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Environmental Compliance Reactions to R & D Practices and Intellectual Capital: A Worldwide Evidence

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Abstract

Our ecosystem and mainly our natural resources represent a vital ecological portfolio. Environment is good for business at a time business is not keen to invest in compliance measures. Sustaining the environment is costly and adds additional burden. The burden not only financial, it is mainly technical and managerial. Producing renewable energy and maintaining freshwater resource, reducing electricity production and emissions depend also on R & D practices such as trademark and patent applications. This also needs engineers, technicians, scientists and human capabilities with continuous knowledge and intellectual capital. The main research hypothesis has tested the effect of environmental protection and compliance on the R&D in intellectual capital creation. Environmental reactions are measured by "renewable internal freshwater resources", "electricity production from renewable sources", "access to electricity" and "alternative and nuclear energy", while R & D practices are measured by "trademark applications", "technicians in R&D" and "patent applications".

Research hypotheses has been tested using panel regression analysis according to GMM technique. Using data of 94 countries during the period from 2001 to 2019, findings show that there are significant effect of "trademark applications" on "renewable internal freshwater resources" and of "technicians in R&D" on each of "electricity production from renewable sources" "access to electricity" and "alternative and nuclear energy". Besides, "patent applications" seems to have significant effect on "alternative and nuclear energy". Results have found that countries that have made environmental improvements are those who have invested in intellectual capital and made significant steps in improving their environmental R&D Capabilities.

Keywords: environmental compliance, environmental knowledge, environmental R & D, green economy, sustainable policies.

1. Introduction

The complexity of economic and demographic development is the major factor in increasing environmental degradation. Demographic patterns make urban areas environmentally vulnerable. Deficient environmental features exist all over the world. Natural World Heritage Sites (NWHS) are progressively under pressure from human behaviors. Losses are happening in almost every single Natural World Heritage Site across the world. Scientists have found that human pressure has increased in more than 60 percent of the sites in the last 24 years. The human footprint increased in two-thirds of the sites that were studied, and even more alarming is the majority of the sites were damaged beyond repair (Allan, Venter, Maxwell, Bertzky, Jones, and Watson, 2017). Protecting the environment has a cost. In that respect, less developing countries (LDC) are facing a major challenge, which is the high costs of protecting the environment. Even in industrial countries, the consumption of black energy, the emissions from factories and vehicles, deforestation, the chemical wastes, untreated sewage water, excessive transport facilities, unplanned construction and urban designs, in addition to secondary pollutants and defective agricultural programs continue to damage the Environment. Moreover, environmental degradation is a major problem in newly industrialized countries (NICs) economies that have advanced towards complete industrialization. China, as an example is responsible for more than 27% of total global emissions in 2021. In that context, scientists from the University of Notre Dame have conducted a study that confirms the relationship between toxic pollution, climate risks to human health. The study has indicated that China and India are the two largest countries, that have, not only high mortality ranks of annual deaths associated due to toxic pollution, with 2.3 and 1.9 million premature deaths a year, but they are the most polluting countries on the globe

(Zhongming, Linong, Xiaona, Wangqiang, and Wei, 2021). The environmental degradation cost in China increased from 511 billion yuan to 1,892 billion Yuan from 2004 to 2017. The environmental benefits of industrial transformation have emerged in China, that has done huge efforts to decrease the cost of environmental degradation from 10% in 2014 to 2% in 2018, but simultaneously, this implied enormous investments in green economy and cleaner production methods. (Ma, Peng, Yang, Yan, Gao, Zhou, and Wang 2020). The cost of going greener and environmentally friendly is huge, where the U.S. accounts for 11% of the global total worldwide emissions. In the United Sates, the official source for spending data for the U.S. Government shows that the Environmental protection Agency's (EPA) budget and spending in Fiscal Year 2021 enacted a budget around $ 9 billion dollars with a workforce of around 15,000 employees (EPA, 2022). However, the Environmental Protection Agency and the National Institutes of Health were big losers during the Presidency of Donald Trump, in comparison to planetary science at researches at NASA stands to gain. Under the Trump plan, the first budget proposal called for double-digit cuts for the Environmental Protection Agency (EPA) and the National Institutes of Health (NIH) budget. The United States have seen an important alteration in its national research agenda, at a time the US administration decided to retreat from environmental and climate programs. (Reardon, Tollefson, Witze, and Ross, 2017).

