Economy and Environment Review | Volume: 05 / N°: 01 (April 2022), p 467-490

Entrepreneurship, Innovation and Sustainability: Testing Environmental Kuznets Curve Hypothesis in Developed Countries

Mekhzoumi Lotfi [1], Harnane Nadjoua [2], Altawati Othman Ahlaam [3]

[1] University of El-Oued (Algeria), mekhzoumi-lotfi@univ-eloued.dz
[2] University of Khenchela (Algeria), harnane.nadjoua@univ-khenchela.dz
[3] Open University –Tripoli (Libya), ahlam@staff.ou.edu.ly

Received: 01/01/2022 *Accepted: 25/02/2022* *Published: 01/04/2022*

Abstract:
This paper aims to examine the impact of entrepreneurship and innovation on environment, using CO2 emissions as dependent variable, and entrepreneurship computed by Total Early-Stage Entrepreneurial Activity (TEA) and R&D expenditure (RDE) to measure innovation, as independent variables. Panel data has been used to investigate the existence of the EKC in 19 developed countries covering 2001 to 2019. The results supported the evidence of inverted N-shaped pattern of the EKC hypothesis is confirmed. The estimation results of GLS panel data model indicated to a positive impact of (TEA) and a negative impact of innovation on environmental degradation.
Keywords: Entrepreneurship; Innovation; CO2 emissions; EKC.
JEL Classification Codes: L26, O44, Q55, Q56.

***Corresponding author**: Lotfi Mekhzoumi, **e-mail:** mekhzoumi-lotfi@univ-eloued.dz*

1. INTRODUCTION

Economic and non-economic development are boosted by entrepreneurship, which creates jobs and improves goods. Entrepreneurs, according to Schumpeter, are the catalysts for change, innovation, economic dynamism, and growth. Researchers and politicians have recognized the significance of entrepreneurship since that time. While innovation is not a new concept in economics, it has been understood in different terms and included in many economic concepts such as knowledge, capital accumulation, market behaviour and mechanical advances. Entrepreneurs' primary goal is to meet an unmet need or to enhance the way that need is presently being met. As a consequence of achieving this essential and promising aim, good social and environmental benefits may not necessarily be generated as a result of the project. On the contrary, entrepreneurial activity is significantly (and historically) connected to environmental harm. That is what prompted us to investigate the phenomenon of the impact of innovation and entrepreneurship on the environment, so, for more details we ask the following question:

How do entrepreneurship and innovation affect environment in the developed countries?

The following hypotheses can be relied upon:

- ‘Total Early-Stage Entrepreneurial Activity’ has a statistically insignificant impact on environmental degradation in the developed countries.
- ‘Research and development expenditure’ has a negative moderate statistically significant impact on environmental degradation in the developed countries.
- ‘Energy consumption’ has a strong positive statistically significant impact on environmental degradation in the developed countries.

The main objective of this research is to investigate the role and effects of entrepreneurship and innovation as the engine of economic development on environment by incorporating entrepreneurship and innovation as an aspect of sustainability into an econometric environmental Kuznets (EKC) model to evaluate the role of entrepreneurship and innovation on environmental improvement. Even though entrepreneurship, technology, and innovation are all qualitative notions, we refer to them as variables in this study. We will consider these two concepts as variables in our model to see if there is a relationship between their occurrence and CO2 emissions. Total Early-Stage Entrepreneurial Activity is the indicator we use to measure entrepreneurship. We utilize research and development expenditure (R&D) to measure innovation. To improve our model, we added both energy consumption per capita and population density, which have a major impact on emissions.

In general, relevant literature has been divided into two categories. Most commonly, the EKC is used to illustrate the relationship between economic development and EKC. Economic development and entrepreneurial activity are discussed in the second stream. There are two main streams of research that have been done in the past. The first focuses on the relationship between economic development and environmental degradation, most commonly in the form of the EKC. It also examines the relationship between economic development and entrepreneurship in the second stream. Entrepreneurial activities and environmental degradation are considered and linked in this paper, which adds numerous new factors to the EKC.

(Schumpeter, 1931, p. 72) proposed that entrepreneurs starting new businesses provided the engine for economic growth, he saw that progress itself can be "mechanized" just as well as managing a stationary economy and this mechanization of progress is likely to affect individual initiative (entrepreneurship) and capitalist society almost as much as stopping economic progress. (Baumol, 1990, p. 901) mentions that entrepreneurs are individuals who are clever and inventive to find means to increase their wealth, strength and reputation, and he contends that it is to be anticipated that not all of them will be deeply concerned as to whether the activity that accomplishes these objectives adds much or little to the social product or, in that respect, whether it is a real obstacle to production.

(Salgado-Banda, 2005, pp. 1-46) studied the impact of entrepreneurship on economic growth through the use of two measures. The research examines 22 OECD countries and discovers a significant relationship between the selected measure of productive entrepreneurship – the degree of innovation of different countries – and economic growth, while the alternative measure, due to self-employment, appears to be negatively correlated with economic growth. (Cao, 2018, pp. 1-40) examined the relationship between entrepreneurship, innovation and economic growth in 125 countries including developed and developing countries for the period 2006 – 2016. The results suggest that in short-term, the impact of innovation and entrepreneurship on growth is not significant or even have negative significance in developing countries. But the losses in short-term will be compensated in long-term since they show a positive and significant correlation in both groups of countries.

(Ben Youssef, Boubaker, & Omri, 2017, pp. 1-10) Used a modified environmental Kuznets curve model to show that formal and informal entrepreneurship are conducive to reduced environmental quality and sustainability in 17 African countries however informal entrepreneurship contributes more than formal entrepreneurship to this environmental degradation. The relationship between entrepreneurship and sustainable development turns strongly positive in the presence of high levels of innovation and institutional quality.

