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THE ROLE OF ENTREPRENEURSHIP AND INNOVATION IN THE ENVIRONMENTAL AND ECONOMIC DIMENSIONS OF GROWTH*

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Abstract. This study is mainly performed to examine the effects of renewable energy, entrepreneurial activity, and innovation on GDP and CO₂ emissions in 13 European countries from 2002 to 2017. The estimation of the feasible generalized least square (FGLS) method shows that the share of renewable energy consumption in accordance with the total energy consumption, entrepreneurial activity, and innovation, defined by the number of patents, increases the economic growth but inversely decreases CO₂ emission. The share of research & development expenditure to GDP lowers the CO₂ emission without having any impact on the economy. With reference to these results, a set of implications are deduced, specifically for policymakers. The substitution of renewable energy and the encouragement of innovative entrepreneurs to undertake green businesses are essential to attain the objectives of sustainable development.

Keywords: entrepreneurship; innovation; economic growth; environment; European countries

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1. Introduction

Dynamic cultural entrepreneurship and a well-studied national innovative ecosystem are indicatives of the socio-economic well-being of the countries throughout the world. In this vein, Barba-Sanchez et al. (2022, p. 1) ascertain that entrepreneurial activity is basically crucial for its contribution to an area's economic and social development. It increases employment creation as a vehicle for reaching competitiveness as well as innovation in the market. Almodóvar-González et al. (2020, p. 9) suggest that entrepreneurial activity plays a different role depending on the economic stage of the country. Pradhan et al. (2020, p. 1114) demonstrate that higher innovation

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and entrepreneurship promote long-run economic Growth in Eurozone countries. Facchini (2009, p. 8) confirms that an entrepreneur's role is significant in the development process by improving the production techniques with product innovation propositions, which may interrupt the market consumption routines. The final objective of the business undertaking is mainly to replace the traditional competitive means with more revolutionary ones. Schumpeter (1934, p. 66) shows that entrepreneurs are innovators, who open up new markets, modern ways of firm organization, and trendy inputs, making their projects more appealing. Colino et al. (2013, p. 2) consider entrepreneurship as distinctive individuals, describing human capital in the neoclassical production function. Accordingly, entrepreneurship contributes to the productive system by a combination of productive factors, notably capital and labor. In this respect, more entrepreneurial resource allocation implies higher levels of production and well-being. Facchini (2009, p. 4) corroborates that the entrepreneur theory introduced by Kirzner (1973, 2005) is designed to explain how to improve the economic well-being of the population of the rich countries rather than to elaborate on the variable Y through the production function. More precisely, it is a theory about searching for the creation of new goods and services, added to their variety augmentation and possible cheapness. The concept of the green market is motivated by the growth in environmental awareness. According to Gupta and Dharwad (2021, p. 3603), increasing demand for environmentally friendly products induces today's consumers to be more and more concerned with the environment by being inclined to green markets. Even the entrepreneurs are more cautious today by being much closer to socially responsible citizens. They know their roles in a sustainable business environment, looking for a better future. Shepherd and Patzel (2011, p. 144) argue that entrepreneurial act results in new products and services which are compatible with people's health. It is actually well-documented by a set of researches in biotechnology and pharmaceutical industries. Kirzner (1973, p. 30) thinks that alertness is the quality that practically allows entrepreneurs to identify opportunities for profits. Shepherd and Patzel (2011, p. 144) mark out that entrepreneurs are essentially motivated by profit-making and, notably, the actions making the market more and more efficient. Dean and McMullen (2007, p. 69) argue that the entrepreneurial acts are likely to lead to overcoming the market efficient functioning barriers, contributing to more reasonable use of environmental and natural resources, and to a more ecologically sustainable economy. In this context, entrepreneurship is considered a solution to many environmental issues. It results in sustainable economic growth (Shepherd and Patzel, 2011; Omri, 2018; Jinjiang et al., 2020). Shepherd and Patzel (2011, p. 137) believe that the entrepreneurial acts can keep the ecosystem intact, react to climate change, lessen the environmental degradation and deforestation, diversify the agricultural activities with the flow of freshwater supply, and finally maintain biodiversity. Omri (2018, p. 9) studies the impact of entrepreneurial activity on CO_2 emission. He shows that the contribution of entrepreneurship to environmental degradation is lower for high-income countries compared to the upper-middle-income, lower-middle-income, and low-income countries. Ben Youssef et al. (2020, p. 232) confirm that the combination of entrepreneurship and sustainable development seems to be useful when it is accompanied by innovative tendencies and societal quality. Indeed, the main objective of this study is to deeply expand the investigation of the roles played by innovation and entrepreneurship in relation to sustainable development and the maintenance of a dynamic economy in euro countries. A test of the contribution of entrepreneurial activity, innovative economic growth, and environmental protection in European countries will be conducted.