The Working Group on Environmental Auditing (WGEA), under the International Organization of Supreme Audit Institutions (INTOSAI), using its audit mandate and audit instruments in the field of environmental protection policies, in the field of water and fresh water availability and infrastructure, similar to the variables we are assessing in this paper ("renewable internal freshwater resources" (RR), and "alternative energy" (AN). The group conducted an auditing on the environmental obligations of the Oil Pipeline of Heavy Crude OCP project of the Ministry of Energy and Non-Renewable Natural Resources in Zealand in 2021. The main Audit Objective is to assess the compliance of government bodies with domestic environmental legislation, in addition to the government performance and compliance with environmental policies and program. Even in New Zealand, the report concluded that the government should invest on knowledge and technical capital in order to increase the efficiency of the environmental management. (WEGA, 2021). The Controller and Auditor-General concluded that the expenditure were inappropriate and reported major agency and individual agency initiatives failures, especially in environmental compliance (Ryan, 2021).

According to the Artificial Intelligence Index Report (2021), the research and development (R&D) efforts have a fundamental impact on artificial intelligence (AI) progress. Since the technology first captured the imagination of computer scientists and mathematicians in the 1950s, AI has grown into a major research discipline with significant commercial applications. The number of AI publications has increased dramatically in the past 20 years. The rise of AI conferences and preprint archives has expanded the dissemination of research and scholarly communications. Major Powers, including China, the European Union, and the United States, are racing to invest in AI research. The R&D applications aim to capture the progress in this increasingly complex and competitive field.

This paper shows many cases where environmental protection all over the world depends on investments made, especially in the R&D area and in Intellectual capital creation. We have quoted several researches that shows that environmental protection, environmental concerns, health and infectious threats diseases, climate change and cleaner energy production, none of which can be tackled meritoriously if R&D and intellectual Capital Formation is deprived of funding and technical assistance coming from research programs. Eco-innovation is important to improve water or noise emissions, avoid hazardous substances, and increase recyclability of products. (Horbach, Rammer and Rennings, 2012). The paper even works on analyzing data from 94 counties as shown in the Descriptive and Diagnostic Statistics and Correlation coefficients between research variables

As a conclusion, we certainly approve and conform to the idea mentioned in most of the studies stating that Economic Instruments (EI), especially Environmental Economic Instruments (EEI) and Taxation Policies are not the most efficient tools to reduce polluting emissions. R&D and Intellectual Capital do not appear frequently in Environmental debates. Technical progress for energy-saving and resources utilization driven by technology and investments in environment-friendly R & D is fatal for environmental protection and remediation. (Carraro and Galeotti 1997).

Consequently, and because of these assumptions, this paper link environmental protection to R & D practices and capital formation. Environmental reactions have been measured by "renewable internal freshwater resources", "electricity production from renewable sources", "access to electricity" and "alternative and nuclear energy". R & D practices are measured "trademark applications", "technicians in R&D" and "patent applications".

After this fist introductory section (1), section (2) define the research problem, while section (3) defines the terms and section (4) shows the literature review. Section (5) is for testing hypotheses and (6) presents the descriptive and diagnostic statistics. Section (7) is about measuring variables and developing hypotheses needed to present the concluding remarks in section (8). The paper presents at the end an extensive list of references of around 50 sources and researches.

2. Problem Statement

Most of the environmental economic researches stress on the impact of financial tools, and taxation measure, within Environmental Economic Instruments (EEI) to control pollution. A wide range mention the cost of environmental deterioration per country of globally and find out that for example that at least one billion people have no access to potable water, and 2.5 billion people lack sufficient sanitation facilities. (The World Bank, 2020), However, few concentrate on the impact of R&D and intellectual capital hasn't been appeared frequently in environmental debates. Investing in environment-friendly R & D and technical progress is fatal for environmental concerns such as energy-saving and resources utilization. (Carraro and Galeotti 1997).