(Mensah , et al., 2018, pp. 29678–29698) investigated into the effect of innovation on CO2 emissions in 28 OCED countries at an individual level for the recent period 1990 to 2014. They employed three key models based on the STIRPAT model, the economic-EKC growth model, and the innovation-EKC model. The findings revealed that innovation plays a key role towards mitigation of CO2 emissions in most OECD countries. Non-renewable energy accelerates emissions whiles renewable energy sources mitigate emissions. Research and development (R&D) improves environmental quality and the EKC for both economic growth and innovation, valid for a few economies of the OECDs.

(Kövendi, Nagy , Uddin, & Kang, 2021, pp. 1-47) examined the impact of entrepreneurship, technology, and innovation on the Environmental Kuznets Curve, using data from 2006-2016. By applying quantile regression to the panel data and grouping countries in peer groups, they found evidence for an N-shaped EKC relationship in developed countries, whilst an inverted N-shape in developing countries. The results confirmed that renewable energy consumption has a negative effect on environmental degradation. they also found evidence that entrepreneurship increases CO2 emissions in developed countries. On the contrary, they found that innovation increases emissions in developing countries and decreases emissions in developed countries.

2. Theoretical framework

2.1 Entrepreneurship, innovation and economic growth:

The relationship between entrepreneurship and economic growth has preoccupied economists since it was recognized, following the inability of endogenous models to explain the residue, that human action would be at the origin of economic growth. On a theoretical level, two approaches have provided arguments clarifying this relationship: the Schumpeterian approach and the Neo-Austrian approach which is based on the work of (Kirzner, 1973, p. 30).

For Schumpeter, the entrepreneur is the driving force behind economic growth, its role in the liberal economic system consists in the implementation of new combinations, that is to say innovations. Through his innovations, the Schumpeterian entrepreneur induces imbalances in the market as part of the process of creative destruction. This creative destruction is at the origin of economic dynamism and long-term growth to the extent that the exit of certain firms on the market frees up resources previously used otherwise and makes it possible to reallocate them in new combinations, according to this approach, the effect of entrepreneurship on economic growth results from the intrinsic qualities of the entrepreneur, precisely his ability to innovate, that is to say to economically value an invention, a discovery, an idea.

This activity involves the execution of new combinations. For this, five types of innovation have been distinguished: the introduction of a new product, the introduction of a new production or sales method, the opening of a new market, the implementation of a new type of industrial organization, the conquest of a new source of raw materials.

Thanks to its various innovations, the Schumpeterian entrepreneur is looking for the creation of new profit opportunities, these can arise from increased productivity (Nzaou, 2015, p. 53) so Schumpeter said : « The role of the entrepreneur is to transform or revolutionize the production pattern by exploiting an innovation, or more generally, an untried technological possibility foe producing an old one in a new way… to undertake such new things is difficult and constitutes a distinct economic function, Firstly, because they lie outside of the regular activities that everyone knows, and secondly because in many respects the world avoids » (Audretsch D. B., 2006, p. 201).

Thus, greater productivity can translate into increased competitiveness and increased growth, overall, entrepreneurship promotes economic growth through the introduction of innovations that add value. However, it should be noted that the Schumpeterian approach emphasizes the innovative entrepreneur, which suggests that it excludes from its field the self-employed without innovative vocation; while this type of so-called necessity entrepreneurship should not be overlooked as it is booming in developing countries, some of which are experiencing fairly high growth rates. The New Austrian approach to entrepreneurship, of which (Kirzner, 1973, pp. 37-42) is the main representative, focuses on the role of the entrepreneur in balancing the markets.

(Sternberg & Wennekers, 2005, p. 198) show that the relationship between entrepreneurship and economic growth is difficult to grasp since different types and different phases entrepreneurship influence economic growth. Also, the relationship is bidirectional in the sense that entrepreneurship encourages economic growth which in turn can affect the arbitration of individuals between different professional occupations including entrepreneurship.

Finally, measuring entrepreneurship is a very delicate task as there is no consensus on a reliable and practical set of indicators. In very detailed study, (Iversen, Jorgensen, & Malchow-Moller, 2008, pp. 17-22) summarized the different ways to measure entrepreneurship, but the most commonly used measure is what is called "business demography", which is the creation, disappearance and evolution of the number of companies over time or their degree of volatility. Despite these limitations, numerous empirical studies have attempted to identify the effects of entrepreneurship on the economic growth of developed nations. (Audretsch, Keilbach, & Lehmann, 2005, p. 85) show that entrepreneurship measured by the entry and exit rate of companies positively influence growth in terms of productivity. For their part, (Wennekers , Van Stel, Carree, & Thurik, 2010, pp. 3-5) find that the flow of new entrepreneurs tends to decrease with the level of development at some point, to increase again from this point.

Linking entrepreneurship to economic growth is certainly not new, there was many studies that try to explain the relation between the two concepts. In conventional (theoretical) economics, awareness of the value of entrepreneurial operation has been lacking for a while (Baumol, 1990, p. 911). Entrepreneurship, which is impossible to capture in statistical calculations, has vanished from conventional (neo-classical) economics, and (Kirzner, 1973, pp. 30-31) who found that, in terms of product quality and price, technology, the neo-classical paradigm restricted the entrepreneur's decision-making within constraints completely foreign to the sense in which real world entrepreneurs usually work.

2.2 Entrepreneurship and Sustainability:

Eco entrepreneurship, social entrepreneurship, sustainable entrepreneurship, as well as institutional entrepreneurship, have all addressed the link between entrepreneurship and sustainability. Entrepreneurship for sustainable development is a multidimensional phenomenon that connects entrepreneurial activities, market reforms, and large-scale societal developments on social, environmental, and economic levels. Sustainability, innovation, and entrepreneurship are viewed as a two-way diffusion process, with innovation and adoption occurring among both users and providers of sustainable products and services, and being shaped by investor and governmental influences.