2. Literature Review

2.1. Entrepreneurship, innovation, and growth

Joseph Schumpeter (1883-1950) affirms that a market-oriented economy is continuously adapting a dynamic system, which creates new opportunities through a steady constructive change. The essence of capitalism, associated with entrepreneurs, implies a constant search for novelty and innovation. The entrepreneurs seek a turn through their research and development (Schumpeter 1934). They rule out old competitive sources by replacing them with new ones, following production technique improvements. They break the existing consumers' routines, which predominate the market. The goal of the business undertakers is simply to seek new competitive means. Conversely, the market process can also be a creative and non-destructive construction (Audretsch et al., 2006). In

fact, it is an accumulated knowledge that no longer reflects a rift. It reveals a sense of continuity since the entrepreneurs respond to the incomplete commercialization of the new knowledge produced by the large groups (Audretsch et al., 2006; Facchini, 2009). Firms' knowledge contribution brought into the market is a favor for business-undertaking as well as new firms' entrance. Added to this business environment is the entrepreneurs' knowledge emanating from their different individual experiences. Shane (2000, p. 449) corroborates that their knowledge allows them to identify opportunities for profit-making. With respect to the Solow Model, Facchini (2009, P. 9) argues that economic growth is measured by the production function. More importantly, the endogenous growth theory elaborates the scene furtherly by adding the traditional factors of production, known as labor, capital, and knowledge. Unlike these factors, knowledge is characterized by spillover effects. In line with the politicians, economic experts confirm that to reach an expected level of growth, an investment in research and human capital is inevitable. Nevertheless, Audretsch et al. (2006) argue that knowledge production is inadequate if it does not emanate from the entrepreneurs themselves. They think that the entrepreneurs are the missing link in the theory of endogenous growth. In the endogenous growth model, the firm produces knowledge (A) in the initial stage, which turns into the input in the consecutive one. Galindo and Méndez (2014) examine the relationships between entrepreneurship, innovation, and growth in 13 developed countries from 2002 to 2007. They find out that the more entrepreneurial activity and the more innovative sources are, the more economic enhancement looks like. In addition, their examination implies that a positive but tighter money supply is likely to intensify innovation and entrepreneurial activities. Pradhan et al. (2020) scrutinize the effects of entrepreneurial acts, innovative applications, and economic growth on the Eurozone countries between 2001 and 2016 by carrying out the Granger causal relations. By using the vector error-correction model, their study shows that entrepreneurship along with innovation stimulates a noticeable economic growth in the long run. However, in the short run, the case is different in terms of causal relations, which shows inconsistency. Their findings indicate that the Eurozone countries are required to base their developmental strategies on policies promoting regular innovations and creating entrepreneurial incentives.

