H. H. (2015). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Natural Hazards, 79, 621-644.

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics & Finance, 5(1), 1379239.

Boufateh, T., & Saadaoui, Z. (2020). Do asymmetric financial development shocks matter for CO 2 emissions in Africa? A nonlinear panel ARDL–PMG approach. Environmental Modeling & Assessment, 25, 809-830.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., ... & Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. British journal of sports medicine, 54(24), 1451-1462.

Brännlund, R., Ghalwash, T., & Nordström, J. (2007). Increased energy efficiency and the rebound effect: Effects on consumption and emissions. Energy economics, 29(1), 1-17.

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions?. Energy policy, 113, 356-367.

Baz, K., Xu, D., Ali, H., Ali, I., Khan, I., Khan, M. M., & Cheng, J. (2020). Asymmetric impact of energy consumption and economic growth on ecological footprint: using asymmetric and nonlinear approach. Science of the total environment, 718, 137364.

Bilgili, B. C., & Gökyer, E. (2012). Urban green space system planning. Landscape planning, 360.

Brey, C., Snyder, T., Wang, X., Wilkinson-Flicker, S., ... & Hinz, S. (2017). The Condition of Education 2017. NCES 2017-144. National Center for Education Statistics.

Del Amo, E. M., Rimpelä, A. K., Heikkinen, E., Kari, O. K., Ramsay, E., Lajunen, T., ... & Urtti, A. (2017). Pharmacokinetic aspects of retinal drug delivery. Progress in retinal and eye research, 57, 134-185.

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the environmental Kuznets curve. Journal of economic perspectives, 16(1), 147-168.

Du, G., Liu, S., Lei, N., & Huang, Y. (2018). A test of environmental Kuznets curve for haze pollution in China: Evidence from the penal data of 27 capital cities. Journal of Cleaner Production, 205, 821-827.

Fakher, H. A., Ahmed, Z., Acheampong, A. O., & Nathaniel, S. P. (2023). Renewable energy, nonrenewable energy, and environmental quality nexus: An investigation of the N-shaped Environmental Kuznets Curve based on six environmental indicators. Energy, 263, 125660.

Farhani, S., Chaibi, A., & Rault, C. (2014). CO2 emissions, output, energy consumption, and trade in Tunisia. Economic Modelling, 38, 426-434.

Gill, A. R., Viswanathan, K. K., & Hassan, S. (2018). The Environmental Kuznets Curve (EKC) and the environmental problem of the day. Renewable and sustainable energy reviews, 81, 1636-1642.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement.

Génesis-Carolina, T. G., Viviana, T. D., & Wilman-Santiago, O. M. (2021, June). Expenditure on R&D, GDP and its impact on the Ecological footprint in South America. In 2021 16th Iberian Conference on Information Systems and Technologies (CISTI) (pp. 1-8). IEEE.

Grimm, N. B., Foster, D., Groffman, P., Grove, J. M., Hopkinson, C. S., Nadelhoffer, K. J., ... & Peters, D. P. (2008). The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. Frontiers in Ecology and the Environment, 6(5), 264-272.

Huang, X., Ding, A., Gao, J., Zheng, B., Zhou, D., Qi, X., ... & He, K. (2021). Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China. National Science Review, 8(2), nwaa137.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO2) in Chinese provinces. Ecological economics, 60(1), 228-245.

Ike, G. N., Usman, O., & Sarkodie, S. A. (2020). Testing the role of oil production in the environmental Kuznets curve of oil producing countries: New insights from Method of Moments Quantile Regression. Science of the Total Environment, 711, 135208.

Iqbal, N., Abbasi, K. R., Shinwari, R., Guangcai, W., Ahmad, M., & Tang, K. (2021). Does exports diversification and environmental innovation achieve carbon neutrality target of OECD economies?. Journal of Environmental Management, 291, 112648.

Kaika, D., & Zervas, E. (2013). The Environmental Kuznets Curve (EKC) theory—Part A: Concept, causes and the CO2 emissions case. Energy policy, 62, 1392-1402.

Kabeel, A. E., El-Maghlany, W. M., Abdelgaied, M., & Abdel-Aziz, M. M. (2020). Performance enhancement of pyramid-shaped solar stills using hollow circular fins and phase change materials. Journal of Energy Storage, 31, 101610.

Koch, N., Islam, N. F., Sonowal, S., Prasad, R., & Sarma, H. (2021). Environmental antibiotics and resistance genes as emerging contaminants: methods of detection and bioremediation. Current research in microbial sciences, 2, 100027.

Kumar, S., Managi, S., & Matsuda, A. (2012). Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. Energy Economics, 34(1), 215-226.

Kasperowicz, R. (2015). Economic growth and CO2 emissions: The ECM analysis. Journal of International Studies, 8(3), 91-98.

Lacheheb, M., Rahim, A. S. A., & Sirag, A. (2015). Economic growth and CO2 emissions: Investigating the environmental Kuznets curve hypothesis in Algeria. International Journal of Energy Economics and Policy, 5(4), 1125-1132.

Lonial, S., Lee, H. C., Badros, A., Trudel, S., Nooka, A. K., Chari, A., ... & Cohen, A. D. (2020). Belantamab mafodotin for relapsed or refractory multiple myeloma (DREAMM-2): a two-arm, randomised, open-label, phase 2 study. The lancet oncology, 21(2), 207-221.