Sustainable entrepreneurship is in essence the realization of sustainability innovations aimed at the mass market and providing benefit to the larger part of society. By realizing such (radical) sustainability innovations sustainable entrepreneurs often address the unmet demand of a larger group of stakeholders. Stakeholders are groups or individuals that materially affect or are affected by a firm’s activities. Stakeholder demands go beyond narrow economic interests of shareholders and are the ultimate sources of entrepreneurial opportunities for sustainability innovation, discovery and exploitation of which is at the core of sustainable entrepreneurship. Sustainable entrepreneurship is characterized by some fundamental aspects of entrepreneurial activities which are less oriented towards management systems or technical procedures, and focus more on the personal initiative and skills of the entrepreneurial person or team to realize large-scale market success and societal change with environmental or societal innovations. (Schaltegger & Wagner, 2011, pp. 229–233)

Although sustainable entrepreneurship has many features in common with environmental and social entrepreneurship, the coherent pursuit of economic viability, social equity, and environmental stability distinguishes sustainable entrepreneurship from other concepts. The following Table outlines some definitions of sustainable entrepreneurship with the aim of identifying differences and similarities (Urbaniec, 2018, pp. 1773-1779).

2.3 The environmental Kuznets curve (EKC):

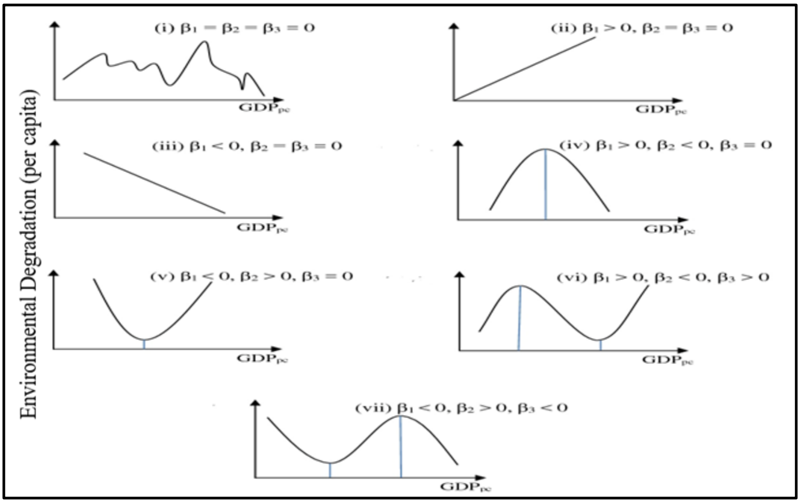
Economic growth has traditionally been seen as a "synonym" with environmental degradation. Researchers have found that economic growth can also correlate with environmental conservation. Sustainable development can be viewed as an approach aimed at calming the relationship between economic development and ecosystem(s) (Almeida, Cruz , Barata, & García-Sánchez, 2017, p. 127). The impact of economic growth on ecosystems has been extensively studied through statistical models, using different variables and methods. But the conclusions are still like a complex black box. In fact, several findings have shown that an economic system can put ecosystem(s) under stress and, as a consequence, harm its sustainability (Machado, Schaeffer, & Worrell, 2001, p. 409).

Therefore, a popular hypothesis widely used in the field of environmental economics literature for quantitative modelling of economic growth - environmental degradation is known as the environmental Kuznets curve, which is referred to as EKC (Azam & Khan, 2016, p. 561). The theoretical relationship between environmental degradation and economic growth is usually described as follows (Grossman & Krueger , 1991, p. 6):

$$\text{EDcp}_{i,t} = \beta_0 + \beta_1 GDPpc_{i,t} + \beta_2 GDPpc^2{}_{i,t} + \beta_3 GDPpc^3{}_{i,t} + \beta_4 Z_{i,t} + \varepsilon_{i,t} \text{ .... (01)}$$

where EDcp stands for per capita environmental degradation, GDPpc stands for per capita income, and Z includes all other variables that may affect environmental quality. Depending on the sign of different parameters related to individual income (β_1 to β_3), EKC will take different forms. When per capita income is plotted along the horizontal axis and the per capita environmental degradation index is plotted on the vertical axis for a particular country, we generally get a relationship that takes the following forms:

Figure 1. The Environmental Kuznets Curve (EKC)



Source : (Phong, 2019, p. 44)

In the existing literature, three different empirical specifications were used to analyze the EKC hypothesis (Bolük & Mert, 2014, pp. 439-446); (Grossman & Krueger, 1995, pp. 353-377): log-linear, quadratic, or cubic form. These forms can be generalized by using other factors such as time, regional characteristics, and technical factors like external variables. Different combinations of coefficient symbols have different curve forms.

Table 1. Curve shape of the relationship between environment and income

Model	**Value of βi**	**Forms of the curve**
Model 1	β1 = β2 = β3 = 0	no
Model 2 (linear)	β1 > 0, β2 = β3 = 0	Linear monotonically increasing
Model 3 (linear)	β1 < 0, β2 = β3 = 0	linear monotonically decreasing
Model 4 (quadratic)	β1 < 0, β2 > 0, β3 =	U-shaped relationship
Model 5 (quadratic)	β1> 0, β2 < 0, β3 = 0	inverted U-shaped relationship
Model 6 (cubic)	β1 > 0, β2 < 0, β3 >	N-type relationship
Model 7 (cubic)	β1 < 0, β2 > 0, β3 <	inverted N-type relationship

Source: (Uchiyama, 2016, p. 43)

As shown in Table 1., there are six models for the curve, and the meanings vary from model to model. broadly speaking, linear monotonically increasing; linear monotonically decreasing; U-shaped relationship; inverted U-shaped relationship; N-type relationship; and inverted N-type relationship.

3. Data and Methodology

3.1 Data:

This study uses annual data from 2001 to 2019 for 19 developed countries, namely, Australia, Belgium, Denmark, Canada, Finland, France, Germany, Hungary, Ireland, Italy, Japan, South Korea, Netherland, Norway, Spain, Sweden, Switzerland, the USA, and the United Kingdom. The countries were chosen according to the availability of data for the variables that will be considered in the analysis. Table 2. describes the dependent and independent variables of the study, including their definition and sources.