2.2. Entrepreneurship, innovation, and environmental sustainability

Several studies confirm that entrepreneurship plays an important role in environmental sustainability. Jinjiang et al. (2020) conducted research examining the contribution of opportunity-based entrepreneurship to the environmental quality of 67 countries from 2015 to 2017. Their findings intensify that entrepreneurship is positively related to environmental quality and that institutional context has a positive moderating effect on opportunity-based entrepreneurship in addition to the environmental quality of sustainable development. Omri (2018) investigates the relationship between entrepreneurship and CO₂ emission from 2001 to 2011 in 69 countries subsumed under four cognate income-based panels: 22 high-income developed countries, 14 upper-middle-income countries, 23 lower-middle-income countries, and 10 low-income countries. The findings accentuate that entrepreneurial activity, particularly in high-income countries, affects the environment negatively at first. However, later, the environmental scene gets better. It shows an inverted U-shaped connection between entrepreneurial activity and environmental contamination. Evidently, the entrepreneurial acts are a remarkable factor in getting fewer environmental problems, solely in the high-income developed countries. Hanohov and Baldacchino (2017) point out that entrepreneurial knowledge accelerates the process of opportunity seizing. Accordingly, it is recommended that entrepreneurial knowledge and skills are efficient in leading to sustainable development. Nakamura and Managi (2020) emphasize the U-shape relation between entrepreneurship and the marginal cost of CO₂ emissions in economic development. Japan, as a developed country, has a median level of CO₂ marginal cost, and China, for instance, which has a low level of CO₂ abatement, witnesses higher rates of entrepreneurial activities. For countries positioned close to the turning point, further promotion of environmental and social entrepreneurship through technological innovation will help achieve greater sustainable progress; this fact seems vital for future sustainable development. Ben Youssef et al. (2018) analyze the effect of entrepreneurial activity on environmental degradation from 2001 to 2014. Their analysis shows that entrepreneurship activity in Africa leads to environmental degradation. With reference to innovation and institutional variables in the analysis, the impact of both forms of entrepreneurship on sustainability seems positive, indicating that a higher level of

innovation and better quality of institutional variables constitute a motivating force to reach a higher level of entrepreneurship and sustainability. Mongo et al. (2021) use an autoregressive distributed lag (ARDL) model from the pooled mean group (PMG) estimator to examine the impact of environmental innovations on CO₂ emissions of 15 European countries from 1991 to 20014. Their findings show that in the long-term, the environmental innovations lower the CO₂ emissions. However, in the short term, the effects are rebound. Their study is a recommendation of introducing new policies combining the environmentally economic tools with the ecological economy. This economic integration is an incentive for regulatory changes, encouraging individuals to consume in a different way. It makes them favor products and services with less undesirable effects on the environment. Du et al. (2019) investigate the impact of green technology innovations on CO₂ emissions based on a data panel covering 71 economies from 1996 to 2012. They show that the effect of green technology innovations on the reduction of CO₂ is intertwined with the level of income. Green technology innovations are not essentially very effective in reducing CO₂ emissions for the economies whose income levels are below the threshold. The mitigating effect of green technology is clearly noticeable for high levels economies overcoming the threshold. However, the transition of regime occurs at an extremely high-income level.

3. Methods

This study explores the effect of entrepreneurial activity and innovation on GDP and CO₂ emissions in 13 European countries[†] from 2002 to 2017. Following Maalej and Cabagnols (2020), the Cobb–Douglas production functions are adopted. Four-way linkages are investigated by making use of the following system of equations:

Alternative specifications of the growth function:

$$\text{Eq1: } Y_{it} = A_1 GFCF_{it}^{\alpha_{1i}} RE_{it}^{\alpha_{2i}} TEA_{it}^{\alpha_{3i}} RD_{it}^{\alpha_{4i}} e^{\pi_{it}}$$

$$\text{Eq2: } Y_{it} = A_2 GFCF_{it}^{\varphi_{1i}} RE_{it}^{\varphi_{2i}} TEA_{it}^{\varphi_{3i}} PAT_{it}^{\varphi_{4i}} e^{\delta_{it}}$$

Alternative specifications of the environmental function:

$$\text{Eq3: } CO_{it} = A_3 Y_{it}^{\theta_{1i}} RE_{it}^{\theta_{2i}} TEA_{it}^{\theta_{3i}} RD_{it}^{\theta_{4i}} e^{\varepsilon_{it}}$$

$$\text{Eq4: } CO_{it} = A_4 Y_{it}^{\beta_{1i}} RE_{it}^{\beta_{2i}} TEA_{it}^{\beta_{3i}} PAT_{it}^{\beta_{4i}} e^{\mu_{it}}$$