Environmental Management and Environmental protection both depend nowadays more and more on technology. The applications of the Environmental Management System (EMS), Cleaner Production (CP) methods and efficient pollution control, in the business or by government require more investments in Technology, intellectual capital, and R&D. The green economy and the circular economy are one of the results of the development of cleaner technologies. (Wang, Yang, Fu, Fan, and Zhou, 2021). Efficient and sufficient investments is one the causes of biodiversity protection and unsustainable use of resources. This all requires capital, wages and subsidies to support conservation activities, but also and mainly, to fund exploration and research and to support conservation measures undertaken conducted by governments, industry, and individuals. Regardless of the willingness, institutional setup and/or the vitality of having policies that protect the environment, taking care of the environment has been associated to a cost, which is called "Compliance Cost" (Markopoulos, Staggl, Gann and Vanharanta, 2021). It is associated to a "Social Cost" (Horry, Booth, Mahamadu, Manu and Georgakis, 2021).

Worldwide, an amount of about $7.3 million is spent in the health sector to treat waterborne diseases (Dakkak, 2016). A water treatment plant (WTP) could cost more than $ 1 billion. The Bahr El-Baqar plant in Egypt, which is the largest wastewater treatment plant in the world, costs 20 billion Egyptian pounds ($1.27 billion). It has a production capacity of about 5.6 million cubic meters per day of triple-treated water. In that respect, the U.S. Bureau of Reclamation, the Research and Development Office called for a WTP cost-estimating guideline for planning and research activities. The bureau called for a planning, research, and design WTP in term of cost and management (U.S. Bureau of Reclamation, 2017). In India, there are more than one thousand (1,631) sewage Treatment Plants (STPs) with a total capacity of 36,668MLD covering 35 States in the year 2020-21. A report of the Central Pollution Control Board of the East Arjun Nagar of Delhi made the previous inventory and stressed on the knowledge management of the STP (Central Pollution Control Board, 2021). The risks of a mismanagement of such plants such as the biggest Bahr El-Baqar plant or even a small number of the (1,631) sewage Treatment Plants (STPs) in India, or similar facilities anywhere around the world could be deadly. The World Bank estimates the annual cost of the health effects associated with inadequate drinking water, sanitation, and hygiene in Egypt by LE 26 billion to 56 billion in 2016/17. The cost reach 1.61% of Egypt's GDP in that year. These are the cost of mortality, cost of morbidity and cost of health effects (The World Bank, 2019).

Many scholars have concluded that there is always a direct relationship between the size of the company and it is spending on environmental protection, in different parts of the world (Szőke, 2021). SME's but mainly micro-enterprises, face a problem of funding environmental compliance, especially in tourism (Chan and Ho, 2006) and Industry (Labella, Fort, Saïsset and Rosa, 2021). Whenever the company itself is financially viable, or is has a business performance (Darnall, Henriques and Sadorsky, 2008), or works in an international context or is taking care of its social and business image, it will spend more on Environmental Protection, Compliance measures and Environmental management Systems (EMS procedures). Environmental Compliance and EMS procedures) need Financial Support and two main elements that are R & D and Intellectual Capital. This is a problematic question in lots of countries, not only in emerging economies (Voinea, Hoogenberg, Fratostiteanu and Bin Azam Hashmi, 2020), nut also in the US (Ogunrinde, Shittu and Dhanda, 2020) and Europe (Martín-de Castro, Amores-Salvadó and Navas-López, 2016). Therefore, the purpose of this paper is to show the link and the impact of investments in intellectual capital and R&D on environmental protection measures and measurements.

The first variable which is “Trademark applications” and brands or industrial technology, trade names and logos used on goods and services needs lots of investments and Intellectual Capital and R&D. The second variable “technicians in R&D” is a determinant factor that depends on human resources and intellectual capital. Bringing more technicians in R&D is an investment that is made on people. It will help protecting the environment through new technics and technologies. The third variable, which is “patent applications”, needs also intellectual capabilities, and not only physical investments. But, would “trademark applications” have an impact on “renewable internal freshwater resources”, and the number of “technicians in R&D”, would it have an impact on “electricity production from renewable sources”, “access to electricity” and on “alternative and nuclear energy”?. Thirdly, would “patent applications” have significant effect on “alternative and nuclear energy”?