Table 2. Description of the variables considered in the analysis

Variable	Definition	Source
Dependent Variable		
Per capita CO2 (CO2cp)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacturing.	International Energy Agency
Independent variables		
GDP per capita (GDPpc)	GDP per capita is gross domestic product divided by midyear population in constant 2010 U.S. dollars.	World Bank
Energy consumption per capita (ECpc)	Energy use refers to the use of primary energy before transformation to other end-use fuels.	Our World in Data
Total Early-Stage Entrepreneurial Activity (TEA)	Percentage of 18-64 population who are either a nascent entrepreneur or owner-manager of a new business	Global Entrepreneur ship Monitor
Research and development expenditure (RDE)	"Research and development expenditure (% of GDP)	UNESCO
Population density (POPd)	Population density is midyear population divided by land area in square kilometers population of their country of origin.	FAO and World Bank

Source: Researchers' elaboration

The dependent variable in our study is Per capita CO2 emissions (CO2cp), which represents one of the most important indicators of environmental degradation. Our key explanatory variables are: GDP per capita (GDP pc), Energy consumption per capita (ECpc), Total Early-Stage Entrepreneurial Activity (TEA), Research and development expenditure

(RDE), and Population density (POPd).

3.2 Estimation Strategy:

We estimate an empirical model consisting of a relationship between CO2 emissions (CO2cp) and the explanatory variables, given by:

$$CO2cp = F(GDPpc, GDPpc^2, GDPpc^3, ECpc, TEA, RDE, POPd) \text{ …….. (02)}$$

All the series are transformed into natural logarithmic form. The log-linear specification presents consistent and efficient empirical results compared to simple linear modeling (Shahbaz, Loganathan, Zeshan, & Zaman, 2015). The log-linear specification is modeled as follows:

$$LCO2cp_{it} = \alpha_{it} + \beta_1 LGDPpc_{it} + \beta_2 LGDPpc_{it}^2 + \beta_3 LGDPpc_{it}^3 + \beta_4 LECpc_{it} + \beta_5 LTEA_{it} + \beta_6 LRDE_{it} + \beta_7 LPOPd_{it} + \varepsilon_{it} \text{ ………… (03)}$$

In the present study, the presence of the EKC hypothesis is empirically tested using a panel data set, covering 19 countries over during 2001-2019. The selected empirical strategy is subject to theoretical considerations, dataset structure, and the potential econometric issues that need to be carried out in this investigation. The use of panel data is the first remedy to address some of the above-listed issues in the presence of the EKC in the selected developed countries. This study follows the previous research practice, which suggests that static estimators, namely fixed effects (FE) and random effects (RE) are more commonly used in panel data analysis. The suitability of the two alternative estimators is assessed on a theoretical basis, the relationship to be investigated, and the type of the data (heterogeneity; unobserved effects), and on the diagnostics tests. Random effects (RE) estimator is preferred in situations, where the unobserved country effects are assumed to be uncorrelated with the included regressors (Gujarati, 2004, pp. 647-651). On the other hand, the fixed effects (FE) estimator accounts for such correlation between the unobserved heterogeneity and explanatory variables in the model, within each cross-sectional observation, e.g., between countries. The FE rather than the RE is more frequently applied in the entrepreneurship-economic performance literature. Favoring the use of (FE), (Wooldridge, 2013, pp. 504-506).

The study relies on the Hausman test to confront the decision of which is the most appropriate estimator for this investigation (Hausman, 1978, pp. 1251-1271). The null hypothesis states that there are no systematic differences between the two estimators, i.e., that the (RE) model is valid. A rejection of the null hypothesis suggests that the fixed effects (FE) are being preferred over the random effects (RE) (Baltagi B. , 2021, pp. 359-366).

Given the potentially unattractive trade-off between robustness and efficiency, (Barro & Sala-i-Martin, 1997, p. 13) and (Temple, 1999, p. 129) argue that the use of fixed effects in empirical growth models has to be approached with care. The price of eliminating the misleading component of the between variation – namely, the variation due to unobserved heterogeneity – is that all the between variation is lost. There are alternative ways to reveal this point, but consider the random effects GLS estimator of the slope parameters, which will be more efficient than the within-country estimator for small T, when the random-effects assumptions are appropriate. This GLS estimator can be written as a matrix-weighted average within-country estimator and the between-country estimator, which is based on averaging the data over time and then estimating a simple cross-section regression by OLS (Durlauf, Johnson, & Temple, 2005, p. 567).

4. Results and discussion

4.1. Descriptive statistics:

Table 3. displays descriptive statistics (mean and standard deviation) of the variables that were included in the analysis. The descriptive statistics provide a summary of the sample and observations in the panel data.

Table 3. Description of the variables considered in the analysis

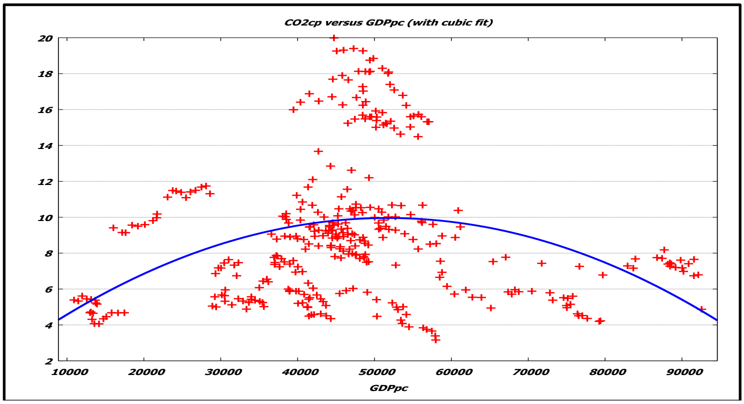
Variable		Mean	Std. Dev.	Min	Max	Observations
CO2cp	overall	9.041745	3.916869	3.16	19.99	N = 361
	between		3.854362	4.636842	17.11263	n = 19
	within		1.108408	6.118061	12.52543	T = 19
GDPpc	overall	47025.76	16573.76	10916.81	92556.32	N = 361
	between		16603.64	13771.33	88628.76	n = 19
	within		3576.671	36922.88	70930.7	T = 19
GDPpc2	overall	2.49e+09	1.75e+09	1.19e+08	8.57e+09	N = 361
	between		1.75e+09	1.92e+08	7.86e+09	n = 19
	within		4.05e+08	1.35e+09	5.62e+09	T = 19
GDPpc3	overall	1.45e+14	1.62e+14	1.30e+12	7.93e+14	N = 361
	between		1.61e+14	2.72e+12	6.98e+14	n = 19
	within		3.80e+13	1.70e+13	4.58e+14	T = 19
ECpc	overall	57223.79	22798.48	24560.78	115926.9	N = 361
	between		22980.28	27737.64	109856.3	n = 19
	within		4252.346	44274.44	68961.1	T = 19
TEA	overall	7.20777	3.123317	1.48	18.75	N = 361
	between		2.584052	3.741579	11.89895	n = 19
	within		1.847065	1.676191	14.19303	T = 19
RDE	overall	2.244876	.8075588	.86123	4.763	N = 361
	between		.7786264	1.163438	3.368106	n = 19
	within		.2760529	1.15058	3.63977	T = 19
POPd	overall	169.3681	157.8523	2.526978	531.8688	N = 361
	between		161.8165	2.880765	510.6216	n = 19
	within		6.480447	148.4112	190.6153	T = 19