The logarithmic transformation of the four equations is given by:

$$\ln(Y_{it}) = \ln(A_1) + \alpha_{1i} \ln(GFCF_{it}) + \alpha_{2i} \ln(RE_{it}) + \alpha_{3i} \ln(TEA_{it}) + \alpha_{4i} \ln(RD_{it}) + \pi_{it}$$

$$\ln(Y_{it}) = \ln(A_2) + \varphi_{1i} \ln(GFCF_{it}) + \varphi_{2i} \ln(RE_{it}) + \varphi_{3i} \ln(TEA_{it}) + \varphi_{4i} \ln(PAT_{it}) + \delta_{it}$$

$$\ln(CO_{it}) = \ln(A_3) + \theta_{1i} \ln(Y_{it}) + \theta_{2i} \ln(RE_{it}) + \theta_{3i} \ln(TEA_{it}) + \theta_{4i} \ln(RD_{it}) + \varepsilon_{it}$$

$$\ln(CO_{it}) = \ln(A_4) + \beta_{1i} \ln(Y_{it}) + \beta_{2i} \ln(RE_{it}) + \beta_{3i} \ln(TEA_{it}) + \beta_{4i} \ln(PAT_{it}) + \mu_{it}$$

The subscript $i=1, \dots, N$ denotes the country while $t=1, \dots, T$ signifies the time period. “ π, δ, ε and μ ” are the residual term assumed to be identically, independently, and normally distributed. The parameters, $\alpha_j, \varphi_j, \theta_j$ and $\beta_j / j=1, \dots, 4$, are the returns to scale associated with the explanatory variables $\ln(A_j / j = 1, \dots, 4)$ is a global constant. Variable “Y” is the gross domestic product per capita (constant 2010 US\$); “CO” is the CO₂ emissions (metric tons per capita); GFCF is the gross fixed capital formation per capita (constant 2015 US\$); “RE” is the renewable energy consumption (% of total final energy consumption); “TEA” is the Total Early-Stage Entrepreneurial Activity rate ; innovation variables: “RD” is the research and development (R&D) expenditure (% of GDP) and “PAT” is the number of patents per thousand of population (residents and non-residents). The

[†] Sweden, Finland, Norway, United Kingdom, Germany, Belgium, Netherlands, Croatia, France, Greece, Spain, Switzerland, and Hungary

entrepreneurial activity variable is collected from the Global Entrepreneurship Monitor (GEM) data and the rest are collected from the World Bank Indicators.

Equations 1 and 2 are used to explore the marginal effects of gross fixed capital formation, the share of renewable energy to total energy consumption, R&D expenditure, the number of patents per thousand of population, and entrepreneurship activity on economic growth. Several works maintain that the driving forces of economic growth are: GFCF (Maalej and Cabagnols, 2020; Saidi and Omri, 2020), RE (Maalej and Cabagnols, 2022), TEA (Pradhan et al. 2020; Dhahri et al., 2021), innovation: RD and PAT (Pradhan et al. 2020; Maradana et al., 2019).

Equations 3-4 are used to examine the marginal effects of economic growth, renewable energy, R&D expenditure, and entrepreneurship activity on CO₂ emission. Several research corroborate that the CO₂ emissions is maintained by: Y (Rahman and Vu, 2020; Maalej and Cabagnols, 2020, 2022), RE (Maalej and Cabagnols, 2022), TEA (Jinjiang et al., 2020; Nakamura and Managi, 2020), innovation: RD and PAT (Dauda et al. 2019; Maalej and Cabagnols, 2022).

Following the approach of Maalej and Cabagnols (2020), a set of specifications tests will be performed to determine the appropriate estimation model for four-panel data. The data will be analyzed with STATA 13

Table 1. Correlation matrix between study variables

	lnCO	lnY	lnGFCF	lnRE	lnRD	lnPAT	lnTEA
lnCO	1.0000						
lnY	0.3421	1.0000					
lnGFCF	0.2832	0.9720	1.0000				
lnRE	-0.4079	0.1331	0.1895	1.0000			
lnRD	0.1767	0.6528	0.6604	0.1966	1.0000		
lnPAT	0.2334	0.5859	0.5647	0.2012	0.5803	1.0000	
lnTEA	-0.2141	0.0125	-0.0101	0.2064	-0.2154	-0.0992	1.0000

The table 1 above indicates that there is a very important correlation between lnY and lnGFCF (COR(lnY, lnGFCF)=.972). It reveals a very close relationship between the two variables. For the innovation variables, the table displays the existence of a positive association between lnRD and, respectively, lnY and lnGFCF (COR(lnRD, lnY)=.652 and COR(lnRD, lnGFCF)=.660). Similarly, the positive association between lnPAT and, respectively, lnY, lnGFCF and lnRD is also significant, exceeding 50%. This result clearly shows the importance of innovation in capital and economic growth. The close links between these variables are likely to lead to problems of collinearity and ultimately disturb the estimates of the model parameters.

