The relationship between ESG, Environmental Performance, R&D investments and Lean Green Innovation in the Corporate Venture Capital world

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Abstract

This thesis examines the relationship between the ESG score, lean green innovation, environmental performance, defined by the emissions score, and the level of R&D investments, in the corporate venture capital world (CVC). Limited information is, indeed, available in the literature concerning lean green innovation. The study considers a sample of CVC companies analyzed in the time window going from 2002 to 2020, more precisely 68 firms from the U.S. Within the study, both direct relationships and joint effects are observed of ESG and R&D investments on lean green innovation and of the latter on the environmental performance. The outcomes give more insights into the importance of lean green innovation and the other factors in reducing greenhouse gas emissions (GHG). The research findings confirm that higher ESG and R&D levels lead to enhanced lean green innovation and that increasing lean green innovation brings better environmental performance and lower GHG emissions for CVC investors. These observations contribute to the recent literature because they give insights into lean green innovation and the importance of integrating ecological factors into corporate investment strategies to enhance the competitive advantage.

Keywords: ESG, Corporate Venture Capital, Lean Green Innovation, GHG emissions, R&D investments, Environmental Performance

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Resumo

Emissões de Gases com Efeito de Estufa Desempenho Ambiental Desempenho Financeiro Esta tese examina a relação entre a pontuação ESG, a inovação ecológica, o desempenho ambiental definido pela pontuação das emissões e o nível de investimentos em I&D no mundo do capital de risco empresarial (CVC). De facto, existe pouca informação disponível na literatura sobre a inovação ecológica. O estudo considera uma amostra de empresas de CVC analisadas no período de 2002 a 2020, mais precisamente 68 empresas dos EUA. No âmbito do estudo, são observadas relações diretas e efeitos conjuntos dos investimentos em ESG e I&D na inovação ecológica e desta última no desempenho ambiental. Os resultados fornecem mais informações sobre a importância da inovação ecológica e dos outros factores na redução das emissões de gases com efeito de estufa (GEE). Os resultados da investigação confirmam que um maior nível de ESG e de I&D conduz a uma maior inovação ecológica e que o aumento da inovação ecológica conduz a um melhor desempenho ambiental e a menores emissões de GEE para os investidores em CVC. Estas observações contribuem para a literatura recente, uma vez que fornecem informações sobre a inovação ecológica e sobre a importância de integrar factores ecológicos nas estratégias de investimento das empresas para aumentar a vantagem competitiva.

Palavras-chave: ESG, Capital de risco empresarial, Inovação Verde e Enxuta, Emissões de gases com efeito de estufa, Investimentos em I&D, Desempenho ambiental

Título: A relação entre ESG, desempenho ambiental, investimentos em I&D e Inovação Verde e Enxuta no mundo do Capital de risco empresarial

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1. INTRODUCTION

During the preceding decades, there has been little concern from the general public regarding the sustainability and environmental problems that the world has been facing. However, the worsening of precise factors and situations has recently increased awareness regarding these topics. As an example, political discussions have come to place nowadays regarding the disasters caused by climate change, a topic that was faced within the report that the IPCC (*Intergovernmental Panel on Climate Change*) issued in 2022 (*IPCC, 2022*). Governments and policymakers' intent is to circumscribe the negative outcomes of environmental misconduct by introducing specific regulations concerning sustainability. Nevertheless, some scandals involving even the governmental sphere (*Armstrong, 2020*) and the banking system with the financial crisis from 2008 (*Beloskar and Rao, 2023*), have worsened the crisis. Moreover, according to IPCC, the increasing quantity of GHG emissions will sooner or later cause the world to experience severe and irreversible consequences of the environmental impacts that individuals and businesses have on the natural systems around them. For instance, disruptive changes in weather, rising ocean and sea levels caused by the melting of enormous blocks of ice, together with more difficulties in the realization of agricultural activities and production, are a few of the natural disasters characterizing recent times.

It is for these reasons that researchers are battling to sensibilize the population, both individuals and businesses, in order to let them understand the importance of preserving the environment that surrounds everyone. As per O'Garra and Fouquet (2022), especially after COVID-19, people are beginning to pay attention to what consequences their decisions lead when talking about the environment; their study is aimed at understanding people's willingness to reduce travel consumption and their intention to transition to a more sustainable low – carbon pathway. Additionally, Sun et al. (2022) demonstrated as well how GHG emissions are on their way to being reduced, with this reduction being guided by an increasing share of clean sectors and technological advancements. Therefore, it can be confirmed that greenhouse gas emissions represent the main driver of the environmental issues hitting the globe nowadays and causing the catastrophic disasters of global warming, such as the drastic rising of temperatures (*Su and Ang, 2017*).

Undoubtedly, the effort to reduce the general impact that people's decisions could have on the environment must be defined not only by individuals or researchers; the whole corporate and business field, indeed, has to collaborate in order to positively impact the world. Moreover, firms and companies have the power to influence the decisions of individuals, therefore the former change should be coming from them.

As a consequence, Corporate Social Responsibility (*CSR*) should be not considered anymore as a sole obligation to morally respect, but it has become an established objective. It revolves around taking responsibility for social, economic, and environmental matters regarding the impact coming from their operations and business decisions. Recently, it also has encompassed the comprehensive framework of Environmental, Social, and Governance (*ESG*). They represent non–financial factors used to define the company's performance together with other financial characteristics. CSR has evolved during the history of businesses going from being a theoretical concept to being a real strategy used by firms to align their operations with values imposed by society and the general economy (*Carroll, 1979*).

This current study, indeed, aims to comprehensively explain the intricate connection between lean green innovation and ESG, R&D investments, and environmental performance linked to greenhouse gas emissions. In particular, the research wants to underline the effect that these factors have on firms' investment decisions. In fact, the urge to invest in innovation, and, more specifically into green innovation, represents, nowadays, a global need, in order to avoid the aforementioned natural consequences becoming completely irreversible, more than they already are right now.

Delving into the details of the study, focuses on Corporate Venture Capital investors (*CVC*), that define investment strategies realized by affirmed companies in private entrepreneurial ventures (*Wadhwa et al., 2016*). CVC investments are indeed often used as a means to gain technological expertise, and, consequently, enhance their environmental performance and decrease their level of greenhouse gases (*Battisti et al., 2022*). Therefore, it can be stated that the CVC world is connected with innovation because its focus is to increase technological innovations (*Da Gbadji et al., 2015*). Moreover, the foundations of the benefits of the corporate venture capital strategy are related to the original Resource – Based View (RBV) concept (*Wernerfelt, 1984; Barney, 1991*), which was initially based only on human and tangible resources, but later included also the environmental and social aspects that were previously mentioned (*Pereira and Bamel; 2021 Battisti et al., 2022*).

Besides being a good strategy, because it permits to enhance the grade of innovation and technological expertise, CVCs allow the enhancement of competitive advantage by facilitating access to social and environmental resources; furthermore, by combining the increased technological innovations together with the usage of social and responsible assets and resources, corporate venture capital strategies lead to higher financial results, as confirmed by the literature, such as per Wadhwa and Kotha (2006), Keil et al. (2008), Vrande et al. (2011), Benkraiem et al. (2023).

Given the relationship between CVC and innovation, and since the corporate venture capital investments strategy gives also access to environmental and social resources, the research specifically references the concept of green innovation. Green innovation defines a specific type of innovation whose main aim is to reduce environmental impact. It has become a fundamental aspect for those firms who want to pursue enhancements in their ESG and CSR factors (*Rennings and Rammer, 2011*). Furthermore, as per Horbach, (2008), green innovation is driven by the presence of environmental regulations, market demands, and the willingness of the companies to increase their competitiveness. Consequently, it enhances the competitive advantage of the firms that decide to pursue investments in green innovation.

Additionally, innovation, and green innovation as well, can be considered proxies for lean innovation and lean management concepts. In fact, lean innovation represents the relationship between product and process innovation and development with lean management core factors. In the literature, it is possible to find aligning studies from different researchers that confirm the positive correlation between innovation and lean management and lean innovation. For instance, as per Dües et al. (2013), it is possible to identify some synergies between the two aspects, such as overlapping of the same sustainable goals. Following the approach by Carney et al., (2019) and Zulfiqar et al., (2020), this current study wants to define the relationship between green lean innovation, explained by patents, the propensity to patents, and the conversion rate of R&D expenses into good patents, and non – financial corporate factors, such as ESG practices or the environmental performance, comprehensively indicated by the firms' commitment on reducing their GHG emission levels.

Another focus of the research regards the mediating role of expenditures in research and development, defined by the R&D investment variable, seen as the ratio between R&D expenses over revenues. In particular, as the literature has already demonstrated, investments in R&D positively impact innovation (*Pegkas et al., 2019*), while there are still conflicts when talking about green innovation. In fact, Luo and Zhang (2021) explain how R&D has an inverted N-shaped effect on green innovation, therefore it can reach even negative outcomes if it is badly managed. Therefore, the current research wants to deeply analyze research and development's relationship with innovation and, especially, with green innovation. However, the role of R&D within the study is also examined as an interaction term with lean green innovation, analyzing how the joint venture between these two factors impacts the company's environmental performance.

The research utilizes a dataset characterized by a total of 68 analyzed corporate venture capital investors, with a total of 911 investments going from 2002 to 2020. The contribution of this research in the literature regards the addressing and the confirmation of the relationship between lean innovation, and especially lean green innovation, with ESG and environmental performance, with an ulterior study regarding its correlation with R&D investment. Moreover, the Natural Resource – Based View (*NRBV*) concept, which introduces, within the already–explained RBV framework, the ESG and emissions factors, is considered in the model with relation to the corporate venture capital investments. The perspective within the CVC investment strategies is given by the parent company's point of view and wants to prove the effective role that CVC has when talking about technological enhancement and the improvement of environmental performance.

Further, the paper is structured as follows: Chapter 2 focuses on explaining the theoretical background needed to apprehensively understand the topic and what the existing literature has brought regarding the various discussions. Chapter 3 comprehensively defines the methodology that was used within the research, while Chapter 4 describes the statistics and the empirical outcomes of the regression models explained in Chapter 3. Chapter 5 wants to ulteriorly confirm the just–explained results by evaluating the robustness of the regression models. Chapter 6 comprehensively comments on the overall discussion and presents an overview of the limitations of the paper and the consequent possible future actions that could be undertaken to furtherly improve the outcomes. Eventually, the end of this thesis presents the appendix and the bibliography, which was consulted to provide the theoretical overview and to correctly analyze the results.

2. LITERATURE REVIEW

2.1 VENTURE CAPITAL: HOW DOES IT WORK?

This research focuses on investments that firms, that are involved in the Venture Capital field, realize toward innovation, especially in green innovation.

Delving more into the topic of venture capital, to better understand its impact on startups and innovation, it must be said that it aims to cover the gap between those early-stage businesses, typically financially sustained by the government, and corporations or other investors that intervene during a later stage and relate to lower - risk capital sources. (*Bob Zider, 1998*).

It has been expanding as a recent phenomenon, mainly in the United States because of the American culture known to be more risk taker, and thanks to a well–developed entrepreneurial ecosystem like Silicon Valley (*Kaplan and Lerner, 2016*). Nonetheless, venture capital is additionally influenced by other macroeconomics–related indicators, such as expected returns or alternative investments, or also the overall economic health. For example, considering the case in which the economy grows, there would be more appealing investment options and the demand curve for venture capitalists would, consequently, shift to the right. However, the level of interest rates could also represent an influential factor in the supply of venture capital investments: an increase in interest rates would bring to decreasing willingness of venture capitalists to invest in VC funds (*Gompers and Lerner, 2004*).

The Venture Capital fund is usually structured as a limited partnership where the general partner, representing the venture capitalist, invests a percentage of the fund, while the other investors, called the limited partners, invest the rest. Limited partnerships often last for a limited time, such as ten years for venture capital funds, with the possibility of expanding it up to three years. At the end of this time period, cash and securities on hand are expected to be given to those who invested during the life of the fund (*Voith, 1998*).

It is thanks to venture capital operations that the most successful businesses nowadays, such as Google, Amazon, Uber or Facebook, managed to become the economic forces that everyone knows. They indeed received financial support from venture capital funds and therefore were considered VC–backed companies. Through an econometric analysis, some research studies have also proved that, after controlling for some specific variables and factors, VC–backed firms present higher growth rates in comparison to those who are not (*Colombo and Grilli, 2010*).

2.2 DIFFERENT TYPES OF VENTURE CAPITAL

In the realm of venture capital, different types of investors can be distinguished. According to Bertoni et al. (2013), various factors should be taken into account when diversifying among venture capitalists, including investment targets, screening evaluation techniques, knowledge and expertise, governance frameworks, and goals. Out of all the differentiations, the most interesting one is between *Independent Venture Capital* (IVC) and *Corporate Venture Capital* (CVC) (*Bertoni et al., 2013*).