Source: Stata/MP 16 outputs.

The dependent variable mean, CO2 emissions (CO2cp), in the developed countries under study is 9.041745, it can be observed that the mean belongs to the range between 3.16 as the minimum value and 19.99 as the maximum value of the CO2 emissions (CO2cp) worldwide.

Figure 2. shows the cubic curve fitting diagram for environmental pollution and the per capita GDP in the developed countries.

Figure 2. Cubic curve



Source: gretl outputs

It can be seen from Figure 2. that the cubic curve conforms well-inverted U-shaped.

The correlation matrix was performed to check whether the variables included in the specified econometric models suffer from high correlation. Table 4. displays the descriptive statistics of correlation among the dependent and the independent variables:

Table 4. correlation matrix of the variables considered in the analysis

	LCO2cp	LGDPpc	LECpc	LPOPd	LTEA	LRDE
LCO2cp	1					
LGDPp	0.1315	1				
LECpc	0.6205	0.465	1			
LPOPd	-0.4021	0.3572	-0.0535	1		
LTEA	0.366	0.039	0.3277	-0.0641	1	
LRDE	0.1396	0.3132	0.31	0.0149	-0.0484	1
VIF		1.37	2	1.74	1.24	1.28
1/VIF		0.72	0.5	0.57	0.8	0.78

Source: Stata/MP 16 outputs.

After considering the above-outlined correlation issues, we use the variance inflation factors (VIFs) to examine the existence of the multicollinearity problem. The variance inflation factors (VIFs) are below 10, thus, it indicated that there are no problems of multicollinearity.

4.2. Estimation results :

Table 5. shows the Fixed effects and random effects estimations:

Table 5. Fixed effects and random effects estimations

Fixed-effects (within) regression — Number of obs = 361
Group variable: country — Number of groups = 19
R-sq: within = 0.8384; between = 0.2722; overall = 0.2725
Obs per group: min = 19; avg = 19.0; max = 19
F(7,335) = 248.30
corr(u_i, Xb) = -0.9394 — Prob > F = 0.0000

LCO2cp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
LGDPpc	-36.23976	18.66599	-1.94	0.053	-72.95708	.4775561
LGDPpc_2	3.379754	1.807625	1.87	0.062	-.1759725	6.935481
LGDPpc_3	-.1053075	.0582115	-1.81	0.071	-.2198137	.0091987
LECpc	1.309762	.0517472	25.31	0.000	1.207971	1.411552
LTEA	-.0181161	.0126152	-1.44	0.152	-.0429311	.0066989
LRDE	.040284	.0338813	1.19	0.235	-.0263629	.1069309
LPOPd	-.5524602	.1161788	-4.76	0.000	-.7809921	-.3239284
_cons	120.1038	64.30354	1.87	0.063	-6.385795	246.5934
sigma_u	1.0443292					
sigma_e	.0562636					
rho	.99710585	(fraction of variance due to u_i)				

F test that all u_i=0: F(18, 335) = 422.40 — Prob > F = 0.0000

Random-effects GLS regression — Number of obs = 361
Group variable: country — Number of groups = 19
R-sq: within = 0.8275; between = 0.4032; overall = 0.4298
Obs per group: min = 19; avg = 19.0; max = 19
Wald chi2(7) = 1560.70
corr(u_i, X) = 0 (assumed) — Prob > chi2 = 0.0000

LCO2cp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
LGDPpc	-28.38874	19.11149	-1.49	0.137	-65.84657	9.069085
LGDPpc_2	2.73379	1.852408	1.48	0.140	-.8968629	6.364442
LGDPpc_3	-.0884877	.0597132	-1.48	0.138	-.2055234	.0285481
LECpc	1.367984	.0489498	27.95	0.000	1.272044	1.463924
LTEA	-.0162853	.0131319	-1.24	0.215	-.0420233	.0094527
LRDE	-.0160633	.0338084	-0.48	0.635	-.0823265	.0501999
LPOPd	-.0133097	.0437691	-0.30	0.761	-.0990955	.0724762
_cons	86.50613	65.66986	1.32	0.188	-42.20442	215.2167
sigma_u	.29159788					
sigma_e	.0562636					
rho	.96410686	(fraction of variance due to u_i)				

Source: Stata/MP 16 outputs.

It is evident from the outputs of the previous table that the comparison between the pooled model and the fixed effects model based on the restricted Fisher statistic (F) test, which indicates the rejection of the null hypothesis and acceptance of the alternative hypothesis, meaning that the fixed effects model is the best. After obtaining the estimates of the random-effects model, it is required to perform a Hausman test for the comparison between the fixed effects model and the random-effects model.