3. Defining the Terms

This paper has used a wide range of environmental terms and concepts, such as Environmental Pollution, Iconological Footprint, Circular Economy or Green Economy, Closed-loop System, Eco-conscious, Energy Efficient and Sustainability. Environmental terms and definitions are nowadays familiar and commonly used. However, some of the terms are extensively used in different contexts and by different capacities. The term “Sustainably” is an example. The term sounds the same but have different meaning according to the area of expertise. We usually here the use of sustainability with terms such as sustainable product, sustainable engine, sustainable planning or sustainable housing, sustainable consortium or sustainable car. The word “sustainable” or “sustainability” is used to refer a perceptive that will endure through a longer period. It is overlapping with the term accompanying "sustainable development. Moreover, it is often used in reference to a long-term process or a perpetuation, without mainly referring to environmental aspects. The paper is using the term according to the "Brundtland Report" Our Common Future (1987) to guaranty the needs of the current generations without conceding with the needs of future generations and their rights to use future resources through an unconventional approach that would use environmentally friendly actions (Velásquez, 2021; Banerjee, Gupta, and Koner, 2022). The paper is also using terms such as cleaner production (CP) as integrated business operations to improve quality of life. It is a holistic view to include “greening of the supply chain”, recycling of materials and applying an environmental philosophy in product development. (Kjaerheim, 2005). The paper use the term renewable sources as subsystem of the whole Earth Ecos and one of the most important aspects of the economy (Mobus, 2022; Velásquez, 2021; Allaeva, 2022).

4. Literature Review

This section presents some of the previous work, which has been conducted in the area of linking Environmental Management and Regeneration to R & D Practices and Intellectual Capital Formation. We have explored around 75 Papers, conference proceedings and writings related to the impact of R&D and Intellectual capital formation on Environmental Sustainability. We have started our review since 1992, the year that have witnessed the Earth Summit in June 1992. The Rio de Janeiro Earth Summit was a major United Nations conference. It had an impact on Environmental movements and Environmental Policies and action plans all around the world. That is why we have chosen to review the research work done during the last 30 years to track the major evolutions of the Impact of R&D and Intellectual Capital Formation on Environmental Management and Regeneration.

It goes without saying that protecting the Environment has a cost. It needs money. It also needs technology as well as technical Knowledge. In this part, we will review some of the work that explains and link the two variables (Environmental Management and Regeneration capabilities to both R & D Practices and Intellectual Capital Formation). There is always a strategic correlation between environmental performance and R&D. A paper published in 1994 examine the relationships between environmental requirements, policies and R&D management. The paper concludes that R&D management does not only require only new management systems, but innovative arrangements and facilities to create environmentally sustainable products (Roome, 1994).

Victor, Chang and Blackburn have conducted a major work that relates Environmental regeneration to Intellectual Capital and R&D on a macroeconomic level in 1994. The article has been published as result of an increasing awareness in the early nineties after the Earth Summit in 1992. The authors tried to link the impact of environmental preservation policies on economic growth. They have developed an economic model where environmental regeneration goods depends on cleaner production methods. The impact of production of environmentally-friendly and environmentally-unfriendly good and services comes from research and development. They find that the GDP can witness great losses if cleaner production methods, which depends mainly on R&D and the formation of intellectual capital in the industry, are not used as a national strategy (Victor, Chang and Blackburn, 1994).

Later, a paper on Environmental Management Systems (EMS) and business performance has linked the adoption of EMS with the business performances that needs financial facilities. The authors have explored the impact of institutional pressures on the business community and how far these pressures makes them ready or not to invest in capital formation to adopt EMS. The paper has used OECD survey data from industrial entities in Germany, Hungary, but also from United States and Canada. Finding have indicated that business is much more motivated to accept and use EMS tools if the company is export oriented, or have an increasing employee commitment and environmental R& D policies. Such cases have created greater overall facility-level business performance to motivate the company to adopt EMS procedures (Darnall, Henriques, and Sadorsky, 2008).