2.2.1 INDEPENDENT VENTURE CAPITAL (IVC)

Independent Venture Capital has had a great influence in the business field, and it also represented the subject of a lot of studies in the venture capital literature. IVC firms provide support and assistance in strategic management, and HR, it allows business owners to get in touch with potential investors and acquirers (*Sørensen, 2007*). IVC companies focus on investments in risky firms, able to scale the market, and with high expected growth rates; both capital funding and managerial services and strategic advice represent a provision of IVC (*Blum, 2015*). Independent Venture Capital funds are similar to limited liability partnerships (LLP). It usually happens that general partners, the GP, raise funds from limited partners, LP, and subsequently allocate the money to entrepreneurial ventures (*Alvarez-Garrido and Dushnitsky, 2016; Gorman and Sahlman, 1989; Gompers and Lerner, 2004*). However, IVCs tend to solely aim for financial return and act for a period of time of around ten years (*Gompers and Lerner, 1996*).

The two most common exit strategies for Independent Venture Capital firms are the Initial Public Offering (IPO) or the Acquisition (*Marc Okkerse, 2019*). Particularly, the former is mainly taken into consideration by IVC–backed startups with higher investments and higher expected value, while the latter is preferred by early-stage businesses with more uncertainty and with a greater probability of being acquired. (*Guo et al., 2015)*

As per Blum, 2015, it has been discovered that the proportion of successful exit strategies for IVCs is actually very limited. This is mainly due to some factors, such as: diseconomy of scale, quick exits instead of prolonged in time ones, dependency on fund inflows, inadequate connection between the services given by IVCs and the portfolio firm.

Therefore, the only way for IVCs to manage to receive greater exit rates is to stop providing funding during periods with already large quantities of capital inflows; moreover, they should lower their funding provisions to companies that have slight possibilities of accomplishing a successful exit (*Blum, 2015*)

2.2.2 CORPORATE VENTURE CAPITAL (CVC)

Corporate Venture Capital investments have been increasing in number and quality over the years, and, by the end of the last decade, they represented an important fraction of the comprehensive venture capital market (*Dushnitsky, 2008*). As an example, a recent study has proved that 60% of the American businesses have been funded by CVC investments, with a median size of 140 million dollars (*Jean et al., 2011*; *Guo et al., 2015).*

The first form of CVC appeared during the 1960s in the United States with the intention of entering into the market of the newly developed technologies (*Dushnitsky and Lenox, 2006*). As an example, General Electrics (GE) and 3M corporation (MMM) characterized some of the early adopters that focused on investing into start – ups to enhance innovation.

However, since the 1970s, operations from Corporate Venture Capital companies faced a sharp decrease, and the reasons why this happened were mainly linked to difficulties of introducing these newly developed technologies into large and already established businesses (*Chesbrough, 2002*).

It was only after the 1980s and especially during the decade from 1990s onwards that the CVC activities encountered a steady resurgence, thanks to technology evolving at a consistent pace (*Gompers and Lerner, 2000*). Moreover, internet was acquiring relevancy during the aforementioned time period, and this led to the arising of the *dot - com* firms and the consequent affirmation of the dot – com boom (*Dushnitsky and Lenox, 2006*). More specifically, this boom was the reason why the number of VC investments on startups into the technology field increased, especially those who had as their main focus the adoption of internet, such as e-commerce, online services and so forth (*Gompers and Lerner, 2001*).

The 2000s were characterized by a period of stagnation, with various restructurings of CVC investment techniques, subsequent to the dot – com explosion (*Chesbrough, 2002*); however, during the 2010s, the number of investments by CVC firms rose again in transactions and commission of capital (M*aula et al., 2003*). This occurred thanks to an action of diversification that the investors decided to pursue. In fact, the investments were not only related to technology, as it happened during the dot – com boom, but, instead, involved more fields, such as healthcare, fintech, clean energy and green innovations (*Hill and Birkinshaw, 2008*). Another development that led to the rise of CVC investments in the 2010s was the cooperation between investors and the affirmation of co – investments into early - stage businesses (*Wadhwa and Kotha, 2006*).

The rising of Corporate Venture Capital investments arrived at the modern times: CVC has become almost a vital function within the strategic management of corporates (*Wadhwa and Kotha, 2006*), technology is still evolving, and VC is focusing on what is new nowadays, such as Artificial Intelligence (*Hill and Birkinshaw, 2008*). Furthermore, ESG and sustainability topics are becoming more and more relevant, due to the challenges that the world is facing to this day such as global warming. For this reason, a lot of Corporate Venture Capital fundings are being directed towards innovations that are able to reduce corporates' impacts on the environment and on the natural living and non – living ecosystems (*Dushnitsky and Lenox, 2006*).

From what has been said about CVC investments, they therefore can be involved in a lot of fields, going from the technological one to health and safety or either the environmental one, and permit early – stage business to reach an equilibrium in their strategic management plannings (*Rossi et al., 2020*).

Through CVC investments, companies manage to get recent technologies and enhance their expertise (*Maula et al., 2013*). In fact, as per Battisti et al. (2022), these investments represent a source of knowledge and innovation for investors.

Diversely from independent venture capital, whose lifespan is on average of approximately ten years, corporate venture capital usually does not have a precise, specific and fixed lifespan, because it can be based on the company's priorities regarding its strategy or on the market conditions (*Dushnitsky and Lenox, 2006*).

Different exit strategies could be mentioned when talking about CVC (*Lemley and McCreary, 2021*, such as: initial public offering (*IPO*), acquisitions, company buyback, secondary sales, liquidation (*MacIntosh, 1998*).

Even though corporate venture capital seems to produce a better outcome than other forms of venture capital investments, there are also some challenges that CVC has to solve. Among them, a distinction between two sets of obstacles can be made (*Siegel et al., 1988*): the first concerns corporate management, while the other one is linked to the activities that the CVC itself does daily. Among the former, the absence of specific goals concerning venture activities or, additionally, not adequate financial commitment or even an undervaluation of the risk regarding the investments. In the second group, the absence of compatibility between corporate and entrepreneurial cultures, together with the incapacity to make independent decisions (*Siegel et al., 1988*)

2.2.3 DIFFERENCES BETWEEN IVC AND CVC

As per Alvarez-Garrido and Dushnitsky (2016), there are substantial differences between IVC and CVC. CVC is indeed an established corporate that defines a minority equity investment into external start – ups. On the other hand, IVCs are financial investors specialized in undertaking equity investment in these early – stage businesses, with the only aim of increasing the financial return coming from the aforementioned investments.

Independent venture capital firms invested into innovations that were experiencing important booms in a specific time period (*Chemmanur et al., 2014*), while corporate venture capital ones always aim at finding early – stage businesses with similar capacities and expertise of CVCs' own research laboratories. In this way, it would be a sort of collaboration between the corporate venture capital investors and the start – ups onto which they invest, with the objective of constantly creating never – talked - before concepts (*Lerner, 2012*).

Additionally, even the final aim of the two types of venture capital investors is different (*Alvarez-Garrido and Dushnitsky, 2016*). In fact, the fundamental goal of independent venture capital is to augment the financial return coming from the investments. They manage to satisfy this objective by investing into early – stage businesses with relevant potential; they act as a guide during their lifespan and provide them with the right funding, until they reach the time of the exit, usually realized through IPOs or acquisitions, as mentioned before in this research. Therefore, their only focus is the financial performance (*Gompers and Lerner, 1999*; *Colombo and Grilli, 2010*).

On the other hand, CVCs do not only care about the financial return; they strive also for the achievement of strategic advantages for the parent company, sometimes becoming even more important than the financial aspect. They want to enhance their expertise in new technologies and discover new potential targets to acquire and maximize the parent company's business (*Chemmanur et al., 2014; Maula et al., 2005*). The early–stage businesses onto which the investments are made usually have a lot in common with the CVC firms' strategic objectives. The latter want to introduce these newly developed technologies within their operations, but, sometimes, this process is a long one, therefore the investment horizon for corporate venture capital is wider than IVCs' (*Hill et al., 2009; Ivanov and Xie, 2010*).

Nonetheless, it can sometimes happen that a connection between corporate and independent venture capital arises in business terms, creating the Venture Capital Syndicate (VCS), where the two types of venture capital investors operate together intending to create additional value (*Wright and Lockett, 2003*). This permits the two parties to collaborate, sharing objectives and resources, and to create a mix of various investments within a portfolio, that would lower the overall risk (*De Clercq and Dimov, 2004; Ferrary, 2010*).

Moreover, as per Chemmanur et al. (2014), firms backed by corporate venture capital are more open to innovation than IVC–backed firms and this result is given by measuring both the quantity of patents and the citations, measure of the quality. In particular, according to this just–mentioned study, from the quantity point of view, CVC–backed firms produce approximately 27% more patents three years before the IPO concerning those who are IVC–backed, or 45% more patents after the initial public offering. Talking, instead, about the citations, those companies that are related to corporate venture capital receive around 18% citations more than those linked to independent venture capital before the IPO, and 13% more citations after the IPO. In both quantity and quality cases, CVC seems to be better at pursuing and developing innovation than IVC (*Chemmanur et al., 2014*).

2.3 CORPORATE VENTURE CAPITAL AND GREEN INNOVATION

It has been proved how CVC investments represent an optimal means to foster innovation within the portfolio firms onto which the former decide to invest. These innovations can regard various fields, and, among them, a relevant one concerns the sustainable innovation. As per Chesbrough (2002), the early – stage businesses are encouraged to integrate products and technologies within their processes and operations that could help enhance their sustainable, environmental and social goals. In fact, the environmental performance is highly increased for firms that are related to CVC activities (*Dushnitsky and Lenox, 2005*).

In the literature, much research delve into the topic of how corporate venture capital could be possibly related to sustainability, and, according to Döll et al. (2022), CVCs also manage to help creating ecosystems for both investors and start – ups. In fact, corporations' contribution is to offer services and support, both strategic and financial, to the early – stage businesses (*Kim et al., 2019*), while the latter contribute to the ecosystem by proposing innovative solutions that could enhance the former's sustainability desired results.

Moreover, it is important to notice how companies that invest into start – ups with great attention on sustainability can have a dual impact on their core business: environmental and financial improvements, leading to an increase in their competitive advantage (*Wadhwa and Kotha, 2006; Bertoni et al., 2011; Leten et al., 2016*). According to Lee and Kang (2015) the innovations, onto which CVCs invest, could, in this case, bring lower costs and operational efficiency, because of their abilities on reducing waste, but also to increased sales, thanks to the access into new and bigger markets (*Pahnke et al., 2015*). The investment diversification could additionally lower the risk and contain the probability of non – success; additionally, it could increase the clients' dedication to the business (*Haanaes et al., 2010*) and the probability of partnerships and syndicates with other VC investors (*Ceccagnoli et al., 2018*). The entirety of the benefits that was just mentioned could lead to the affirmation of sustainable start – ups in the market (*Lee et al., 2018*).

In order to increase competitive advantage by relying on sustainability, companies tend to invest into radical innovation (*Weber and Weber, 2007*) and obtain competitive advantage (*Keil, 2000*). They usually do this by concentrating on investments into green innovation.

Green innovation is about the realization of technologies and the provision of services, whose main focus is the diminution of environmental risk and the increase in sustainable impact (*Karimi Takalo et al., 2021*). It not only regards the reduction of the negative influence of some factors or decisions towards the environment, but it is also about creating new opportunities for the firms and gaining competitive advantage (*Rennings, 2000*). Consequently, it can be defined how green innovation is important for the effectiveness of the corporates' operations and activities, but also for compliance with environmental rules (*Chen et al., 2006*).

As already explained earlier in this research, CVCs invest into start – ups to gain also competitive advantage, especially if they present a relevant involvement in sustainability and if their activities do not have any negative social and/ or environmental impact. Consequently, as per Wernerfelt (1984), who explained the Resource – Based View concept (RBV), companies can be considered as a set of resources that defines the uniqueness of each firm. The variations between these characteristics permit to define the distinction of their performance overtime (*Barney, 1991*). These assets can be differentiated into various types such as tangible or not, linked to expertise or not, human capital and so on (*Priem and Butler, 2001; Pereira and Bamel, 2021*).

The problem with the Resource – Based view theory is that it does not take into consideration the fact that the market is subject to constant changes and does not give the right importance to innovations in technology and in the environment field. Due to the establishment of laws that require the integration of environmental factors within firms' businesses (*Porter and van der Linde, 1995; Porter, 1995; Wubben, 2000)*, the Natural Resource – Based View theory is introduced in the CVC world. As per Benkraiem et al. (2023), this theory defines the good influence that the good management of the firm's environmental impact could have on its performance, both environmental and financial. This would consequently affect even the competitive advantage (*Barney et al., 2011*). The NRBV can also be used as a way of responding to environmental uncertainty (*Cristina De Stefano et al., 2016*).

The Natural Resource–Based View theory seems to be optimal to explain the relationship between CVCs and their decision to invest in innovation, especially when talking about green innovation, that would enhance their competitive advantage. The literature also shows how syndicates between businesses could amplify green innovation outcomes (*Ma et al., 2019*).