Table 6. Hausman test

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
LGDPpc	-36.23976	-28.38874	-7.851017	4.28902
LGDPpc_2	3.379754	2.73379	.6459647	.4079755
LGDPpc_3	-.1053075	-.0884877	-.0168199	.0128648
LECpc	1.309762	1.367984	-.0582224	.0235034
LTEA	-.0181161	-.0162853	-.0018308	.0016696
LRDE	.040284	-.0160633	.0563473	.0109997
LPOPd	-.5524602	-.0133097	-.5391505	.1137822

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 35.32
Prob>chi2 = 0.0000

Source: Stata/MP 16 outputs.

The output of the previous table shows the rejection of the null hypothesis and acceptance of the alternative hypothesis; therefore, the fixed effects model is the best. The next step is to run the diagnostic tests for the fixed-effects model.

Table 7. Fixed-effects diagnostic tests

Pesaran's test of cross-sectional independence	**Modified Wald test for groupwise heteroskedasticity in fixed effect regression model**	**Heteroskedasticity-robust Born and Breitung (2016) HR-test**
2.202, Pr = 0.0277	chi2 (19) = 2845.12 Prob>chi2 = 0.0000	HR-stat = -0.13 p-value = 0.894

Source: authors' elaboration based on STATA16 outputs

Pesaran CD (cross-sectional dependence) test was used to test whether the residuals are correlated across entities. Cross-sectional dependence can lead to bias in test results (also called contemporaneous correlation) (Pesaran, 2004, pp. 1-39). The result of the Pesaran test indicates the rejection of the null hypothesis and the acceptance of the alternative hypothesis which indicates that the model is suffering from the problem of non-cross-sectional dependence.

The Modified Wald statistic was used to assess the groupwise heteroskedasticity in the residuals of a fixed-effect regression model. The modified Wald statistic is workable when the assumption of normality is violated, at least in asymptotic terms (Greene, 2020, pp. 157-159). The null is homoskedasticity (or constant variance). According to the results of the modified Wald test above, we reject the null hypothesis and accept conclude heteroskedasticity.

Many tests for serial error correlation in panel data models have been proposed in the literature. The HR-test was used to test the first-order serial correlation in fixed effect panel data models without gaps (Born & Breitung, 2016, pp. 1290-1316). The null hypothesis is no serial correlation. Therefore, we accept the null hypothesis and reject the alternative hypothesis, which concludes the residuals devoid of the first-order autocorrelation.

Diagnostics tests of the specified model suggest the presence of cross-sectional dependency and heteroscedasticity and the absence of serial correlation. The fixed effects estimator was either inconsistent, biased, or inefficient in the presence of heteroscedasticity and serial correlation. To illustrate this, heteroscedasticity would make the estimates inefficient and their standard errors biased. GLS (Generalized Least Squares) is normally designed to produce an optimal unbiased estimator of β for the situation with heterogeneous variance. It can also deal with the problems of heteroscedasticity and serial correlation. Information on GLS can be found in (Greene, 2020, pp. 346-350).

Table 8. Generalized Least Squares model estimation

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroskedastic with cross-sectional correlation
Correlation:   no autocorrelation