Knowledge diffusion in Environmental area need a holistic innovation space. Conti and others studies the intensity and direction of knowledge flows in renewable energy sources (RES) technologies over the period 1985 to 2010 across the US, Japan and the EU15. They found a fragmented EU innovation space until the beginning of the century, but that fragmentation shrank in parallel and due to increasing stronger EU environmental commitments during the last 20 years, and this went also in with a demand-pull policies (Conti, Mancusi, Sanna-Randaccio, Sestini, and Verdolini, 2018). Shabunina, Shchelkina and Rodionov have worked on the same idea as we do to link environmental performance to knowledge and innovation, but the North-West Federal District (NWFD) of the Russian Federation (RF) for the period of 2000-2014. Their idea is to link the transformation into an eco-economic space of a region based on eco-efficiency technics, management methods and eco-innovation to shift activities into green economy. They have used statistical indicators abs variable such as environmental quality index and population health indicator as well as the ecologized human development index. The article presents the insights of statistical indicators of the environment and public health that is correlated to the dynamics of knowledge efficiency of innovations (Shchelkina, and Rodionov, 2017). Social capital has gained importance in economic development and sustainability when we have seen that development depends not only on money (financial capital) and natural resources, but on education and skills (human capital) needed for economic innovation. Manning (2010) review the growing literature bridging social capital (SC) and knowledge management (KM). He identified the causal factors and connection between SC and KM. He is influenced by the explanations of (Granovetter, 1985) and (Coleman, 1988) the most relevant for understanding of market activity and examining the SC and KM interface. Both (Granovetter, 1985) and (Coleman, 1988) are an exemplary source to understand also the creation of knowledge management and capital formation in institutions. They tackled this issue from an institutional background, which also help to understand why some institutions comparing with other are also keen to develop intellectual capital and spend on R&D in environmental protection and management.

As mentioned earlier in the problem statement, environmental innovation need investment that is more intensive. If we compare investments made all over the world by governments in green economy, the share will of course be much smaller comparing to investments made in infrastructure or industry or even in health sector, despite the fact that a number of diseases and health problems are due to environmental pollution. It seems that investments made in green innovations and R&D produce a lower return relative to innovations in other sectors (Marin and Lotti, 2017).

Regarding R& D practices, studies have shown that, while the influence of government and the economic environment are seen to encourage innovation ecology, having R&I resources, human capital, and early seed funding are key indicators of innovation. Innovation relies on a supportive infrastructure that is both economic and social (Griffiths et al., 2009). Innovators, creators and inventors become motivated to continue with their work only when they are assured of the ownership of their innovation, creations and inventions . Kalanje (2006) shows that intellectual property (IP) could either refer to the "unique or value-adding creations of the human intellect that results from human ingenuity, creativity and inventiveness .

Countries need to consider adequate protection before engaging with external actors in order to prevent unwanted knowledge theft, and this is typically solved through the application of IP protection rights (Brem et al., 2017). In this way, countries would be able to protect their citizens from unnecessary infringements from externalities . For policy-makers, supporting more efficient patenting and trademark processes in start-ups, spin-offs and new businesses would be a way to improve the efficiency of innovation in general. For instance, the costs of filing and maintaining IPRs should be more distinctive for small or big organisations because without distinction in the filing and maintenance of IPRs, small and medium enterprises (SMEs) may not able to afford them. This negatively affects the growth of new businesses and innovation. Society's dominant motive for having a patent system is to improve the provision of innovation by offering inventors temporary, transferable rights to protect their inventions from imitation, enough for capturing or appropriating sufficient returns from their inventions to pay back for their R&I in return for enabling disclosure of the inventions (Holgersson & Granstrand, 2017).

Research and development/innovation should not be the preserve of academia only, but should also be fostered by charitable organisations as well as public and private sectors . Government can foster a culture of quality research in a country through enactment of various legislation frameworks. This may require a serious commitment to funding R&I projects and uptake of such R&I outputs. This is because R&D alone without any uptake may not result in any innovative outputs as shown in other studies (Odhiambo & Ntenga, 2016).

The Magazine of Research and Development reports that the USA has traditionally led the world in all aspects of R&D for more than 50 years, due to combined large industrial and government research spending and investment. However, this overwhelming advantage has changed in recent years as the rate of R&I investments in Asia exceeded that of the USA. Lately, there has been a change in the nomenclature to R&I, replacing the traditional R&D. The rationale for the change from R&D to R&I is meant to differentiate the two, based on their outputs. Evidence suggests that, R&D may not necessarily result in innovative outputs as opposed to R&I (Agolla& Makara, 2018).