4. The Estimated Method and Results

The set of tests, notably Likelihood Ratio, the Breusch-Pagan LM and the Hausman are used to identify the individual-specific effects (the fixed and random ones). It is deduced that the regression model is supposed to be an individual FE model for Eq1 and Eq2 and an individual RE for Eq2 and Eq4.

The Breusch-Bagan and modified Wald tests are conducted, respectively in order to detect the existence of intra and inter individual heteroscedasticity in the residuals of the individual FE and RE model. It is noticed that the phenomenon of heteroscedasticity is present in four equations.

A Pesaran's (2004) CD test is used to identify possible cross-sectional dependence in the error term between the entities (De Hoyos and Sarafidis, 2006). The errors exhibit cross-sectional correlation in four equations.

Finally, a serial correlation is responsible for several optimistic standard errors (Torres, 2007). To check this complication, a Wald test is performed, which validates the presence of the first-order autocorrelation in the four equations.

The AR1 process may differ across countries. It gives rise to panel specific AR1 (PSAR1) (Beck and Katz, 1995). The restriction of a common autocorrelation parameter is reasonable when the individual correlations are nearly equal, and the time series are short (StataCorp, 2019). Conversely, in the current study, the time span is long (16 years), and the individual correlations are different according to each equation. In conclusion, the panel specific AR1 is chosen, and at the same time the error structure is determined by the panel heteroscedasticity, autocorrelation, and contemporaneous correlation (HPAC) in four equations.

Estimations are performed with the feasible generalized least square (FGLS) method (Blackwell, 2005). FGLS have the same optimal properties as GLS for panel data. It avoids the GLS assumption that specifies the covariance matrix Ω , which is known (Podestà, 2002). Reed et al. (2009) find that FGLS is the overall best performer on efficiency ground, but it does not concern the confidence intervals. The estimations are performed independently on each of the four equations. They are represented in the following table 2.

Table 2. Estimation results

Explanatory variables	Growth function		Environmental function	
	Eq 1: lnY	Eq2: LnY	Eq 3: lnCO	Eq4: LnCO
lnY			.304***	.338***
lnGFDF	.713***	.739***		
lnRE	.014***	.005**	-.191***	-.191***
lnTEA	.016***	.013***	-.030***	-.030***
lnRD	.0007		-.022***	
lnPAT		.016***		-.024***
Cons	4.073***	3.912***	-.507***	-.892***
Wald chi2(4)	7032.03***	9091.83***	1077.54***	1218.97***

Note: ***denotes significance at the 1% level

**denotes significance at the 5% level

4.1. Results of growth function: Eq1 and Eq2

The results show that the effect of the variable lnGFDF is positively remarkable on lnY in European countries (lnGFDF->lnY~ 0.7). These studies' findings confirm that the gross fixed capital formation is the engine of economic Growth (Maalej and Cabagnols, 2020; Saidi and Omri, 2020).

Principally, they indicate that the renewable energy consumption share with regard to the overall amount of energy consumption increases the economic growth. It reveals the increase in renewable energy consumption, being replaced by non-renewable energies, which improves growth in the European countries. The results collaborate with the results of Maalej and Cabagnols (2022, p. 17), which support that the renewable energy consumption share in accordance with the overall amount of the energy consumption raises the economic growth in the Northern European countries. In contrast, Dogan et al. (2020, p. 4) argue that the effect of renewable energy consumption on economic growth depends on the income level of the OECD country. When renewable energy consumption is peroxided by total consumption or absolute value, the effect is positive for lower and low-middle income. However, the effect of renewable energy on growth becomes negative for middle, high-middle, and higher income. In low-income (like Estonia, Iceland, Slovak, Slovenia, and Luxembourg), renewable energy has a positive impact on GDP, while in high-income countries (like considering 2010 data, United States, United Kingdom, Japan, Italy, Germany, and France) renewable energy exerts a negative influence over GDP. But when the renewable energy is peroxided by the renewable energy consumption share in relation to the overall amount of

the energy consumption, the result implies a negative impact on growth. Furthermore, the present results shed more light on the influence of innovation on the impact of renewable energy on growth. The current study's findings show that the contribution of renewable energy to economic growth is different between Eq1 ($\ln RE \rightarrow \ln Y = 0.14$) and Eq2 ($\ln RE \rightarrow \ln Y = 0.05$). This is probably explained by the effect of renewable energy on economic growth, which could be influenced by innovation per se.