2.3.1 LEAN AND GREEN INNOVATION

Innovation, especially green innovation, could be considered as a proxy for lean innovation within the corporate side of a firm. As per Schuh et al. (2011), lean innovation indicates the correlation between product and process innovation and development with lean management core factors. It is very much related to the value system that clarifies the values of every innovation project. These are specifically decided by the important shareholders in the innovation process and in line with the firm's strategic management planning and values. Some of these lean innovation values aim, for example, at reducing waste and, consequently, at reducing the impact that the company would have towards the environment, as explained by the *Lean Six Sigma* (LSS) methodology (*George, 2003*). In recent decades, LSS has been developing at a steady pace, becoming a basis for operations within various companies, because of its capacity to reduce costs, improve customer and employee satisfaction, maximize stakeholder value, and make operational processes quicker. Particularly, concerning the relation with employees, nowadays it has been evolving the necessity for employees to be innovative. Regarding the relation between lean innovation and employees, Tan et al. (2023) have investigated public–sector firms to study the impact of the combined effect between LSS and innovation training and, eventually, found out the important role of the senior management's transformational leadership. It indeed enables and enhances the positive effect that innovation training and LSS have on employee behavior.

Furthermore, as per Solaimani et al. (2019), firm innovativeness is comprehensively defined and enhanced by the Lean philosophy. It regards a company's "hard" and "soft" processes, and, particularly, it is linked to five explanatory factors related to the innovation management field. Among these principles, the following can be mentioned: coaching leadership, learning culture, employee appreciation, learning routines, and collaborative networks. Delving more into the specifics, the researchers have investigated the impact that these principles have on innovation by analyzing the behavior towards 243 Dutch firms. They eventually found out and demonstrated the positive and crucial influence that these aspects have on a firm's innovativeness, thanks to an interrelated socio-technical system where the hard and soft processes correctly act.

Within the framework of lean principles, the literature also aligns when talking about opportunities in New Product Development and in enhancing innovation. In fact, according to Marion and Friar, (2012), lean innovation is improved when companies, more specifically small ones and start-ups, are able to commercialize new products in a rapid and efficient way through the technique of outsourcing. For instance, among the possible strategies, the following can be mentioned: robust strategic collaborations with external agents, exploiting quick prototyping resources while supporting R&D, testing goods and markets priorly to producing enormous quantities, helped by short-run producers. These researchers, therefore, eventually proved how external outsourcing, especially when talking about small and newly–formed businesses, permits them to remain agile by enhancing innovation with new products in the markets, while also decreasing the amount of costs that these companies are meant to sustain.

Always talking about resources related to lean innovation, Bicen and Johnson, (2014) have explored how start-ups manage to pursue innovation while existing in a turbulent market and in an environment characterized by limited resources. They explain the presence of four attitudinal factors that function as catalysts for the enhancement of innovation when there are few resources available to develop new products. These four factors are: intention, inspiration, integration, and indefatigability. Bicen and Johnson eventually demonstrate how limited resources, combined with the presence of these attitudinal factors, manage to enhance the innovation performance. Moreover, these four aspects define the basis for the so-called *Lean Innovation Capability* (LIC). Lean Innovation Capability is furtherly defined by Bicen and Johnson, (2015). They analyze comparative case studies for ten start-up companies operating within difficult markets. What is found is that there are two contextual factors that influence the value of the resources: the market type and the business model. Delving into the specifics, it can be said that companies that see the limited presence of resources as an issue that inhibits the development of innovation, actually have more difficulties, rather than those that consider these limitations as an enabler, that instead own a distinct capability. This distinct capability is what was previously defined as LIC, described as a characteristic able to explain the company's willingness and potential to assess various ideas meeting fundamental customer needs. The firm would subsequently validate the learning through constant feedback given by the market. Therefore, it can be said that lean innovation helps improve radical innovation by letting companies with few resources maximize them, based on the core necessities of the customers. Even Johnson et al., (2023) delved into the Lean Innovation Capability argument, trying to confirm the LIC concept as a distinct characteristic that permits to differentiate between lean and non-lean innovators. They align with what Bicen and Johnson had found previously. Johnson et al. indeed demonstrated that firms with higher levels of Lean

Innovation Capability managed to develop innovations with fewer resources in *munificent* environments[1], confirming the relevance of Lean Innovation Capability in leading to successful innovation. Moreover, they define LIC as a four-dimension concept that includes factors such as product-market fit, mission-oriented leadership, and network learning capabilities. The fourth aspect would be experimentation culture, although it is not empirically tested by Johnson et al. because it was considered as less relevant than the other three. The combined effect between these factors defining LIC helps the improvement of innovation under limited resources.

Going back to lean green innovation, through Lean Six Sigma, lean manufacturing, and innovation can be considered connected to sustainable activities (*Dornfeld and Linke, 2012*). The literature has studied how lean practices could be associated with green initiatives and innovation with the final aim of enhancing the environmental result of the firm (*Sarkis et al., 2011*). As an example of this consideration, Faulin et al. (2019) studied how, within the logistics and transportation world, lean techniques can support sustainability achievements with the help of green innovation.

As per Dües et al. (2013), it is possible to identify some synergies between green innovation and lean innovation that could support the supposition of this paper of considering innovation, and, more specifically, green innovation, as a proxy for lean innovation. First of all, lean innovation is considered one of the most important and useful means for green innovation to reach its goals; on the other hand, green practices reduce waste and try to diminish resource consumption, fundamental factors for lean management. Moreover, always from the studies conducted by Dües et al. in 2013, lean companies, that manage to integrate green innovation practices within their business, get to better final situations than those who do not implement them, therefore producing a phenomenon of synergy.

Furthermore, as per Li (2011), using green innovation as a proxy for lean can be explained by making a reference to the four paradigms of LARG, meaning Lean, Agile, Resilience, and Green (*Carvalho & Cruz – Machado, 2009*). The first represents the efficiency improvement and the reduction of waste; the second wants to improve flexibility to the market being dynamic; the third

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[1] https://www.sciencedirect.com/topics/social-sciences/munificence *Munificence: relates to situations in which the resources available to a set of companies are few or even absent, affecting their potential to adapt their operations*

one refers to how the supply chain tries to resist any form of difficulty; the last one wants to diminish the impact towards the environment.

Eventually, there can be found a lot of studies in the literature proving, through empirical findings, the correlation between lean and green, and that could support the idea onto which this research relies, about green innovation representing a proxy for lean innovation. As an illustration of this, King and Lenox (2001) and Bhattacharya et al. (2019) are two of the many that confirm the synergy between the two aspects, stressing the common goals and the complementarity in practices; moreover, the two forms of innovations are guided by the same innovative nature of the companies.

This current study wants to investigate more deeply the relation between lean innovation and the factors that could have an impact on it. Particularly, having previously explained how lean innovation is strictly connected with sustainability and with the corporate actions aimed at reducing a company's impact towards the environment, e.g. reducing GHG emissions, the corporate scores regarding ESG, and emissions are taken into consideration in relation to lean green innovation.

2.4 RELATIONSHIP BETWEEN ESG AND LEAN GREEN INNOVATION

Firms nowadays are more and more sensitized in increasing their involvement in environmental and social factors (*Pekovic and Vogt, 2021*) and it is required from them to act in compliance with these aspects (*Chan, 2005*). This does not revolve only around the laws that these companies are expected to follow, but also regarding the actions that shareholders want them to pursue (*Chen et al., 2015*).

Particularly, the introduction of Environmental, Social, and Governance (ESG) practices into the firms' business planning has become important. A lot of studies in the literature have shown the relevance of ESG activities within corporate strategies, saying that those who integrate ESG have also stronger innovations (*Friede et al., 2015*). Moreover, the literature has also found a non - indifferent correlation between sustainability activities and financial performance (*Whelan et al.*); as per Clark et al. (2015), 88% of the analyzed studies confirmed the companies' performance with robust sustainability activities to be better than others that do not implement them. In addition, as per Reber et al. (2022), if a firm owns an important ESG score, this will be considered as a signal of transparency and honesty of the firm itself. This would consequently result in an alleviation of shareholders' apprehensions (*Guerrero-Villegas et al., 2018*), and into a decrease of the overall costs (*Friede et al., 2015*).

Nevertheless, there are some aspects to take into consideration when studying the impact of ESG on innovation. Specifically, with high values of ESG score, a relevant risk comes together with them (*Solow, 1957; Holmstrom, 1989; Maslach, 2016*), especially when talking about failure in the innovation process (*Li and Li, 2024*). Therefore, from one side of the story, ESG could increase risk – tolerance thanks to higher levels of transparency and engagement (*Dunbar et al., 2019*), but, as per He et al. (2023), after their study in China, ESG could also affect negatively the corporate risk-taking, especially in weaker corporate governance with less information transparency.

The literature has deeply studied the relationship between ESG and innovation quality and found a positive impact that a high ESG score could have on innovation. (*Li and Li, 2024; Cabaleiro-Cerviño and Mendi, 2024*). However, this has been studied for specific markets and observed for a small time window. For example, Xu et al. (2020) concentrated their studies on 223 Chinese firms from 2015 to 2018. They wanted to prove how ESG performance could lead to better green innovation quality. The researchers also proved how ESG performance leads to a more elevated patent value within a company. However, Xu et al. (2020) were only focusing on Chinese firms and on a more restricted time window. Therefore, there is a gap and this needs to be studied and tested in more countries. This is the reason why, in this current study, one of the goals is to understand the impact of ESG score on innovation, taking into consideration a different geographical sample of companies, considered from the U.S., and a wider time window, being from 2002 to 2020. Moreover, the current research wants to focus on a particular side of innovation, that is lean green innovation, not comprehensively explained by the literature.

Hypothesis 1: CVC firms' ESG score positively affects their lean green innovation

Moreover, the ESG score could furtherly be classified into the three single pillars that explain the ESG rating of the investor. These three pillars, being Environmental, Social, and Governance, are deeply analyzed in the current research with the intention of understanding whether they have a positive connection to lean green innovation and how they impact it.

Hypothesis 1.1: The three ESG pillars, namely Environmental, Social, and Governance, positively affect lean green innovation.

2.5 ENVIRONMENTAL PERFORMANCE, INNOVATION AND LEAN GREEN INNOVATION

Concerning greenhouse gas emissions, a lot of countries, all over the world, have enacted different laws about this topic, because of the pressure that it has on it. Many researchers have studied the impact that emissions could have on companies' value. In particular, Aggarwal and Dow (2011) have demonstrated the negative influence that GHG emissions have on a firm's corporate performance, especially if the level of these emissions is unchecked. The bad correlation is further aggravated in case the managers of the aforementioned companies decide not to disclose information about their emissions. In fact, Matsumura et al. (2014) examined the influence of GHG emissions on firm value by analyzing emissions for companies on the *Carbon Disclosure Project (CDP)* from 2006 to 2008. The Carbon Disclosure Project is a not–for–profit charity established in 2000, whose main aim is to manage investors and companies' environmental impacts [2]. Going back to Matsumura et al. (2014), they found that the value of the companies that decided to disclose the information about GHG emissions was approximately $2.3 billion greater than the one owned by the non-disclosing. Consequently, not only do firms tend to disclose data about emissions, but they also want the world to know about their activities.

Companies' decision to demonstrate their choice of reducing GHG emissions does not uniquely help them achieve a higher firm value. There is indeed a relationship between emissions and financial return. This connection is explained by Boiral et al. (2012), who were not very sure about the common view that sees a positive connection between environmental and financial performance. Nonetheless, they discover a win-win relation between the commitment to reduce GHG and economic performance, gaining a competitive advantage thanks to this commitment (*Stubbs and Cocklin, 2008*). Moreover, another side of the literature discovers how the financial performance is maximized nor when the level of emission is too high nor too low, but whenever it reaches an average level (*Misani and Pogutz, 2015*).

Regarding the topic of innovation and its relationship with the level of GHG emissions, the literature has been craving to solve the dilemma of whether higher levels of innovation could lead to the reduction of emissions. Particularly, Jordaan et al. (2017) demonstrated how some specific

[2] https://www.cdp.net

investments were successful in reducing greenhouse gas emissions, such as renewable portfolio standards. The problem was that no data was ready to be given to investors for them to exploit these opportunities; consequently, clear communication and an alignment between regional policies and federal commitments had to be defined. Long et al. (2017), instead, proved that innovation in product processes managed to have a positive influence on the environmental performance of firms in Korea. These papers, though, were published in 2017 and had a specific geographical focus, therefore probable research could fill the geographical and temporal gap, trying to extend these results. Moreover, this regards only generic aspects of innovation, but, given that this paper is focused on lean green innovation, it could contribute to the literature by giving more insights related to green innovations.