Agolla& Makara (2018) investigates the role of innovation in economic diversification, through a review and synthesis of related literature on innovation and economic diversification. The study argues that leveraging innovation by developing economies is likely to result in robust diversification and competitiveness of such economies. The paper highlights some pertinent issues that countries need to put into place as a way to promote innovation. The paper contributes by proposing a conceptual framework that can be used to guide innovation activities for competitiveness.

Odhiambo & Ntenga (2016) argues that research has a positive impact on the quality of life as it contributes to the improvement in living conditions, social cohesion, health, education and cultural advances. It also plays a crucial role in government policy modelling and implementation. Research also has a positive spillover effect on business and commercial entities. Through research, knowledge is transferred between research entities and business entities – which impact positively on the growth and profitability of business entities.

Another issue that needs to be taken into consideration when evaluating the role of research in economic development is the spillover effect of academic research on innovation and industrial-development processes. Through academic research, the latest knowledge is disseminated from academia to industries. As such, R&I should not be seen as a preserve of academia only but also other institutional players in the economy. Government should encourage individuals and private organizations, through appropriate subsidies, to participate in R&I in the economy (Agolla& Makara, 2018).

Regarding environmental sustainability, it is important to address that the environmental one is one of the 3 sustainability main pillars (environmental, economic and social), where: 1) Environmental sustainability: where all of earth's environmental systems are kept in balance while natural resources within them are consumed by humans at a rate where they are able to replenish themselves . 2) Economic sustainability: where human communities are able to maintain their independence and have access to the resources that they require, financial and other, to meet their needs. 3) Social sustainability: where universal human rights and basic necessities are attainable by all people, who have access to enough resources in order to keep their families and communities healthy and secure.

Earth Policy Institute (2016) shows that sustainability describes how dynamic systems remain diverse and productive over time. Sustainability for human beings is the ability to preserve the quality of life we live in the long term, which in turn depends on the conservation of the natural world and the responsible use of natural resources. The term sustainability has become widespread and can be applied to almost every aspect of life on earth, from the local to the global level and over different periods of time.

Fernández, López & Blanco (2018) verifies that efforts in innovation have a positive effect on reducing CO2 emissions. To this end, an econometric model has been estimated. The scope of this work includes the European Union (15), the United States and China between 1990 and 2013. The estimate is performed using a linear regression by ordinary least squares using as independent variables the expenditure on R&D and the energy consumption. The results of the model support the hypothesis that spending on research and development contributes positively to the reduction of CO2 emissions for developed countries. Regarding the regions, the corrective effect in the European Unión (15) compared to the figures in the United States is highlighted. In conclusion, this work shows that R&D spending can be recommended, not only as an engine of economic growth of any economy, but as a driver of sustainable development, where growth can be reconciled with lower CO2 emissions.

Khan, Nafees, Rahman& Saeed (2021) indicates that sustainable development has a key role in economic growth and improving environmental quality. By adopting the idea of sustainability, many countries of the world showed the successful results of the conservation of natural resources, by increasing life expectancy, controlling the growth of the human population, and increasing industrial and food production with an impressive economic output. Sound regulations, price mechanisms, taxes, and trading systems are important to integrate the economy to establish a sustainable production and consumption framework.

Compared with previous work, this paper concerns investigates the environmental reactions to R & D practices using data of 94 countries during the period from 2001 to 2019. This is why, findings could be generalized and shed lights on these causal relationships.

5. Measuring Variables and Developing Hypotheses

This paper addresses a main question about the environmental reactions to R & D practices: This has been applied on 94 countries during the period from 2001 to 2019. Therefore, this paper tries to address the following questions:

1- Is there a significant effect of “trademark applications” on "environmental sustainability"?

2- Is there a significant effect of “technicians in R&D” on "environmental sustainability"?

3- Is there a significant effect of “patent applications” on "environmental sustainability"?

Environmental reactions have been measured by four variables, which are “renewable internal freshwater resources” (RR), “electricity production from renewable sources” (EP), “access to electricity” (AE) and “alternative and nuclear energy” (AN). R & D practices are measured by three variables, which are “trademark applications” (TA), “technicians in R&D” (RD), and “patent applications” (PA).