Estimated covariances      =       190          Number of obs      =        361
Estimated autocorrelations =         0          Number of groups   =         19
Estimated coefficients     =         8          Time periods       =         19
                                                Wald chi2(7)       =   84998.00
                                                Prob > chi2        =     0.0000
```

LCO2cp	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
LGDPpc	-167.2508	3.012717	-55.51	0.000	-173.1556	-161.346
LGDPpc_2	16.53468	.2877981	57.45	0.000	15.9706	17.09875
LGDPpc_3	-.5436431	.0091525	-59.40	0.000	-.5615817	-.5257046
LECpc	.7216157	.0062674	115.14	0.000	.7093319	.7338995
LTEA	.2233952	.0019037	117.35	0.000	.219664	.2271263
LRDE	-.0971403	.003592	-27.04	0.000	-.1041804	-.0901002
LPOPd	.0086942	.0016395	5.30	0.000	.0054808	.0119076
_cons	556.4982	10.47367	53.13	0.000	535.9701	577.0262

Source: Stata/MP 16 outputs.

The result of the Generalized Least Squares model used to solve the heteroscedasticity and serial correlation problems differs from the fixed-effect regression model and the robust fixed-effect model. The number of statistically significant variables re-rise to seven.

Energy consumption (LECcp) estimates CO2 emissions with approximately *0.*721% for each 1% rise. This is not dissimilar to (Haseeb, Xia, Danish, Baloch, & Abbas, 2018, pp. 1-15) for BRICS countries; and (Jaunky, 2011, pp. 1228-1240) for 36 high-income countries.

The Entrepreneurial activity pushes CO2 emissions in developed countries reached at when 1% increase in the Total Early-Stage Entrepreneurial Activity (TEA) causes around 0.223% rise in LCO2. Although this increase is relatively weak, it argued that entrepreneurship raises environmental degradation, which in turn shrinks sustainable development in developed countries. Research focusing on the effects of entrepreneurship on the EKC relationship is limited, making it difficult to draw parallels. (Nakamura & Managi, 2020, pp. 1-14) found that CO2 emissions are low in proportion to countries with high entrepreneurial ratios and high in proportion to countries with low entrepreneurial ratios. (Omri, 2017, pp. 46-55) concluded that the contribution of entrepreneurship to environmental degradation is lower in the case of high-income countries compared to the other country samples.

The research and development decelerate CO2 emissions in developed countries reached at when 1% increase in the research and development expenditure (LRDE) causes around *0.0*97% fall in LCO2. What can be deduced is that our results fully support the findings of (Ahmad, Khan, Rahman, Khattak, & Khan, 2019, pp. 1-22) who found that innovation supports a reduction in CO2 emissions in OCDE countries. A negative correlation between R&D and CO2 emissions has been found for developed countries, but in order to reduce CO2 emissions more effectively, R&D must be focused on sustainable solutions and development. The topic then becomes how to shift R&D expenditures to research sustainable solutions instead of conventional ones. Business owners and prospective entrepreneurs might benefit from updating their teaching techniques, according to (Rashid, 2019, pp. 1-23). This could be used as a tool to assist alter basic beliefs about how firm and innovation should be done, as well as the definition of a successful business. The dissemination of sustainable development knowledge, according to (Rahmana & Bawono, 2021, pp. 657–668), will also lead to an increase in the number of businesses adopting a sustainable strategy. As a result, the training should begin with ideas such since the triple bottom line, as the strategy of incorporating environmental and social value into economic value generation may affect how firms function and what sort of R&D they invest in. In the conclusion, a transition to greener R&D activities is anticipated to have a rippling effect on the future of sustainability of innovation and entrepreneurship.

The positive spillovers of the density population (LPOPd) may be explained by migration effects. Furthermore, distancing behavior consists of two aspects: relocating contaminated sources and moving out of areas of intensive pollution. Therefore, migration could be an important contributing factor behind the population spillover effects on neighbor emission. Parenthetically, groups in different communities have the different ability to migrate away from polluted areas, thus the migration effects also tend to increase environmental inequality and be a driving force of the EKC (Dinda, 2004, pp. 431–455).

Finally, the evidence of the EKC is confirmed in the developed economies. Specifically, GDP per capita makes CO2 emissions shrink (as evidenced by the negative coefficient of LGDPpc), while the square of GDP per capita increases CO2 emissions (as denoted by the positive coefficient of LGDP2). Meanwhile, the cubic of GDP per capita decreases CO2 emissions (as denoted by the negative coefficient of LGDP3), which implies that the movement of CO2 emissions follows the inverted N-shaped pattern of the EKC hypothesis.

5. CONCLUSION

Growth theories, particularly neoclassical, endogenous, and Schumpeterian growth theories, have been used to examine the interaction between entrepreneurship and economic growth. While the relationship between entrepreneurship and innovation on the one hand and sustainability on the other has received little attention. The relationship between CO2 emissions and economic growth has been examined in a number of research over the past few decades. Economic Growth and CO2 Emission Model (EKC) is one of the paradigms that focuses on the relationship between economic growth and CO2 emission. The importance of this research is that it incorporates the role of entrepreneurship and innovation in the challenge of sustainability through the use of the EKC environmental Kuznets curve approach.

In the context of this article, we examined the impact of GDP per capita, entrepreneurship and innovation on CO2 emission in the 19 developed countries during 2001-2019. The results using the static approach estimators, suggested that the coefficient of 'Total Early-Stage Entrepreneurial' has a significantly negative impact in explaining variation in environmental degradation measured by CO2 emission in developed countries. Furthermore, the coefficient of the innovation measure: 'research and development expenditure' has a significant negative impact on explaining variation in the dependent variable. The findings confirm the EKC hypothesis, showing EKC evidence in developed countries. GDP per capita, in particular, reduces CO2 emissions; the square of GDP per capita, on the other hand, increases CO2 emissions; simultaneously, the cubic of GDP per capita reduces CO2 emissions. This suggests that CO2 emissions follow the inverted N-shaped pattern assumed by the EKC hypothesis.

The current study's findings assisted us in generating some significant policy implications to improve sustainability and environmental quality via two critical essential approaches: entrepreneurship and innovation. Despite the inverse relationship between innovation and carbon emissions, this effect is still limited (0.09 percent), In addition to the positive relationship between entrepreneurship and carbon emissions, which necessitating that developed countries should double their efforts in promoting and supporting sustainability and reducing environmental degradation. In order to minimize CO2 emissions resulting from energy usage, the majority of which originates from fossil fuels, they need devote more resources and logistics to this effort. The utilization of cleaner and more efficient fossil fuels such as natural gas and higher-grade coal is critical for these countries to achieve their energy security goals. A strategy that encourages the use of renewable energy in all economies is also a viable option for reducing emissions. Increased research and development R&D expenditures on renewable energy sources or market mechanisms that encourage enterprises' behaviour to boost their renewable energy usage are two more ways to reduce energy related pollution. Since renewable energy is made up of numerous distinct energy sources, R&D expenditures must be strategically allocated among them.