Indeed, delving more into the green innovation realm, few papers in the literature have specified the relationship between the firms' green innovation investments and their commitment to reduce emissions. In particular, past papers have demonstrated the positive effects of the integration of practices that are ecological and sustainable within the operational businesses of the firm on the company's performance (*Oliva et al., 2018*), both financial (*Sánchez-Infante Hernández et al., 2020*) and organizational performance(*Long et al., 2020; Orazalin, 2020*). Nevertheless, there was less research concentrating on the influence of innovation processes and practices, especially lean green innovation, on environmental performance. Some studies were about CSR and innovation, such as Zhou et al.,(2019), while others studied the concept of environmental strategy. For instance, Hart, (1995) considered environmental strategy as a variable able to explain the environmental performance. In fact, those companies able to integrate sustainable strategies within their businesses, manage to enhance their environmental performance as well (*Solovida and Latan, 2017*).

In this paper, lean green innovation is linked to environmental strategy; hence, the aim of lean green innovation is to improve environmental performance. Therefore, this paper wants to prove that lean green innovation should be considered not only as something to be respected in order to align with the stakeholders' willingness. This current research wants also to demonstrate the capacity of lean green innovation to improve the competitive advantage of every investor, not only due to the improvement of firms' financial performance but, additionally, to demonstrate that investing in sustainable product processes and innovations could lead to a better environmental performance and to an effective reduction of the greenhouse gas emissions.

Hypothesis 2: Lean green innovation has a positive impact on environmental performance measured by Emissions score

2.6 RESEARCH AND DEVELOPMENT AND LEAN GREEN INNOVATION

The original definition of R&D goes back to 1963 when the OECD *Frascati Manual* was published for the first time. Later, in 1993, there was an enhancement that brought to define Research and Development as a work with the aim of enhancing knowledge and with the scope of using this knowledge as a means to create new products and to develop innovation[3]. Even though Djellal et al. (2003) talk about the underestimation of R&D in businesses' activities nowadays and do not manage to explain the modest attention that companies reserve to it, William Baumol (2002) stresses the importance of R&D activities, proving its relevance on strategic planning. Even Gault (1998) states that research and development activities are, most of the time, underestimated or directly unrecognized. Regarding this situation, according to Djellal et al. (2003), the reason why this happens with R&D is because of its lack of ability to explain some of the particularities of the creation of new expertise in services. In other words, the definition provided by OECD does not give R&D the correct weight that it should receive, and this specifically reduces the potential of these activities in creating new knowledge (*Djellal et al., 2003*).

According to Archibugi and Planta (1996) and to the OECD definition of R&D, R&D evolves into three main phases: the first one regards a more fundamental aspect of R&D, where overall expertise is gained with no precise aim in thought. Secondly, there is applied research, whose focus is to apply this research to something more specific. Thirdly, the experimental development to develop practical innovations.

Recent literature has proved how investments in research and development activities are effectively impactful towards firms' performance. Particularly, a lot of studies have demonstrated a positive relationship between research and development and financial performance (*Ayaydın and Karaaslan, 2014*).

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[3] https://www.oecd-ilibrary.org/

Another research instead shows how the capitalization of R&D does not always help the financial performance. In fact, these expenses, according to the IAS 38 standard, could be considered expenses or assets; the effect that this could have on financial performance is practically impossible to predict because these expenditures tend to increase the information asymmetry between shareholders and managers (*Lantz and Sahut, 2005*). Consequently, Lantz and Sahut (2005) suggest that research and development could be positive towards financial performance only if these investments are immediately exploited or adopted within the strategic planning. In this way, the benefits coming from these investments would flourish. Moreover, according to the studies conducted by Bigliardi (2013), if the companies analyzed are *Small* and *Medium Enterprises* (SMEs), then the number of investments made into R&D and, more specifically, towards technology, do not affect the financial performance.

Although the heterogeneity in the findings regarding R&D and financial performance, the literature seems to agree more regarding the relationship with innovation itself. A study conducted on European Union countries (*Pegkas et al., 2019*) between 1995 and 2014 not only shows a positive and significant correlation between the two variables, but also a relation of "co – integration". This means that, in this case, these EU countries should develop the collaboration between research and development, and innovation. Additionally, these findings are furtherly supported by more studies realized in other countries of the world. As an example, Lee and Park (2006) analyzed Korean companies in the electronic and mechanical industries and found out that R&D, together with financial support from the government, enhances the probability of innovation success.

R&D indeed represents a fundamental part of the development of innovation, because, as per Soete and Freeman (1997), it is at the basis of creating new technologies and enhancing the already existing ones. It is important to create a competitive advantage and to define financial growth for the company, thanks to technological enhancement and fostering of productivity (*Griliches, 2007*). A lot of industries have received a lot of gratifications from the integration of R&D within their business planning, with the aim of developing innovation. For instance, in the pharmaceutical sector, drugs and medicines were discovered thanks to this cooperation between R&D and innovation (*DiMasi et al., 2003*); also, in the automotive industry, with the affirmation of electric cars or autonomous driving technologies, where research and development helped defining new and evolved business models, more suitable to the transforming aforementioned industry (*Kley et al., 2011*).

R&D is particularly important when treating sustainable innovation, whose aim is to reduce waste, diminish the impact on nature, to face difficulties such as climate change or environmental degradation. The problem is that, during the last century, R&D's role was still underestimated, as previously explained. This is why Sarpong et al. (2023) have proposed three aspects of R&D to consider when trying to achieve sustainable innovation: *investment, talent,* and *learning institutions.* These three factors coming together have the power to guide a sustainable – innovation growth within businesses. Furthermore, if the analyzed companies have a high ESG score, this could have a good consequence on the R&D personnel, because employees would be satisfied to work in such an uplifting environment, increasing their dedication to the R&D process. This would subsequently add more value to successful innovations (*Li and Li, 2024*).

Talking about green innovation, a study conducted by Luo and Zhang (2021) explains how research and development has an inverted N – shaped effect on green innovation. This means that, during the first period of investments into R&D, there is a limited influence on green innovation efficiency. After a certain threshold is overcome, the limited impact actually transforms, becoming positive and significant. However, the positive impact changes, turning negative, after another threshold is surpassed, because it would indicate probable waste of resources. These various thresholds are not random, but instead related to different factors within the business. As an illustration, they refer to technological process, fundamental for green innovation efficiency, therefore regions with higher enhancements in technology show better efficiency numbers for green innovation. Consequently, even the level of education positively affects green innovation, because it permits to reach a more solid development of technologies. The economic level sometimes has a negative influence because of the possible consumption of resources that it may create. While these factors all result significant in Luo and Zhang's study, regulations about environmental topics seem to not have any significant influence.

Other studies in the literature give, instead, a more robust consideration of the relationship between green innovation and R&D investments. As per Xu et al. (2020), research and development affect positively green innovation. In particular, since green innovation performance is measured by the quantity of green patents, green invention patents and green non-invention patents, a positive relation between the two variables permits to affirm that more R&D investments bring to higher number of green patents. This can help managers' decisions to invest in more ecological and sustainable business planning.

This current research would contribute to the existing literature by providing more insights into the relationship between R&D and lean green innovation, possibly confirming what Xu et al. (2020) discovered with their study on the Chinese listed firms. In fact, the current data sample consists of U.S. firms that realized at least an investment in green innovation between 2002 and 2020. Moreover, R&D investments would be represented by the ratio between the R&D expenditures themselves over the total revenues of the corresponding company. It is thought to be a more appropriate variable to consider because it evaluates R&D expenses in relation to what the analyzed company produces as revenues.

Hypothesis 3: R&D investments have a positive influence on lean green innovation

2.7 ROLE OF R&D BETWEEN GREEN INNOVATION AND ENVIRONMENTAL PERFORMANCE

Xu et al. (2020) also investigate ESG and, besides confirming what was already said previously about its positive relationship with innovation and green innovation, they give some insights into the mediating role of ESG between R&D investments and green innovation. Specifically, they discover that a high value of ESG score amplifies the positive impact that investments into research and development have on green innovation. This furtherly means that the R&D investments are better leveraged by the ESG performance on achieving green innovation outputs. It is indeed important to integrate ESG and R&D, both singularly and through an interaction term, according to Xu et al. (2020).

A recent study from Zhu (2022) wanted to understand if there was any correlation between innovation, carbon emissions, and industrial structure development. They found out that the latter has both a direct influence on GHG emission reduction but also the role of a mediator between innovation and environmental performance, specifically on the activity of technological innovation in decreasing the level of greenhouse gas emissions. Consequently, their advice is to promote the development and rationalization of industrial structure, and, also, to promote tech innovation and integrate innovation development strategy.

Following the studies from Xu et al. in 2020 and Zhu in 2022 and the approach they followed regarding the joint venture between two independent variables on the dependent variable, the last hypothesis that this research wants to demonstrate regards an interaction term between two of the previously – explained factors. In fact, the literature has still yet to demonstrate if the level of R&D investments of a company has or not the ability to amplify the positive effect that lean green innovation has on environmental performance. As an illustration of this idea, bringing back the OECD definition of R&D, defined as the willingness to create new knowledge and new innovation, the study wants to understand whether more investments and efforts into creating new expertise could amplify the positive effect that the lean green innovation has on environmental performance.

Hypothesis 4: R&D investment is mediating between lean green innovation and environmental performance.

2.8 HYPOTHESES DEVELOPMENT

The scope of the research is to verify the relationship between ESG, environmental performance, lean green innovation, and R&D investments within the CVC context. Particularly, as an explanation of the four different hypotheses tested in this paper:

H1: A corporate venture capital company owns a definite ESG score. The first hypothesis focuses on the relationship between ESG and lean green innovation performance because it wants to shed light on the environmental behavior of each observed CVC investor. In fact, on the basis of the research, there is the question of whether a high ESG score could enhance lean green innovation, or if the growth of the latter is more impressive in firms with weaker ESG scores that aim to improve their green performance. Moreover, Long et al., (2023) found that in non-high-income countries, higher green innovation capability is linked to higher ESG performance; therefore, this hypothesis wants to fill the gap and understand if in high-income countries, such as the United States, a positive relationship between ESG and green innovation still exists or not.

H2: This hypothesis wants to study the relationship between the Refinitiv Emissions score and the lean green innovation. In particular, it wants to study if the investments into lean green innovation defined by the CVC investors lead to higher environmental performance, meaning lower greenhouse gas emissions. In fact, considering lean green innovation as explained by green patents, as per Carney 2019 or Zulfiqar 2020, the hypothesis wants to demonstrate whether higher numbers and better quality of patents could lead to the enhancement of environmental performance practices.

H3: A firm can decide whether to invest in sustainable practices or in research and development activities that could help enhance green innovation performance. This hypothesis and findings are preparatory for the following one, but also want to align with what the literature has demonstrated. Xu et al. (2020), for example, demonstrated the positive relationship between innovation and R&D in the Chinese market from 2015 to 2018. This current study aims to fill the geographical and temporal gap, understanding whether these findings could be extended in space and time.

H4: The last hypothesis wants to study the interaction term between lean green innovation and R&D investments towards the environmental performance in the CVC context. It is a newly – matured idea that does not yet find alignments in the literature and that wants to prove whether the investments into R&D actually strengthen the effect that an investor's lean green innovation has on its environmental performance. In particular, considering R&D as a moderating variable, this study wants to lead to a more accurate and context-sensitive interpretation of data.

3. METHODOLOGY

3.1 DATA SELECTION

The research approach used in the project focused on Corporate Venture Capital (CVC) firms from the United States. The reason behind choosing US data relies on the fact that a considerable part of the literature focused on studies that targeted other markets, for example, the Chinese one or the Malaysian one. Consequently, since this project wanted also to check if the precedent research could be expanded also for other parts of the world, this path was eventually followed.

Furthermore, from a temporal perspective, the annual range from 2002 to 2020 was selected as the main time window within which the various information was examined.

The initial data regarding the US companies analyzed within the study were thoroughly retrieved from *Thomson VentureXpert.* Thomson Reuters' database information comes from various resources that permit the high reliability of the aforementioned. For example, primary data could be extracted from company reports or also from government sources or other public documents and legislations.

As previously explained, the above-mentioned firms have participated in one or more Corporate Venture Capital investment programs. Moreover, going into a more profound explanation of the dataset, for every single CVC company, data about their investments into green patents were obtained from the *European Patent Office* (*EPO*)'s *PATSTAT* database. The EPO examines patent applications and citations referencing to the *European Patent Convention* that ensures all the legal requirements behind the patents themselves. Within PATSTAT, it is possible to find data concerning bibliographical and legal events that are related to industrialized and developed countries. The patents are considered as a proxy to denote the investments into green innovation. From the same database, additionally, the year, during which these investments were realized, was retrieved, having some companies that invested every year from 2002 to 2020, while others that made fewer investments due to various factors, such as being born more recently than others or having less economic availability to invest into new patents, and so forth.

Moving forward, to retrieve data regarding the scores that each CVC company has had during the considered time window, Refinitiv Eikon was used. Specifically, this database provided information regarding the *ESG score* of each firm, which, according to the definition made available by Refinitiv Eikon itself, represents the overall company score derived from the self-reported data across the environmental, social, and corporate governance pillars[4].