Lazăr, D., Minea, A., & Purcel, A. A. (2019). Pollution and economic growth: Evidence from Central and Eastern European countries. Energy Economics, 81, 1121-1131.

Lin, B., & Moubarak, M. (2014). Renewable energy consumption–economic growth nexus for China. Renewable and Sustainable Energy Reviews, 40, 111-117.

Murshed, M. (2020). An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. Environmental Science and Pollution Research, 27(29), 36254-36281.

Noble, R. T., Griffith, J. F., Blackwood, A. D., Fuhrman, J. A., Gregory, J. B., Hernandez, X., ... & Schiff, K. (2006). Multitiered approach using quantitative PCR to track sources of fecal pollution affecting Santa Monica Bay, California. Applied and Environmental Microbiology, 72(2), 1604-1612.

Neequaye, N. A., & Oladi, R. (2015). Environment, growth, and FDI revisited. International Review of Economics & Finance, 39, 47-56.

Niesters, M., Martini, C., & Dahan, A. (2014). Ketamine for chronic pain: risks and benefits. British journal of clinical pharmacology, 77(2), 357-367.

Oliveira, F. C. D., Marques, T. R., Machado, G. H. A., Carvalho, T. C. L. D., Caetano, A. A., Batista, L. R., & Corrêa, A. D. (2018). Jabuticaba skin extracts: Phenolic compounds and antibacterial activity. Brazilian Journal of Food Technology, 21, e2017108.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American statistical Association, 94(446), 621-634.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and statistics, 61(S1), 653-670.

Pan, C., Abbas, J., Álvarez-Otero, S., Khan, H., & Cai, C. (2022). Interplay between corporate social responsibility and organizational green culture and their role in employees' responsible behavior towards the environment and society. Journal of Cleaner Production, 366, 132878.

Sharma, G. D., Shah, M. I., Shahzad, U., Jain, M., & Chopra, R. (2021). Exploring the nexus between agriculture and greenhouse gas emissions in BIMSTEC region: The role of renewable energy and human capital as moderators. Journal of Environmental Management, 297, 113316.

Sannigrahi, S., Pilla, F., Basu, B., Basu, A. S., & Molter, A. (2020). Examining the association between socio-demographic composition and COVID-19 fatalities in the European region using spatial regression approach. Sustainable cities and society, 62, 102418.

Sarkodie, S. A., & Strezov, V. (2019). A review on environmental Kuznets curve hypothesis using bibliometric and meta-analysis. Science of the total environment, 649, 128-145.

Sabir, S., & Gorus, M. S. (2019). The impact of globalization on ecological footprint: empirical evidence from the South Asian countries. Environmental Science and Pollution Research, 26, 33387-33398.

Sharma, S., Kundu, A., Basu, S., Shetti, N. P., & Aminabhavi, T. M. (2020). Sustainable environmental management and related biofuel technologies. Journal of Environmental Management, 273, 111096.

Sahli, I., & Rejeb, J. B. (2015). The environmental Kuznets curve and corruption in the MENA region. Procedia-Social and Behavioral Sciences, 195, 1648-1657.

Sinha, A., Shahbaz, M., & Sengupta, T. (2018). Renewable energy policies and contradictions in causality: a case of Next 11 countries. Journal of cleaner production, 197, 73-84.

Sinha, A., Shah, M. I., Sengupta, T., & Jiao, Z. (2020). Analyzing technology-emissions association in Top-10 polluted MENA countries: How to ascertain sustainable development by quantile modeling approach. Journal of Environmental Management, 267, 110602.

Tugcu, C. T., Ozturk, I., & Aslan, A. (2012). Renewable and non-renewable energy consumption and economic growth relationship revisited: evidence from G7 countries. Energy economics, 34(6), 1942-1950.

Usmani, Z., Sharma, M., Awasthi, A. K., Sivakumar, N., Lukk, T., Pecoraro, L., ... & Gupta, V. K. (2021). Bioprocessing of waste biomass for sustainable product development and minimizing environmental impact. Bioresource Technology, 322, 124548.

Uzar, U. (2020). Political economy of renewable energy: does institutional quality make a difference in renewable energy consumption?. Renewable Energy, 155, 591-603.

Udemba, E. N., & Yalçıntaş, S. (2021). Interacting force of foreign direct invest (FDI), natural resource and economic growth in determining environmental performance: A nonlinear autoregressive distributed lag (NARDL) approach. Resources Policy, 73, 102168.

Vincent, J. R., Panayotou, T., & Hartwick, J. M. (1997). Resource depletion and sustainability in small open economies. Journal of Environmental Economics and Management, 33(3), 274-286.

Wu, Y., Xu, X., Chen, Z., Duan, J., Hashimoto, K., Yang, L., ... & Yang, C. (2020). Nervous system involvement after infection with COVID-19 and other coronaviruses. Brain, behavior, and immunity, 87, 18-22.

Yilanci, V., & Gorus, M. S. (2020). Does economic globalization have predictive power for ecological footprint in MENA counties? A panel causality test with a Fourier function. Environmental science and pollution research, 27(32), 40552-40562.

Zhang, X., Yao, L., Zhang, S., Kanhere, S., Sheng, M., & Liu, Y. (2018). Internet of Things meets brain–computer interface: A unified deep learning framework for enabling human-thing cognitive interactivity. IEEE Internet of Things Journal, 6(2), 2084-2092.