Again, the present results indicate that entrepreneurial activity improves economic growth in general. The results practically go with those of Almodóvar-González et al. (2020, p.14), which indicate the existence of a positive relationship between entrepreneurship and economic growth in the advanced countries' environments. However, in the context of the poorest countries, entrepreneurial activity slows down economic growth. Comparing the different developmental levels of countries, Linán and Fernández-Serrano (2014, p. 693) affirm the presence of a negative global relationship between entrepreneurial activity and economic growth.

For the variables of innovation, only the number of patents has a positive and significant effect on growth. The effect of R&D expenditure is very weak. It is without significance, which may be explained by the R&D expenditure indirect improvement of the economic growth through the increase of the number of patents (Galindo-Martín et al. 2021). Audretsch et al. (2006) demonstrate that the biggest countries of the European Union witness a low growth but a highly noticeable level of investment in human capital, research, and development. Generally, they view that there is no necessary relationship between growth and investment in R&D. They argue that entrepreneurs are the vehicle for converting knowledge into growth. These entrepreneurs are likely to perceive the opportunities for profits as they are capable of exploring an amount of knowledge that has not been exploited by existing firms yet. They predict that a country will have a level of growth much more significant than that of the entrepreneurs' activities while the investment in R&D is high. Furthermore, they think that a country can have a little investment in R&D but equally compensate for it by an excess of entrepreneurial activities. On the contrary, a country may have a high level of R&D with no noticeable growth.

4.2. Results of environmental function: Eq3 and Eq4

The results show that the effect of GDP on CO₂ emission is positively significant. 1% increase in $\ln Y$ makes a 30% reduction in $\ln CO_2$, which indicates that the production in the European countries causes considerable pollution. Generally, in the developed countries, Muhammad (2019, p. 16) states that CO₂ emission is increased due to the positive effect of economic growth, using the generalized method of moments (GMM) and the Seemingly unrelated regressions model. However, the effects of the Sys GMM model are indicative of the economic growth, which shows a negative and non-significant effect on the CO₂ emissions. Maalej and Cabagnols (2020, p. 141) demonstrate that the effect of GDP on CO₂ emission is positive and significant in the oil-rich Middle East/North Africa (MENA) countries, while it is negative and non-significant in oil poor countries. Omri (2018, p. 9) show that the CO₂ emissions, due to the output growth, are larger for high-income countries, generally relying on the service and industry sectors for growth and development enhancement. These sectors, practically, require extensive use of energy, resulting in a huge amount of CO₂ emission.

The overall amount of the energy consumption considered with regard to the renewable energy consumption share has a negatively significant effect on the CO₂ emission. 1% increase in $\ln RE$ makes a 19% reduction in $\ln CO_2$, which gives evidence that renewable energy use contributes to environmental improvements. With respect to the state-of-the-art, renewable energy is a vehicle for reducing the levels of carbon emissions. It proves the case that the higher use of renewable energy, the lower CO₂ emission (Dogan and Seker, 2016; Maalej and Cabagnols, 2022).

The entrepreneurial activity has a significantly negative effect on the CO₂ emission. 1% increase in $\ln TEA$ causes a 3% reduction in $\ln CO_2$. It clearly indicates that the entrepreneurial activity in Europe is essentially based on an environmentally friendly principle. Jinjiang et al. (2020, p. 6) show that entrepreneurship has a negative impact on

CO₂ emission per capita. It means a positive impact on the environmental quality. Omri (2018, p. 9) affirms that entrepreneurial activity contributes to the environmental improvement of the high-income developed countries, compared to the sample showing other types of countries. Gu and Zheng (2021, p. 623) support that entrepreneurship is proportionally reversible: on the one hand, it promotes the technological progress of enterprises; on the other hand, it exacerbates the environment through the mediating effect of the technological progress. Environmental regulation negatively moderates the impact of the technical effects on pollution. Entrepreneurship does not only promote the productive scale of enterprises but also increases corporate pollution emissions through the scaling mediation effect. Moreover, the environmental regulations negatively moderate the impact of the scaling scale effect on pollution.