Moreover, other non-financial performance metrics were gathered from Refinitiv Eikon, such as *Emissions Score,* which indicates the firm's dedication and capability towards reducing environmental emission in the production and operational processes, consequently representing the environmental performance; *Industry* represents the industry in which the company tends to mainly operate.

Concerning the financial performance data, these were collected using *WRDS* (*Wharton Research Data Services*), a research platform that makes available datasets related to various fields such as financial or economic ones. In particular, one of the datasets used in this project is *Compustat*, which mainly provides accounting data regarding the analyzed firms, such as the number of total assets, long-term debt, revenues, and so on. Moreover, it provides detailed income statements, balance sheets, cash flow statements, and other financial metrics.

In order to obtain the final dataset, that would be used to test the empirical models and the statistical regressions, the various databases retrieved from *Thomson VentureXpert, Refinitiv Eikon, Compustat (WRDS),* and *EPO's PATSTAT* were blended by matching the tickers and the year in which the investments into the patents were made. Subsequently, after the merge of the databases, a total of 70 firms and 1345 observations resulted. Nevertheless, this dataset was further shrunk through a data-cleaning process. Some observations, indeed, ended up being dropped eventually either because some of them were missing, mainly because of some data not present, or because they were outliers that brought some anomalies to the study. This decision was made in order to minimize the impact of incorrect or biased parameters on the research, which resulted in being more robust than it was before the data filtering. Eventually, the current final dataset consists of 68 firms and 911 observations.

3.2 DEPENDENT VARIABLES

Since the aim of this study is to try to understand how variables such as the ESG score could impact the decision of the CVC firms to invest in innovation, especially lean innovation, the current

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[4] *https://eikon.refinitiv.com*

research follows the methodology proposed by Carney et al., (2019) and later also by Zulfiqar et al., (2020) and Zulfiqar et al. (2020) (2). Particularly, in order to analyze the relationship between ESG, RD, emissions score, and lean innovation, the latter is considered as the dependent variable. More specifically, lean green innovation is comprehensively explained by patent application and by the patents' quality defined through citations, but, also, by R&D investments. In fact, Carney et al., (2019), following the approach by Bannò, (2016), classified lean green innovation into patent quality and quantity and also studied the ratio of patent applications to expenses in research and development, defining the propensity to patent, and the ratio between patent citations over the same expenditures, defining the conversion rate of R&D investments into successful patents. Going into more detail concerning this choice, this research adopts four dependent variables, each one of them representing the investment in innovation that the firms realized in that considered year. According to the literature, patents could indeed be used to measure the investor's innovation because they embody knowledge creation (*Wadhwa et al., 2016*) and represent a proxy for innovation output (*Bendig et al., 2022; Dushnitsky and Lenox, 2006).* Going back to the explanation of the dependent variables, these are: *CountG* and *CitationG*, respectively indicating the quantity and quality of green patents, and *Conversion* and *Propensity*, respectively representing the conversion rate and the propensity to new patents.

The difference stressed between *Count* and *Citation* relies on the fact that the first variable measures the quantity of patents on which the firm decides to invest, while the second variable defines the quality of these patents, meaning that the more citations these patents receive by other applications, the higher the quality of the above – mentioned. This aligns with what the literature has said about it (*Chemmanur et al., 2014*; *Cohen et al., 2020; Zhang and Chen, 2023).*

As already explained, count and citations manage to describe a company's capability for green and sustainable practices. There is a problem, though, linked to the *citation* variable. There is the necessity to adjust the latter because of a truncation bias to which the variable is subject. In fact, in 1995 a law was filed in the United States concerning the term of a patent, that began to be 20 years from the filing date of the application. [5] Therefore, there is a significant bias against the more recent patents in the data. Following Hall et al. (2000) and Hall et al. (2001), the citation truncation

[5] https://www.justia.com

bias is corrected by estimating the shape of the citation-lag distribution (*Benkraiem et al., 2023*). The consequent bias involving more recent patents is solved by determining the pattern of the citation-lag distribution, as suggested by Hall et al., (2000). In order to manage more effectively the empirical properties of the variables effectively, their natural logarithm is introduced. Moreover, some of the CVC firms, that are the object of the study, have not invested in any patents during specific periods; therefore, with the intention of preventing the loss of these observations with zero patents or zero citations per patent, the value of one is added to the number of patent and citation counts before applying the natural logarithm (*Chemmanur et al., 2014)*. Thus, *ln(1 + Count)* is referred to as *Count*, and *ln(1 + Citations)* is referred to as *Citations*. Respectively, the variables utilized within the regression models are: *logCouG, logCitG.*

Furtherly, the *emissions score* explaining environmental performance is retrieved from Refinitiv. It indicates the commitment of the investor company to reduce its impact towards the environment, specifically talking about the reduction of greenhouse gas emissions. This variable was comprehensively chosen because one of the aims of the current research is to understand the behavior of the CVC investor that wants to contribute to preserving the natural systems that revolve around each individual. The variable explains how much the company is committed to reduce its GHG emissions. The values of this variable range from 0, indicating the lowest commitment of a firm that apparently does not care about the environmental impact that its decisions have, to 100, meaning that the investor considers this argument as fundamental. In the study, the variable is called *EnvironmPerf* and it is given by the emissions score divided by the value of one hundred, in order to have better empirical outcomes.

3.3 INDEPENDENT VARIABLES

The analysis wants to coordinate with the latest literature by understanding the impact of ESG score (*Mukhtar et al., 2023*) and of the amount of R&D investments in lean green innovation and how the latter influences environmental performance. Therefore, the first independent variable is explained by the ESG score. ESG score, in Refinitiv, is disaggregated into the following pillars, that comprehensively explain what *ESG* actually stands for:

- *Environmental Pillar Score:* it measures the company's impact on the environment, including air, land, water, and complete ecosystems. In particular, it studies how the firm manages to generate long term shareholder value and capitalize on environmental opportunities without affecting the living and non-living natural systems, minimizing the environmental risk. [6]
- *Social Pillar Score:* it analyzes the company's ability to create trust and loyalty towards its workforce, customers, and society. It does this by employing best management practices. It also encompasses the reputation and health of its license to operate. These are fundamental factors when trying to produce long term shareholder value.[7]
- *Governance Pillar Score:* it represents the company's processes and systems and guarantees that the long-term shareholders' interests are aligned with the board members' and executives' ones. Shareholders' value is created thanks to incentives, checks and balances, and best management practices, that aim to supervise rights and responsibilities.[8]

Regarding H2, *lean green innovation* becomes the independent variable, aiming to explain how it impacts environmental performance. The lean green innovation variable is defined following the previously explained approach by Carney et al., (2019), Zulfiqar et al., (2020) and Zulfiqar et al. (2020) (2).

Concerning H3, another independent variable is introduced: *R&D investment (RD)*, given by the ratio between *Research and Development expenses* and *Revenues (Benkraiem et al., 2023),* data retrieved in both cases from the Compustat database. This variable is taken into consideration by aligning with what the literature has found about it. Particularly, as per Xu et al. (2020), R&D investments significantly enhance green innovation, considering the quantity of patents into which every firm studied within this research was investing. In order to have a more standardized distribution of the errors, this variable is calculated as the natural logarithm of the ratio between R&D expenditures and total revenues. This decision permitted to stabilize the variance, reduce issues deriving from heteroscedasticity, and improve the reliability of the regression results.

[6] *https://eikon.refinitiv.com*
[7] *https://eikon.refinitiv.com*
[8] *https://eikon.refinitiv.com*

Furthermore, as per Xu et al. (2020), ESG performance moderates between R&D expenses and green innovation performance. Specifically, it amplifies the positive effect of research and development on green advancement. Consequently, for H4, the independent variable wants to follow Xu et al.'s path of understanding how R&D investments could amplify the positive effect of lean green innovation on environmental performance. Hence, the independent variable regards the interaction term *RD * Lean Green Innovation.*

3.4 CONTROL VARIABLES

With the intention of getting more robust and solid results from the empirical regression that will be further analyzed, a set of six different variables was chosen following the approach considered by the literature. Conducting a comprehensive examination of it, as per Benkraiem et al. (2023), the Capital Intensity ratio was considered (*CAPINTENSITY*), given by capital expenditures divided by the total assets of the firm; furthermore, Revenue Growth (*REVGRO*), which quantifies the annual growth rate in revenues, is being analyzed as the ratio between the total revenue at year t minus total revenue at t-1, everything divided by the total revenue at t-1; therefore it is the year – on – year growth in revenues (*Benkraiem et al., 2023)*. Eventually, even Leverage (*LEVERAGE*) is calculated, described as the fraction between total debt over total assets (*Xu et al., 2020).*

Additionally, *AGE* is introduced into the model following Xu et al. (2020). It is calculated as the natural logarithm of the number of years between 2020, the end year of the observation period, and the year of birth of the CVC company in consideration. Eventually, also the size of the company, defined by its total asset (*SIZE*), and the market value, explained by the product between the closed price and the number of shares outstanding (*MV*), are taken into consideration as control variables within the model.

Table 1 summarizes the definitions of the variables considered in the current research.

3.5 EMPIRICAL MODELING

The objective of the study is to understand how the independent variables, explained above, impact lean green innovation and how the latter influences environmental performance. Besides the consideration of the aforementioned control variables, within every examined empirical model, the regressions are being controlled for investment year fixed effects (retrieved from PATSTAT), and for industry fixed effects (retrieved from Refinitiv), respectively *INVYEAR* and *INDUSTRY.*

Concerning the control variables, as mentioned previously, they are capital intensity (*CAPINTENSITY*), revenue growth (*REVGRO*), financial leverage (*LEVERAGE*), company's age in 2020 (*AGE*), the Size explained by total asset (*SIZE*), Market Value (*MV*).

As explained priorly in this research, the empirical models follow the approach by Carney et al., (2019) and later also by Zulfiqar et al., (2020) and Zulfiqar et al. (2020) (2), who explained lean innovation through patents. Starting from comprehending how the ESG score could affect the CVC investor's level of innovation (H1), the first equation (1) is considered, following this setup:

$$Green\ innovation_{i,t} = \alpha + \beta_1 ESG_{i,t} + \beta_2 CapIntensity_{i,t} + \beta_3 RevGro_{i,t} + \beta_4 Leverage_{i,t} + \beta_5 Age_{i,t} + \beta_6 Size_{i,t} + \beta_7 MV_{i,t} + \beta_8 \sum InvYear_t + \beta_9 \sum Industry_i + \varepsilon_{i,t} \quad (1)$$

Green innovation clarifies the investment decision of each Corporate Venture Capital company to invest in green innovation, and patents are used as proxies to identify innovation. In order to provide a more detailed explanation, for every observation, both quantity (*Count*) and quality (*Citations*) are analyzed, together with the propensity to patent (*Propensity*) and the conversion rate of R&D into successful patents (*Conversion*) (*Carney et al., 2019; Zulfiqar et al., 2020; Zulfiqar et al., 2020).* Consequently, with the aim of understanding how ESG score differently impact on green investment decision, a regression with the aforementioned dependent variables is used. Moreover, as explained earlier in this research, ESG could be ulteriorly classified into its three pillars, *Environmental, Social, Governance* pillars; hence, (1) is additionally analyzed for the pillars, in order to comprehensively explain the impact on lean green innovation.