Inside this framework, we argue that entrepreneurial efforts are required to tackle our environmental challenges, and the major advantages will only be realized by leveraging the innovative ability of entrepreneurs who will build innovative business solutions to handle environmental challenges. Usually, two methods are used to persuade these enterprises (small and large) to conform with the main goals of sustainable development, namely coercive and more voluntary methods. The former is used by governments through regulations and laws, whilst the latter is voluntary promises made by businesses themselves through corporate social responsibility. We also recommend that governments in developed countries think about implementing expanded producer responsibility. Nevertheless, this should be done with prudence because it may have a domino effect on local markets by reducing domestic enterprises' competitiveness.

6. Bibliography List:

- Ahmad, M., Khan, Z., Rahman, Z., Khattak, S., & Khan, Z. (2019). Can innovation shocks determine CO2 emissions (CO2e) in the OECD economies? A new perspective. *Economics of Innovation and New Technology*, 1-22.
- Almeida, T., Cruz , L., Barata, E., & García-Sánchez, I.-M. (2017). Economic growth and environmental impacts: An analysis based on a composite index of environmental damage. *Ecological Indicators, 76,* pp. 119–130.
- Audretsch, D. B. (2006). *entrepreneurship and economic growth.* Newyork: Oxford university press.

- Audretsch, D., Keilbach, M., & Lehmann, E. (2005). The knowledge spillover theory of entrepreneurship and technological diffusion. *In University Entrepreneurship and Technology Transfer*, pp. 69-91.
- Azam, M., & Khan, A. (2016). Testing the Environmental Kuznets Curve hypothesis: A comparative empirical study for low, lower middle, upper middle and high income countries. *Renewable and Sustainable Energy Reviews, 63*, pp. 556–567.
- Baltagi, B. (2021). *Econometric Analysis of Panel Data* (6 ed.). Switzerland: Springer.
- Barro, R., & Sala-i-Martin, X. (1997). Technological diffusion, convergence, and growth. *journal of Economics, 2*, pp. 1-26.
- Baumol, W. J. (1990). "Entrepreneurship:productive, unproductive, and destructive. *The journal of political economy*, *98*(5), pp. 893-921.
- Ben Youssef, A., Boubaker, S., & Omri, A. (2017). Entrepreneurship and sustainability: The need for innovative and institutional solutions. *Technological Forecasting & Social Change*, 1-10.
- Bolük, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy, 74*, pp. 439-446.
- Born, B., & Breitung, J. (2016). Testing for Serial Correlation in Fixed-Effects Panel Data Models,. *Econometric Reviews*.
- Cao, J. L. (2018). *Entrepreneurship, Innovation & Economic Growth: an Empirical Study of Developed & Developing Countries.* Ottawa, Ontario, Canada: University of Ottawa.
- Dinda, S. (2004). Environmental Kuznets curve hypothesis: a survey. *Ecol Econ, 49*, pp. 431–455.
- Driscoll, J., & Kraay, A. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics, 80*(4), pp. 549-560.
- Durlauf, S. N., Johnson, P. A., & Temple, J. R. (2005). GROWTH ECONOMETRICS. Dans P. Aghion, & S. N. Durlauf, *Handbook of Economic Growth* (Vol. Volume 1A, pp. 555-677). Elsevier B.V.

- Greene, W. (2020). *Econometric Analysis* (8 ed.). New York: Pearson Education, Inc. Retrieved from www.pearsonglobaleditions.com
- Grossman , G., & Krueger , A. (1991). Environmental impacts of a North American free trade agreement. *National Bureau of Economics Research Working Paper*. Cambridge: MIT Press.
- Grossman, G., & Krueger, A. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), pp. 353-377.
- Gujarati, D. N. (2004). *Basic Econometrics* (5 ed.). McGraw-Hill Companies.
- Haseeb, A., Xia, E., Danish, Baloch, M., & Abbas, K. (2018). Financial development, globalization, and CO2 emission in the presence of EKC: evidence from BRICS countries. *Environmental Science and Pollution Research*, 1-15.
- Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, pp. 1251-1271.
- Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *Stata Journal*, *7*(3), p. 281.
- Iversen, J., Jorgensen, R., & Malchow-Moller, N. (2008). Measuring entrepreneurship. *Foundations and Trends in Entrepreneurship, 4*(1).
- Jaunky, V. C. (2011). The CO2 emissions-income nexus: Evidence from rich countries. *Energy Policy*, *39*(3), 1228-1240.
- Kirzner, I. (1973). *Competition and entrepreneurship.* Chicago: University of Chicago Press.
- Kövendi, E., Nagy , O., Uddin, G., & Kang, S. (2021). The Effect of Entrepreneurship, Technology, and Innovation on the CO2 Emissions in developed and developing countries. *SSRN*.
- Machado, G., Schaeffer, R., & Worrell, E. (2001). Energy and carbon embodied in the international trade of Brazil: an input–output approach. *Ecol. Econ*, *39*, pp. 409–424.
- Mensah , C., Long, X., Boamah , K., Bediako, I., Dauda, L., & Salman , M. (2018). The effect of innovation on CO2 emissions of OCED

countries from 1990 to 2014. *Environmental Science and Pollution Research*, *25*.

- Nakamura, H., & Managi, S. (2020). Entrepreneurship and marginal cost of CO2 emissions in economic development. *Economic Analysis and Policy*, *67*, 1-14.
- Nzaou, J. (2015, June). Renaissance Entreprenariale et dynamique de la croissance au Congo. *International Multilingual Journal if Contemporary Research*, p. 53.
- Omri, A. (2017). Entrepreneurship, Sectoral Outputs and Environmental Improvement : International. *Munich Personal RePEc Archive*.
- Pesaran, M. (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics*(0435), p. 4 8 2.
- Phong, L. H. (2019). Globalization, Financial Development, and Environmental Degradation in the Presence of Environmental Kuznets Curve: Evidence from ASEAN-5 Countries. *International Journal of Energy Economics and Policy*, *9*(2), pp. 40-50.
- Rahmana, F., & Bawono, A. (2021). Sustainable development toward sustainable enterprise. *Management Science Letters*, *11*, 657–668.
- Rashid, L. (2019). Entrepreneurship Education and Sustainable Development Goals: A literature Review and a Closer Look at Fragile States and Technology-Enabled Approaches. *Sustainability*, *11*, 1-23.
- Salgado-Banda, H. (2005). Entrepreneurship and economic growth: An empirical analysis. *Dynamics, Economic Growth, and International Trade - DEGIT Conference Papers*.
- Schaltegger, S., & Wagner, M. (2011). Sustainable Entrepreneurship and Sustainability Innovation: Categories and Interactions. *Business Strategy and the Environment*, *20*, 222–237.
- Schumpeter, J. A. (1931). The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. *Harvard University Press*.

- Shahbaz, M., Loganathan, N., Zeshan, M., & Zaman, K. (2015). Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. *Renewable and Sustainable Energy Reviews, 44,* 576–585.
- Sternberg, R., & Wennekers, S. (2005). Determinants and effects of new business creation using global entrepreneurship monitor data. *Small business economics, 24*(3), pp. 193-203.
- Temple, J. (1999). The new growth evidence. *Journal of Economic Literature, 37*(1), pp. 112–156.
- Uchiyama, K. (2016). *Environmental Kuznets Curve Hypothesis and Carbon Dioxide Emissions.* Development Bank of Japan .
- Urbaniec, M. (2018). Sustainable Entrepreneurship: Innovation-Related Activities in European Enterprises. *Pol. J. Environ. Stud., 27*(4), 1773-1779.
- Wennekers , S., Van Stel, A., Carree, M., & Thurik, R. (2010). The Relationship between Entrepreneurship and Economic Development: is it U-shaped? *Now Publishers Inc*.
- Wooldridge, J. M. (2013). *Introductory Econometrics: A modern Approach* (Vol. 5). South-Western Cengage Learning.