The obtained results reveal that the innovation variables lower the CO₂ emission. A 1% increase in lnRD gives a 22% reduction of lnCO₂ in Eq1, while a 1% increase in lnPAT provides a 24% reduction of lnCO in Eq2. In this sense, Apergis et al. (2013, p. 57) show that after the adoption of the International Financial Reporting Standards, R&D expenditures lower the CO₂ emission in European manufacturing firms in the UK, France, and Germany. Maalej and Cabagnols (2022, p. 19) clearly indicate that the number of patents per thousand of population causes a reduction in CO₂ emissions in the Northern European countries. Dauda et al. (2019, p. 15033) prove that innovation reduces CO₂ emissions in G6 countries (Canada, France, Germany, Italy, Japan, United Kingdom) while it increases emissions in MENA (Bahrain, Egypt, Morocco, Tunisia, Algeria, Israel, United Arab Emirates) and BRICS countries (Brazil, Russia, India, China, and South Africa).

Conclusion

This study analyzes the effect of renewable energy, entrepreneurial activity, and innovation on GDP and CO₂ emissions in 13 European countries from 2002 to 2017. In the same vein, the estimation of the FGLS method is indicative of the renewable energy consumption with respect to the overall amount of energy consumption as well as the entrepreneurial activity and innovation, defined by the number of patents that increase the economic growth and inversely decrease the CO₂ emission. Similarly, the share of R&D expenditure to GDP lowers the CO₂ emission without having an influence on the economy. Generally, the study's findings give rise to political implications, which are helpful for improving the environmental qualities in the developed countries, being essentially liable to pollution throughout the world with regard to their pursuit of prosperity and global economic importance.

- These countries are required to reduce the extensive use of non-renewable energies, causing serious pollution to the environment. They are recommended to use hydroelectricity, solar energy, and geothermal and wind sources of energy. In addition, they are in an urgent need to show a strong willingness to utilize technological progress to keep an equal balance between their economic growth and environmental friendliness. Their efforts are supposed to control and reduce environmental pollution without doing harm to their economic growth and development. Sarkodie and Adams (2018, p. 1598) maintain that substituting the finite and scarce fossil fuel energy sources with renewable energy ones will not only ensure environmental quality but also lead to escape from an economic dependency on traditional sources of energy. In fact, renewable energy sources are not internationally traded, as is the case with fossil fuels. The high rate of renewable sources accessibility reduces the extensive dependency on fossil fuel importation, which guarantees both secure energy and economic productivity.

- These countries are recommended to encourage innovation and entrepreneurial activities in order to conform to the principles of sustainable development. Pukka (2021 p. 448) emphasizes that technological development is the key to reducing greenhouse-gas emissions. More importantly, technology-specific strategies are needed to meet climate friendliness. Accordingly, supporting innovative entrepreneurs within the framework of sustainable entrepreneurship is suitable for the sustainable development challenge. Gu and Zheng (2021, 623) deduce that measuring the effect of innovative entrepreneurship on the environment is strenuous. Innovative entrepreneurship may be considered a double-edged arm on the environment: on the one hand, innovation may cause

environmental pollution; on the other hand, it is likely to improve the environmental quality with reasonable prudence. Gupta and Dharwad (2021, p. 3606) maintain that the dynamic chain of green products, designs, and supply courses in a system of a green manufacturing process gives rise to a green environment. In this context, green-tending enterprises enable their owners to practice sustainable businesses, which enlighten three elementary pillars of sustainability, notably equitable economic growth, environmental friendliness, and abidance to human rights.

Despite the implications discussed above, we infer that our study suffers from various limitations. Firstly, it measures environmental degradation only by CO₂ emissions while other indicators could have been studied (total Green House Gas emissions: CO₂, CH₄, N₂O, F-gases, etc.). Secondly, it lacks explicit measurements of sustainable entrepreneurship and sustainable innovation. Finally, it studies the effect of entrepreneurial activity and innovation on GDP and CO₂ emissions only in the case of developed countries. Future studies could be triggered by studying this effect for both developed and developing countries and demonstrating how this effect depends not only on the behaviors and motivations of entrepreneurs but also on stages of economic development.

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