Moving forward to the second hypothesis (2), the model considers the impact of lean green innovation on environmental performance. Consequently, H2 is explained by the following:

$$EnvironmPerf_{i,t} = \alpha + \beta_1 Green\ innovation_{i,t} + \beta_2 CapIntensity_{i,t} + \beta_3 RevGro_{i,t} + \beta_4 Leverage_{i,t} + \beta_5 Age_{i,t} + \beta_6 Size_{i,t} + \beta_7 MV_{i,t} + \beta_8 \sum InvYear_t + \beta_9 \sum Industry_i + \varepsilon_{i,t} \quad (2)$$

The control variables and fixed effects do not receive any modification from previous equations. H3 aims to verify whether the R&D investments variable is going to affect positively the lean green innovation. Hence, the third equation (3) considers *RD* as the new independent variable, maintaining control variables and fixed effects:

$$Green\ innovation_{i,t} = \alpha + \beta_1 RD_{i,t} + \beta_2 CapIntensity_{i,t} + \beta_3 RevGro_{i,t} + \beta_4 Leverage_{i,t} + \beta_5 Age_{i,t} + \beta_6 Size_{i,t} + \beta_7 MV_{i,t} + \beta_8 \sum InvYear_t + \beta_9 \sum Industry_i + \varepsilon_{i,t} \quad (3)$$

Eventually, the fourth set of equations explains how R&D investments could enhance the positive effect that lean green innovation has on environmental performance. Firstly, we introduce R&D investments to the equation (2), resulting in the following (4.1):

$$EnvironmPerf_{i,t} = \alpha + \beta_1 Green\ Innovation_{i,t} + \beta_2 RD_{i,t} + \beta_3 CapIntensity_{i,t} + \beta_4 RevGro_{i,t} + \beta_5 c_{i,t} + \beta_6 Age_{i,t} + \beta_7 Size_{i,t} + \beta_8 MV_{i,t} + \beta_9 \sum InvYear_t + \beta_{10} \sum Industry_i + \varepsilon_{i,t} \quad (4.1)$$

Next, the impact of the emissions score and R&D investments on green innovation is assessed by incorporating the interaction term. The second equation of this set is formulated as:

$$EnvironmPerf_{i,t} = \alpha + \beta_1 Green\ Innovation_{i,t} + \beta_2 RD_{i,t} + \beta_3 Green\ Innovation_{i,t} * RD_{i,t} + \beta_4 CapIntensity_{i,t} + \beta_5 RevGro_{i,t} + \beta_6 Leverage_{i,t} + \beta_7 Age_{i,t} + \beta_8 Size_{i,t} + \beta_9 MV_{i,t} + \beta_{10} \sum InvYear_t + \beta_{11} \sum Industry_i + \varepsilon_{i,t} \quad (4.2)$$

In order to prove the accuracy of H1, β_1 has to be positive. Particularly, the hypothesis wants to prove that ESG score has a positive impact on lean green innovation. The same applies to the coefficients of every ESG pillar, whose influence on lean green innovation is expected to be positive. For H2, β_1 should be also greater than 0 because of the positive effect that the emissions score is expected to receive by lean green innovation; similarly, β_1 for H3, considering R&D investments as an independent variable, is forecasted to be above zero because of the beneficial influence of the research and development investments on green innovation. Eventually, considering H4 and the interaction term, the coefficient of the latter, being β_3 should be significantly positive, since firms with high R&D investments are more likely to strengthen the lean green innovation's positive impact on environmental performance.

FIGURE 1

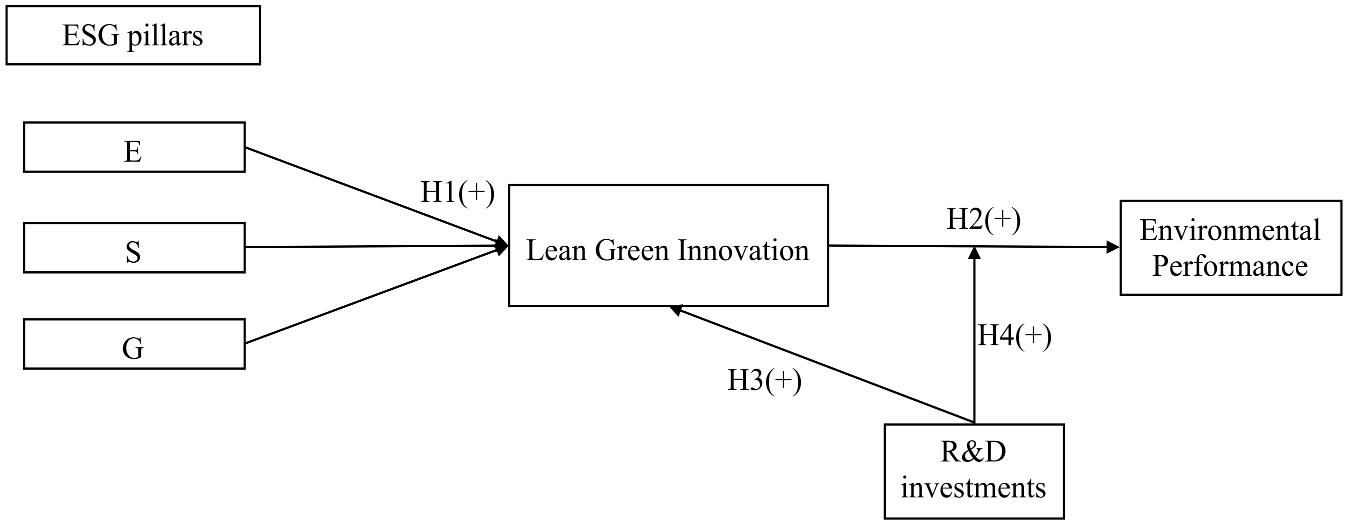

Figure 1 features the dependent variable that is lean green innovation. When talking about H1, where the first independent variable is ESG score and its three pillars, it is expected to have positive coefficients in any case. Going forward, H2 stresses the positive influence that lean green innovation has on environmental performance. H3 studies the forecasted positive impact that R&D investments have on lean green innovation. H4, which studies the impact of the interaction term between lean green innovation and R&D investments, is expected to describe a positive relation as well.

Lean Green Innovation results to be furtherly classified into four concepts, citation and count, that, as previously announced, define respectively quality and quantity of the green patents, but also propensity to new patents, the ratio between the green patent count and R&D expenditures, and the conversion rate of R&D investments into successful patents, seen as the ratio between the citations over R&D.

Eventually, in every regression model, there are six control variables, that limit the influence of external variables and enhance, consequently, the validity and reliability of the research. These are Age, Capital Intensity, Leverage, Revenue Growth, Size and Market Value.

4. EMPIRICAL RESULTS AND DISCUSSIONS

4.1 DESCRIPTIVE STATISTICS

Before going forward with the analysis of the empirical results and the testing of the research hypotheses, it is important to define the descriptive statistics. It represents concise information about the entire population or a sample of a population. Descriptive statistics is based on two fundamental groups of measures: central tendency, such as mean, median, and mode; variability, mentioning standard deviation and variance, skewness, and kurtosis. Hence, descriptive statistics is fundamental whenever the intention is to comprehend the foundational schemes, distinctions, and trends within the analyzed dataset.

Appendix A shows the distribution of the industries to which the companies relate. Remembering that the number of analyzed companies was 68 firms, with a total of 911 observations, after removing the outliers and deleting all the missing values, the distribution refers to the total number of observations. Therefore, the total number *N* refers to the observations and not the single companies.

From Appendix A, it can be noted how the majority of the observations studied in the research refer to three main industries: Health Care (29.09%), Consumer Staples (19.21%), and Industrials (18.66%). The Technology sector follows (11.42%). This, in particular, results to be interesting in relation to the literature by DiMasi et al. (2003), who demonstrated the importance of investments in innovation in the medical field, stressing also the relevance of the cooperation between innovation and R&D.

Table 2 explains the descriptive statistics related to the main variables of the regression models of the study. It includes measures such as mean, median, standard deviation (SD), minimum and maximum, skewness, and kurtosis for each variable. The 68 CVC companies analyzed as a sample within the research present similar values concerning the measures of innovation being patent count and citation count. More specifically, considering citation and count for green patents, the average values are respectively 5.950 and 5.145. The median, represented by the 50th percentile, is, instead, respectively 6.346 and 5.375. Concerning the standard deviation, which is fundamental in order to talk about the variability between variables, the various factors explaining innovation have similar values of standard deviation, approximately around 2, respectively 2.530 and 1.958, meaning that the dispersion is not totally null but overall manageable. Their skewness values indicate also that the innovation variables have distributions that are almost symmetric because skewness is close to 0, respectively being -0.383 and -0.441; since skewness is negative for both of them, it is possible to say that a low negative tail is implied, hence most of the data is concentrated on the right side. For the citation variable, the kurtosis lower than 3 confirms a platykurtic distributions, thus with a kurtosis that is lower than a normal distribution, while for the count variable, its kurtosis slightly greater than 3 suggests the presence of a leptokurtic distribution.

Going forward to the other two dependent variables, being the propensity to patent and the conversion rate of R&D investments into successful patents, they have respectively a mean equal to 0.099 and 0.437, while they have a median respectively equal to 0.031 and 0.079. The fact that their averages are higher than the value of the median signifies that the distributions are right-skewed, a factor that is furtherly confirmed by their positive skewness, respectively equal to 3.626 and 5.022. In order to understand their variability, the standard deviation has to be discussed. Propensity and conversion rate have a standard deviation of respectively 0.202 and 1.064. These values are larger than the averages, confirming the presence of some extreme values. Eventually, their kurtosis is respectively equal to 16.890 and 35.010, some of the highest values of the whole sample.

Eventually, the last dependent variable, the environmental performance, has an average value of 0.661; the median is 0.770, higher than the mean, meaning that there is a slightly left-skewed distribution ulteriorly confirmed by the negative skewness value equal to -1.048. The distribution is slightly platykurtic because the kurtosis is less than 3, equal to 2.969.

The first independent variable, *ESG*, presents a mean equal to 0.633. The value of the median is also interesting because it is higher for this variable than its average. It is indeed equal to 0.680, meaning that there is a slightly left-skewed distribution. This is indeed confirmed when looking at the values of the skewness for these three variables, being negative and equal to -0.786. For the kurtosis, it is equal to 2.890, representing, therefore, a platykurtic distribution.

ESG can be furtherly classified into its three pillars, Environmental, Social, and Governance, whose average values are respectively 0.598, 0.653, and 0.629, with medians equal to 0.680, 0.700, and 0.670. Even in this case, being the values of the median slightly superior to the averages, the distribution would present a slight left skew. This finding is confirmed by the slightly negative skewness for the three pillars, respectively equal to -0.897, -0.607, and -0.492. The standard deviations are moderate, meaning that there is some manageable variability in the scores. They are respectively equal to 0.270, 0.225, and 0.208. The distribution of these pillars seems to be approximately normal, being the kurtosis close to 3, respectively equal to 2.739, 2.518, and 2.338.

Similarly to them, the last independent variable, *RD,* presents a kurtosis value equal to 3.092, representing a very slight leptokurtic distribution, being the coefficient slightly greater than 3. The other statistical values of this variable are different than the other independent variables. In fact, they are all negative. The mean of *RD* is -3.417, while the median is -3.285. The fact that the mean and the median have values that are similar between each other signifies that the distribution is quite symmetric, but negatively distributed. This is furtherly demonstrated by the negative skewness, that defines a negative skewed distribution.

Additionally, even *CapIntensity, RevGro, Size,* and, especially, *MV* all present high values of kurtosis, respectively being equal to 9.417, 17.177, 17.820, and 22.238, indicating the presence of more extreme values. In fact, as an illustration of this, for the market value (*MV*), the maximum value is 9.834 while the minimum is 0.011, and the average value is 0.790 with a standard deviation of 1.022. This result ulteriorly confirms the presence of extreme values for Market Value. From this, it can be stated that there is a high probability that the majority of data concerning Market Value is concentrated on the left side. The statement is confirmed by the positive skewness being equal to 3.485, defining a right-skewed or positive-skewed distribution. A similar situation could be described for the variable explaining the Size of the investor. *AGE* is the only control variable to present a platykurtic distribution, having a kurtosis less than 3, equal to 2.321. The mean value is 4.316 with a standard deviation that is relatively low being equal to 0.742. This means that the dispersion is moderate, while the negative skewness being equal to -0.753 indicates a slight left-skewed distribution, confirmed by the fact that the median, equal to 4.522, is higher than the average value.

In Table 3 it is possible to identify the correlation matrix between the variables analyzed in the research. Firstly, concerning the dependent variables related to green lean innovation, citation and count for green innovation, together with the propensity to patent and the conversion rate. They all present a high positive and significant relation at the level of 1% between each other. In particular, it can be underlined how the strong positive correlation between *logCouG* and *logCitG* being equal to 0.798 defines that those CVC firms that invest in green patents also receive more green citations, meaning that there is a high academic or industry recognition.

Considering propensity and conversion rate, they are positively correlated to count and citations, with coefficients significant at 1%. In particular, the coefficients between conversion and citation and count are respectively 0.566 and 0.518. For propensity, instead, they are equal to 0.524 and 0.646. Propensity and conversion rate are also positively correlated with each other with a coefficient being equal to 0.758 and significant at 1%. The conversion rate is also positively and significantly at 1% correlated to the size and the market value of the investor, with a coefficient respectively equal to 0.351 and 0.202. Even with age, there is a positive correlation. However, with the latter, the correlation is significant at 5% and equal to 0.093. Propensity is positively correlated to size and market value as well, with coefficients equal to 0.506 and 0.241, significant at 1%. Age is significant at 5%, with the coefficient being equal to 0.103. Additionally, propensity has a significant at 1% level and positive correlation with ESG and Environmental performance described by the emissions score, with coefficients respectively equal to 0.135 and 0.153. Eventually, regarding propensity and conversion rate, they are both positively correlated to R&D investments, with coefficients respectively equal to 0.09 and 0.10 and both significant at 5%. This could be explained by the fact that the more the CVC firm invests in R&D, the higher the propensity to patent and the conversion rate of research and development investments into successful patents.

EnvironmPerf seems to be positively correlated to *logCouG,* with a correlation equal to 0.236, indicating the fact that CVC companies who invest in green patents, also have a high environmental performance, therefore a relevant commitment to reduce the level of the GHG emitted. The environmental performance increases together with an increase in the size and in market value of the investor. The environmental performance does not have a significant correlation with the age control variable. It is positively correlated to Market value, with a coefficient equal to 0.228 and significant at 1%.