Data are obtained from the World Bank database and research variables are calculated as follows:

Table 1. Research variables

Variables	Sign	Type
Trademark applications, direct nonresident	TA	Independent
Technicians in R&D (per million people)	RD	Independent
Patent applications, residents	PA	Independent
Renewable internal freshwater resources, total (billion cubic meters)	RR	Dependent
Electricity production from renewable sources, excluding hydroelectric (% of total)	EP	Dependent
Access to electricity (% of population)	AE	Dependent
Alternative and nuclear energy (% of total energy use)	AN	Dependent

This paper aims at testing the following three hypotheses:

1- There’s no significant effect of “trademark applications” on "environmental sustainability".

2- There’s no significant effect of “technicians in R&D” on "environmental sustainability".

3- There’s no significant effect of “patent applications” on "environmental sustainability".

Regarding the second hypothesis, we consider the alternative hypothesis H_0: β # 0 versus null hypothesis H_1: β = 0, where β is the regression coefficient of the following functions:

$$\mathbf{RR = \alpha + \beta_1 TA + \beta_2 RD + \beta_3 PA + \varepsilon} \quad (1)$$

$$\mathbf{EP = \alpha + \beta_1 TA + \beta_2 RD + \beta_3 PA + \varepsilon} \quad (2)$$

$$\mathbf{AE = \alpha + \beta_1 TA + \beta_2 RD + \beta_3 PA + \varepsilon} \quad (3)$$

$$\mathbf{AN = \alpha + \beta_1 TA + \beta_2 RD + \beta_3 PA + \varepsilon} \quad (4)$$

Correlation coefficients between independent variables range from -0.00516 to 0.27062 and this is why we test their effects considering that the problem of multicollinearity does not exist.

6. Descriptive and Diagnostic Statistics

Table 2 illustrates descriptive statistics of the research variables during the research period as follows:

Table 2. Descriptive statistics of research variables

Variables	TA	RD	PA	RR	EP	AE	AN
Mean	27665.56	610.6840	21115.22	1475.929	3.892899	10.59040	98.61238
Median	9180.000	441.5991	983.5000	55.10000	1.572386	7.557467	100.0000
Maximum	273275.0	2682.813	365204.0	13867.70	30.16500	46.45041	100.0000
Minimum	1380.000	10.78234	2.000000	0.600000	0.000000	0.024902	70.68874
Std. Dev.	48971.52	553.3755	58770.84	3261.207	5.814635	10.29449	4.212641
Skewness	2.766686	1.417131	4.149026	2.701146	2.665921	1.588394	-4.367585
Kurtosis	10.54570	4.459703	21.37393	9.709239	10.80495	5.688862	23.77869
Jarque-Bera	430.4830	49.97187	1998.422	364.8100	439.2837	85.16632	2497.947
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	118	118	118	118	118	118	118

Source: Outputs of data processing using EViews 10.

Regarding normality, table 2 shows that Jarque-Bera values indicate that all variables are normally distributed at p-value of 0.01 for most of the research variables. Table 3 indicates the correlation coefficients as follows:

Table 3. Correlation coefficients between research variables

	TA	RD	PA	RR	EP	AE	AN
TA	1.00000						
RD	-0.00516	1.00000					
PA	0.27062	0.08394	1.00000				
RR	0.83084	-0.04907	0.06225	1.00000			
EP	-0.01435	0.41183	-0.01498	-0.02772	1.00000		
AE	-0.01326	0.63653	0.09027	-0.04424	0.14030	1.00000	
AN	-0.04697	0.27321	0.10932	-0.10947	0.03802	0.21500	1.00000

Source: Outputs of data processing using EViews 10.

Regarding multicollinearity, table 3 indicates the correlation coefficients among independent variables range from -0.00516 to 0.27062, which indicates that multicollinearity problem does exist and this is why we will use these variables separately.