Moving to the independent variables side, *ESG* presents a high positive and significant correlation with *EnvironmPerf,* with a correlation coefficient equal to 0.802 and significant at 1%. The meaning behind this is that those CVC investors, which exhibit a high ESG score, tend to also register an elevated environmental performance score. Hence, these firms are also more socially responsible and are characterized by a non-indifferent commitment to reduce their impact on the environment. ESG appears to be negatively correlated to revenue growth, being their correlation significant and equal to -0.214 and significant at 1%; this could mean that those firms with high growth revenues from one year to the following one tend to have lower ESG scores, possibly because they prefer to increase benefits from the financial side and abandon the socially responsible aspect. ESG is also positively correlated with Size, meaning that the bigger the company is, the higher the ESG score tends to be. Moreover, the market value that an investor owns increases together with an increase in the ESG score. The coefficients are respectively equal to 0.231 and 0.250, both significant at 1%. The age control variable is positive as well, but significant at 10%, with a coefficient equal to 0.077.

The three pillars that describe the ESG score have a positive correlation with the green patent count. In particular, *E* and *S* have a significance at 1%, while *G'*s is at 10%. The coefficients are respectively equal to 0.219, 0.186 and 0.085. Propensity and *E* have a strong positive correlation equal to 0.198 and significant at 1%, suggesting that investors with higher environmental activities might have a higher propensity to patent. With *S* the correlation is always positive equal to 0.078 but significant at 10%, while with *G* the positive correlation equal to 0.105 is significant at 5%. Without a doubt, there is a positive and significant at 1% correlation between ESG with any single pillar into which the initial score is classified. Respectively, the coefficients for E, S, and G with ESG are 0.873, 0.896, and 0.710, and the high value of these coefficients furtherly confirms the high correlation between the pillars and the score. Together with ESG, the three pillars are negatively correlated to revenue growth, indicating that the companies that prefer to enhance their growth year by year tend to sacrifice environmental, social, and governance practices. The coefficients, significant at 1%, are respectively equal to -0.196, -0.214 and -0.119.

Eventually, concerning R&D investments, it is very interesting, and in line with the literature, the fact that it has a positive and significant at 1% level correlation both with green citations and counts, respectively being equal to 0.369 and 0.409. Consequently, as R&D investment increases, the number and quality of green patents also tend to boost, implicating an enhanced reputation in sustainability for these CVC firms. Furthermore, *RD* results to be positively correlated to ESG and significant at 10%, with a coefficient equal to 0.073. Moreover, there is a positive correlation with the environmental performance defined by a coefficient equal to 0.074 and significant at 10%; it is also negatively correlated to capital intensity and Age, all significant at 1% and with the correlation factor being respectively equal to -0.236, and -0.111. Nothing can be stated instead referring to *RevGro*, *Size,* and *MV* because their correlations with R&D investments are not significant at any level.

4.2 MODEL 1: THE EFFECT OF ESG ON INNOVATION

In Table 4 it is possible to define the results of equation (1), remembering the differentiation between citations and counts for green innovations and the reference to conversion rate and propensity. Considering the two columns, models (1) and (2) refer respectively to the impact of ESG on the citation of green patents and on the count of the same. The hypothesis (H1) wants to demonstrate the positive influence of *ESG* on the lean green innovation variable, with the distinction afore-explained. By looking at models (1) and (2) it is possible to highlight the positive relationship that *ESG* has on both citation and count related to green patents. More specifically, a marginal increase in the ESG score brings to an average increase of respectively 0.981, and 1.474 in green patent citations and counts, representing the coefficients of the regression model between ESG and lean green innovation. Moreover, these results are significant at the 1% level. Additionally, Table 4 seemingly confirms the positive influence that ESG score has also on the other two variables that define the lean green innovation, being the conversion rate and the propensity to patent, model (3) and (4). In fact, the coefficient of the ESG impact is respectively equal to 0.495 for conversion and 0.094 for propensity to patent, being both significant at the 1% level. This confirms the positive relationship between ESG and lean green innovation.

By taking a look at the control variables, it can be stated that *Size, MV*, and *CapIntensity* all exhibit significance respectively at 1%, 1%, and 5% for the citation model, while they are all significant at 1% for the count model. Their effect is always greater than zero. *MV* is positive, probably because of the higher opportunities that the firm owns when its market value increases. Thanks to this, the CVC investors would indeed invest more in innovation and enhance the quality and quantity of green patents. The size of the firms results to be always positive possibly because of the experience of the investor, the resources, and the solid organizational structure found at the basis of the investor itself, factors that help improve the investments both from the quantity and for the quality of green patents. Eventually, even for *CapIntensity*, it has a positive coefficient in relation to citations and counts for patents. This might be due to firms benefiting from the investments into capital intensity, that permit them to deposit a higher number of patents, improving the quantity but also quality of patents, even though with less significance than the quantity. When focusing on conversion rate and propensity, these three control variables are positive as well, with size being significant at 1% for both of the regression models, while the capital intensity variable is relevant at 1% for the propensity and loses significance for the conversion rate. Market value, on the contrary, is significant at 1% for the conversion and loses relevance for the propensity.

Differently than what happens with the just-explained control variables, for the remaining three, namely *Leverage*, *Age,* and *RevGro*, not only are they never significant throughout the analyzed models regarding citation and count, but they also present diverse relations: *Leverage* and *Age* are positively correlated with the number of green patents, while the former is negative when analyzing the relation with green patent citations. Therefore, companies with more leverage tend to invest in a higher number of patents from the quantity point of view, possibly due to the fact that these types of firms want to increase the number of their intangible assets, like the patents, in order to increase their competitive advantage; nonetheless, the more these companies are leveraged, the lower is the quality of the patents they invest into. This means that high-leveraged investors' only goal is to increase the number of patents they invest in, without caring about their actual technological relevance. Age is always positively correlated to green patent count and citation, indicating that the older the company is, the higher its impact on lean green innovation; nevertheless, the coefficient of the control variable is not significant. Age and leverage are also positive for conversion and propensity, even though their coefficients are significant at 10% for the conversion and lose relevance when referring to propensity. Diversely, revenue growth is always negative, probably meaning that the investors that want to grow from the revenue side prefer to sacrifice their improvement in any form of innovation, but never significant.

Hence, by combining the previously – explained effects that ESG has on the different aspects of green innovation, the outcomes align with the literature that states that ESG has a good impact on lean green innovation. For example, Mukhtar et al. (2023) reached the same conclusion regarding this relationship by analyzing Malaysian manufacturing companies; moreover, Xu et al. (2020)

and Zhang and Chen (2023), after studying the Chinese market, managed to demonstrate the positive impact of ESG score on innovation.

The overall significance of the model seems to be confirmed by the elevated values of the F-statistic, meaning that at least one independent variable comprehensively explains the dependent. The p-values are lower than the 1% threshold, therefore the significance is supported by statistical results. Moreover, by taking a look at the R-squared in order to explain if the variations of the dependent variable are explained by the independent variable, it can be confirmed the significance of the model since the R-squared values are 61.3%, 47.1%, 39.6%, and 50.6% respectively for the models (1), (2), (3) and (4).

4.2.1 ESG PILLARS AND THEIR IMPACT ON LEAN GREEN INNOVATION

ESG score could ulteriorly be disaggregated into the three pillars that define the Environmental, Social, and Governance practices of the CVC firm in question. In particular, Table 5 examines the impact that these three pillars have on lean green innovation.

4.2.1.1. *Environmental pillar*

Considering the first four columns, (1), (2), (3), and (4), they refer respectively to the impact of the environmental practices on the citations of green patents and on the counts of the same, together with conversion and propensity. Models (1) and (2) highlight the positive relationship that *E* has on both citations and counts related to green patents. More precisely, a marginal increase in the Environmental pillar score brings to an average increase of lean green innovation of respectively 0.644 and 1.030. Moreover, these results seem to be significant respectively a 5% and at 1%. Additionally, Table 5 seemingly confirms the positive influence that *E* has also on the other two variables that define the lean green innovation, being the conversion rate and the propensity to patent, model (3) and (4). In fact, the coefficient is respectively equal to 0.341 for conversion and 0.076 for propensity to new patent, being both significant at the 1% level.

Regarding the control variables, it can be noted how *Size, MV*, and *CapIntensity* all exhibit significance respectively at 1%, 1%, and 5% for the citation model, while they are all significant at 1% for the count model. Their effect is always greater than zero. *MV* is positive, possibly because of the higher opportunities that the firm owns when its market value increases. Thanks to this, the CVC investors would indeed invest more into innovation and enhance the quality and quantity of green patents, as it happened with ESG. The size of the firm is always positive together with *CapIntensity*, which has a positive coefficient in relation to citations and counts for patents. When focusing on conversion rate and propensity, these three control variables are positive as well, with size being significant at 1% for both of the regression models, while the capital intensity variable is relevant at 1% for the propensity and loses significance for the conversion rate. Market value, on the contrary, is significant at 5% for the conversion and loses relevance for the propensity.

Leverage and *Age* are positively correlated with the number of green patents, while the former is negative when analyzing the relation with green patent citations. Therefore, companies with more leverage tend to invest in a higher number of patents from the quantity point of view, possibly due to the fact that these types of firms want to increase the number of their intangible assets, like the patents, to increase their competitive advantage; nonetheless, the more these companies are leveraged, the lower is the quality of the patents they invest into. Age is always positively correlated to green patent count and citation, and, together with leverage, is also positive for conversion and propensity, even though their coefficients are significant at 10% for the conversion and lose relevance when referring to propensity. Diversely, revenue growth is always negative and not significant, probably meaning that the investors that want to grow from the revenue side prefer to sacrifice their improvement in any form of innovation.

The overall significance of the *E* model seems to be confirmed by the values of the F-statistic, with a p-value that is less than the 1% threshold, therefore the significance is supported by statistical results. Moreover, by taking a look at the R-squared, its values are 61.3%, 46.9%, 39.5%, and 50.7% respectively for the models (1), (2), (3), and (4).

4.2.1.2 *Social pillar*

Moving forward to the next four columns, (5), (6), (7), and (8), they examine respectively the impact of the social pillar on the citations of green patents and on the counts of the same, on conversion rate and propensity to patent. It is forecasted that *S* should have a positive influence on lean green innovation. (5) and (6) stress the positive relationship that *S* has on both citations and counts related to green patents. More precisely, the coefficients of the regression model between the social pillar and lean green innovation are 1.208 and 1.410 for the citation and count respectively. Moreover, these results seem to be significant at the 1% level. Additionally, Table 5 seemingly confirms the positive influence that *S* has also on the other two variables that define the lean green innovation, being the conversion rate and the propensity to patent, models (7) and (8). In fact, the coefficient is respectively equal to 0.514 for conversion and 0.073 for propensity to patent, with a 1% level of relevance.

Size, MV, and *CapIntensity* all behave as they did for the *E* model, apart from the capital intensity that acquires a 10% significant level for conversion rate. *Age* is positively correlated with the dependent variables and is never significant, while leverage is negatively impacting citation and count and is also significant at 10% for the citation. Revenue growth is always negative and not significant, apart from the citation model where is positive but still not relevant.

The overall significance of the *S* model is confirmed by the values of the F-statistic, with a p-value that is less than the 1% threshold, therefore the significance is supported by statistical results. Moreover, by taking a look at the R-squared, its values are 61.7%, 47.3%, 39.8%, and 50.5% respectively for the models (5), (6), (7), and (8).

4.2.1.3 *Governance pillar*

Eventually, talking about the governance pillar, (9), (10), (11), and (12), study respectively the impact of the governance pillar on the citations of green patents and the counts of the same, on conversion rate and propensity to patent. The coefficients of the regression model between the governance pillar and lean green innovation are 0.207 and 0.728 for the citation and count respectively. However, the coefficient with citation is not significant, different from the relevant-at-1% coefficient for the count. Furthermore, *G* positively influences conversion rate and the propensity to patent, model (11) and (12). In fact, the coefficient is respectively equal to 0.264 for conversion and 0.090 for propensity to patent, being respectively significant at the 10% level and at 1%. This confirms the positive relationship between G and lean green innovation.

Size, MV, and *CapIntensity* all behave as they did for the *E* and for the *S* models, apart from the capital intensity which is not significant for the conversion rate model. *Age* is positively correlated with the dependent variables and is significant at 10% only for the conversion rate. *Leverage* is positively affecting the conversion rate and is also significant at 5%. Revenue growth is always negative and not significant.

The overall significance of the *G* model is confirmed by the values of the F-statistic. R-squared values are equal to 61.0%, 46.2%, 39.3%, and 50.9% respectively for (9), (10), (11), and (12).