7. Testing Hypotheses

This part is about investigating the effects of each of "trademark applications" (TA), "technicians in R&D" (RD) and "patent applications" on each of "renewable internal freshwater resources" (RR), "electricity production from renewable sources" (EP), "access to electricity" (AE) and "alternative and nuclear energy" (AN). Table 4 illustrates the effects of R & D practices on Environmental sustainability using GMM technique, as follows:

Table 4. Effects of R & D practices on Environmental sustainability using GMM technique

Variable	AN	AE	EP	RR
C	71.78441 (102.2160)	0.970952 (0.551256)*	3.348766 (0.913944)***	93.90672 (1.791392)**
TA	0.054724 (0.002730)***			
RD		0.005653 (0.001127)***	0.011541 (0.001585)***	0.004695 (0.001472)***
PA				1.22E-05 (4.20E-06)***
R^2	0.855639	0.253757	0.419034	0.060861
D-W. Stat		0.058738	0.068616	0.005925
Obs.	328	692	664	787

Source: outputs of data processing using EViews 10.

Research hypotheses has been tested using panel regression analysis according to GMM technique. Using data of 94 countries during the period from 2001 to 2019, findings show that there are significant effect of “trademark applications” on “renewable internal freshwater resources” and of “technicians in R&D” on each of “electricity production from renewable sources” “access to electricity” and “alternative and nuclear energy”. Besides, “patent applications” seems to have significant effect on “alternative and nuclear energy”.

This indicates that we can accept the alternative hypothesis for the all research hypotheses, which means that there is a significant effect of each of “trademark applications”, “technicians in R&D” and “patent applications” on "environmental sustainability".

8. Concluding Remarks

This paper aims at investigating the effect of environmental protection and compliance on the R&D in intellectual capital creation. Environmental reactions are measured by “renewable internal freshwater resources”, “electricity production from renewable sources”, “access to electricity” and “alternative and nuclear energy”, while R & D practices are measured by “trademark applications”, “technicians in R&D” and “patent applications”.

Research hypotheses has been tested using panel regression analysis according to GMM technique. Using data of 94 countries during the period from 2001 to 2019, findings show that there are significant effect of “trademark applications” on “renewable internal freshwater resources” and of “technicians in R&D” on each of “electricity production from renewable sources” “access to electricity” and “alternative and nuclear energy”. Besides, “patent applications” seems to have significant effect on “alternative and nuclear energy”. Results have found that countries that have made environmental improvements are those who have invested in intellectual capital and made significant steps in improving their environmental R&D Capabilities.

The paper brings the followings remarks as conclusions:

1- Most of the environmental economic studies stress on financial tools, economic measures, and Environmental Economic Instruments (EEI) and on the cost of environmental deterioration, however, few concentrate on the impact of R&D and intellectual capital on environmental sustainability.

2- When it comes to environmental damage, a fundamental economic approach states that the polluter should pay (PPP). However, governments sometimes do not pay because they change permanently (Tullock, Brady, and Seldon, 2002; Buchanan and Tullock, 1962; Downs, 1957; Tullock, 1979) and do not make long term investment on environmental R&D and on intellectual capital because they will not get an immediate return.

3- Protection policies and measures reach 20% of the remediation cost. Traffic is responsible for around half of all child deaths in Spain, Denmark and Luxembourg. A UK report published by the transport ministry in 2003 claimed Britain had saved more than €320m in healthcare costs by introducing speed cameras at a cost of about €80m (Smith, 2006). However, business sticks with remediation as they consider that the remediation cost is paid only during exception product life cycle.

4- Environmental management and environmental protection relay on technical Environmental Management System (EMS), Cleaner Production (CP) methods and other environmental mechanisms. These technics require investments not only in technology, but also in intellectual capital (Tesfaye, Ayele, Gibril, Ferede, Limeneh, and Kong, 2022). Government should work on increase the share of environmental R&D and intellectual capital in the GDP to encourage business to build its own R&D capacity and Knowledge Management.

5- “Social Cost” should always be higher than “Compliance Cost”, if also added to “remediation cost” and “involuntary compliance”. Therefore, investing in R&D and intellectual capital within a compliance costs is much more rewarding for the environment and for the business (Dzwigol, Trushkina, Kvilinskyi, and Kvilinskyi, 2021). Besides, business corporate social responsibility should play a role to reduce negative pressure on the ecosystem and the environment (Hülsbeck, Hack, Gerken and Ernst, 2021).

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