4.2 MODEL 2: THE EFFECT OF ENVIRONMENTAL PERFORMANCE ON LEAN GREEN INNOVATION

Table 6 describes the relationship between environmental performance and lean green innovation. Delving into the specifics, H2 wants to clarify the relationship between the commitment of the investors to reduce greenhouse gas emissions and the grade of innovation into green patents. In other words, H2 wants to understand whether higher investments in green innovation bring higher values of environmental performance.

More specifically, it can be noted how *EnvironmPerf* is positively correlated to green innovation, either for the quality of the patents and from the quantity side. In fact, from Table 6 it is possible to note that the lean green innovation set of variables presents a positive correlation with the environmental performance dependent variable. In fact, (1) focuses on presenting the positive and significant impact that the green patent citation has on environmental performance. Particularly, the coefficient is significant at 1% and equal to 0.024, meaning that a marginal increase in the quality of the green patents brings an average increase in the environmental performance of 0.024. (2) instead explains the behavior of the count of green patents, defining the quantity of patents. This variable results to be positively connected with the environmental performance as well, significant at 1% and with a coefficient equal to 0.035.
Regarding the other two explanatory variables of the lean green innovation, being the conversion rate and the propensity, they are also positively affecting the environmental performance, with coefficients respectively equal to 0.048 and 0.262, significant at 1%, ulteriorly confirming the hypothesis of the good influence of the lean green innovation towards environmental performance.

Regarding the control variables, it can be noted how *Size, MV*, *RevGro* and *Leverage* all exhibit significance respectively at 1%, 1%, 5%, and 5% for the citation, count, conversion, and propensity models respectively. Size and revenue growth are negatively correlated in all the regression models. This means that the bigger the CVC company that is pursuing these investments into green innovation, the lower the attention on environmental performance. This could be due to the fact that big companies are sometimes more reluctant in pursuing activities that do not directly translate into higher financial performances, therefore the bigger the company the less commitment they have on reducing their GHG emissions. The same thing happens concerning the revenue growth variable. Being the variable significant at 5% for all the regression models, this suggests that it is reliable the interpretation according to which those firms who aim at increasing their yearly revenues, decide to sacrifice their environmental performance. Concerning leverage and market value, they are positively correlated to environmental performance with coefficients equal to 0.233, 0.209, 0.188, and 0.204 for leverage and 0.059, 0.053, 0.068, and 0.070 for market value, for the models (1), (2), (3), (4). The possible interpretation is that companies with higher leverage often face more scrutiny from investors and lenders who are increasingly concerned about environmental risks. These stakeholders may pressure firms to adopt more sustainable practices to manage long-term risks, and consequently improve environmental performance. Hence, the reduction of GHG emissions permits these firms to align with investors' demands and with environmental standards. Regarding market value, instead, companies with higher market values tend to receive pressures from the government and the general public, therefore they are incentivized to enhance their environmental performance.

Talking about the remaining control variables, namely *Age* and *CapIntensity*, they are not significant in the model. Specifically, the first one remains positively correlated with the environmental performance variable, meaning that the older you are the more interest you put into your environmental performance, while the second is negatively correlated. *CapIntensity* is actually significant at 10% when considering the green patent count as the independent variable and the propensity to new patents.

Both the citations and count regression models result to be significant with R - squared respectively being equal to 27.1% and 28.4% for (1) and (2), while it is 27.3% and 27.0% for (3) and (4); the value of the F – statistic confirms the overall significance of the model, having a p-value less than 1%.

Eventually, it can be concluded that these results effectively support Kraus et al., (2020) and Rehman et al., (2021), confirming the positive relationship between the commitment to reduce GHG emissions and the increase in green innovation investments, both for the quality and the quantity side. Green innovation strategies lead to higher environmental performance. Hence, it is important for these Corporate Venture Capital investors to proceed with investing in green innovation, consequently reducing the emissions of greenhouse gas and enhancing environmental performance. This decision would indeed not help solely the company in question, whose level of innovation would enhance, gaining a competitive advantage with respect to its competitors, but it would also contribute to improving the environmental performance and help the environment, whose pollution represents one of the most relevant topics nowadays, by reducing GHG emissions.

4.3 MODEL 3: THE EFFECT OF R&D INVESTMENTS ON GREEN INNOVATION

When talking about innovation, as previously defined in the literature review, the relationship between research and development and innovation is positive and significant as supported by some studies, such as Pegkas et al. (2019), who also supported the idea of a cointegration between R&D and innovation with the intention of maximizing the outcomes. Additionally, Lee and Park (2006) confirmed Pegkas et al. and even introduced the important role of the government in the success of innovation activities. Notably, regarding sustainable innovation, Luo and Zhang (2021) demonstrated the N – shaped effect of R&D on green innovation, describing how the behavior of the former changes with regards to the latter based on the considered time period during which the investments are being realized: at first a limited impact of R&D investments, subsequently more relevant and positive influence, eventually it affects negatively because of the waste of too many resources.

As a consequence of these heterogeneous results concerning research and development, Table 7 wants to highlight the relationship between R&D investments, explained by the ratio between R&D over revenues, and lean green innovation. Specifically, the outcomes show highly significant results at 1% both for citations and for counts of green patents, with positive coefficients respectively equal to 0.803 and 0.677. This means that an increase in R&D investments leads to an average increase also of the quality and quantity of green patents. Delving more into the details, a marginal increase in R&D investments brings an average increase of the quality of the patents by 0.803 and of the counts by 0.677. The practical aftereffect is that companies, in particular CVC ones, which invest in R&D, tend to increase their investment in green innovations not only from the quantity point of view, but, also, more importantly, from the quality point of view. Moreover, the coefficient for the citation is greater than the count one, meaning that the quality improves more rather than the quantity when R&D increases, underlining the importance of R&D investments for innovation and technology.

The critical aspect regards conversion rate and propensity to patents. From Table 7, it appears that the coefficients related to these two dependent variables are not significant and the research cannot confidently generalize and affirm the positive correlation between R&D investments and lean green innovation explained through these two ratios. The probable explanation behind this controversial situation might be related to statistical issues, since both R&D investments and these two dependent variables refer to R&D expenditures.

Hence, the hypothesis is confirmed for the green patent count and citation, supporting the idea implemented by Xu et al. (2020), according to which research and development affected positively green innovation. In the model, both fixed effects and control variables are the same as the previous regression models. *Size* and *MV* are again positively connected with the dependent variables, both citation and count, conversion rate, and propension to patent, significant at 1%, except for MV being significant at 1% for conversion and at 10% for propensity. *Leverage* is negative and significant at 1% and 5% for the citation and count. This is probably due to the fact that the financial pressure limits the innovative output. The negative effect is present also when talking about the green patent count, however, the coefficient is not significant. Concerning *CapIntensity*, it remains significant for all the models, even though it loses relevance for the conversion rate. Other control variables that align with the previous findings are *RevGro,* which keeps its negative and not significant relation to the dependent variables, and the age variable, positive but not significant apart from the conversion rate regression model where it is significant at 10%.

Moreover, the value of the F-statistics guarantees the overall significance of the model, while the R-squared, being equal to 67.9%, 53.9%, 39.1%, and 50.2%, respectively for the models (1), (2), (3), and (4), ulteriorly confirms the positive explanation of the variations of the dependent variable by the independent variables considered.

4.4 MODEL 4: THE MODERATING ROLE OF R&D INVESTMENTS BETWEEN EMISSIONS SCORE AND GREEN INNOVATION

With the intention of enriching the research, following the demonstration of the positive relationship between green innovation and *EnvironmPerf* (H2), as well as of the positive impact that research and development investments have on green innovation (H3), and considering the few information available in the literature regarding the relation between these three factors, the research wants to analyze more the joint effect of R&D investments and lean green innovation on environmental performance.

In fact, what the literature has previously demonstrated, for example, supported by the findings of Xu et al. in 2020, is that R&D positively impacts green innovation and that this influence is amplified by the presence of the ESG factor within the model run by Xu et al. They indeed proved how ESG accurately amplified and strengthened the positive effect of R&D on green innovation. Zhu (2022) instead proved the positive relation between emissions, R&D, and industrial development, stressing how research and development actually amplified this positive connection if inserted as a moderating variable in the model.

This current study wants to shed light, instead, on the relationship between environmental performance and lean green innovation and on how the R&D investments could contribute to amplifying and strengthening this relationship, as ESG did in Xu et al. (2020).

More specifically, Table 8 centralizes on proving the hypothesis according to which R&D investments effectively strengthen the positive relationship between lean green innovation and environmental performance. From the results, it can be noted how the coefficients of the green innovation variables remain positive and significant as in H3, both for citations and for green patent counts, with coefficients respectively equal to 0.082 and 0.142 both significant at 1%. The values of the coefficients of the green patents alone are already more impactful in the model with the interaction term with respect to the model explained in H3. In fact, in H3, the environmental performance coefficient was respectively 0.024 and 0.035 for citations and for counts. Moving forward to the conversion rate and propensity to patents, the impact that they have on environmental performance is still positive and significant at 1%, equal to 0.296 and 3.455. Even in this case, they are significantly higher for the model with the interaction term with respect to the one without, confirming the positive influence that R&D as moderator has in the model.

For the green patent citation and count, the coefficients of the interaction term appear to be relevant at 1%, and the hypothesis seems to be confirmed. Indeed, it can be noted how R&D investment and green innovation actually amplify the positive effect on environmental performance. For the quantity, the outcome is actually even better because the coefficient results to be higher than for citation, meaning that the effect of the interaction term is more relevant when talking about the quantity of the patents rather than the quality. The coefficients are respectively equal to 0.015 for citation and 0.029 for count. The practical reason behind these findings could be that CVC companies that combine their green patent innovations and investments into R&D receive more positive outcomes in their environmental performance. Regarding the conversion rate and propensity to patents, the R&D investment amplifies the positive effect of lean green innovation. In fact, the coefficients of the interaction term are positive and significant at 1%. Respectively, the coefficients are equal to 0.083 and 1.078, confirming the positive strengthening of the effect of the R&D investments in the relation between lean green innovation and environmental performance.

AGE acquires a 10% level of relevance for the model with the green patent count, remaining positively connected. Even *CapIntensity* is mostly not significant, apart from the model with the green patent count, and keeps on being negatively correlated with the dependent variables. The leverage variable is positively affecting green patent citation and count, with a coefficient equal to 0.349 and 0.321 and significant at 1%, while for conversion rate and propensity to new patents, it is significant respectively at 5% and 10%. From Table 8 it also appears that size is relevant for the study since it is negatively correlated and significant at 1%, 1%, and 5% respectively for (1), (2), and (3), meaning that the bigger the CVC company, the lower is the impact on their environmental score. It is not significant in (4). *MV* is always positive, and it is significant at 1% for green patent citation and count, and for conversion rate and propensity to new patents, with coefficients respectively equal to 0.069, 0.066, 0.073, and 0.073. *RevGro* keeps its negative and significant at 5% significance, apart from (4) where it loses relevance.

By giving a look at the value of the F-statistics, it can be stated that it guarantees the overall significance of the model, with the p-value being less than the 1% threshold, while the R-squared, being equal to 29.9% for citations and 33.1% for counts ulteriorly confirms the positive explanation of the variations of the dependent variable, especially of the citations of green patents, by the independent variables considered and by the interaction term. The R-squared for conversion and propensity (3) and (4) is respectively equal to 29.7% and 32.4%.

Therefore, the hypothesis is confirmed, and it is possible to state that R&D investment actually moderates the relationship between lean green innovation and the environmental performance explained by the emissions score. More precisely, the positive effect of green innovation on environmental performance is stronger in firms with high R&D investments.

5. ADDITIONAL ANALYSES

In the context of this research, it seems to be quite relevant to do ulterior analyses with the final aim of explaining in a more comprehensive way the afore-seen empirical results. Specifically, identifying and solving some of the problems that could arise while defining the previously – run regression models is crucial to grant the robustness of the results. Hence, the techniques that will be further used to assess the models will be useful not only to confirm the reliability of the outcomes, but also to have new perspectives from where it will be possible to interpret these results.

5.1 ROBUSTNESS CHECKS

One of the first further analyses realized within the paper regards the heteroscedasticity issue. It happens whenever the standard deviations of a variable are not constant throughout the study, with consequent inefficacy of the OLS, *Ordinary Least Squared*, estimation. According to Rosopa et al. (2013), heteroscedasticity represents the contrary situation to what should be respected when running a statistical regression, that is homoscedasticity. The violation of the latter can bring increasing Type I error rates, happening when a null hypothesis is wrongly rejected, and decreasing general statistical power.

5.1.1 BREUSCH – PAGAN

It is possible to use some statistical tests to verify the homoscedasticity of the analyzed models. As an illustration, the Breusch – Pagan test utilizes the analysis of the squared residuals with the intention of checking the heteroscedasticity; it refers to the Chi-square distribution for the testing of the hypothesis. Consequently, in the case of refusal of the null hypothesis, which is defined by the constant variance of the errors, it means that the model is heteroscedastic.

Table 9 summarizes the outcomes of the Breusch – Pagan test. Particularly, the table has been divided into two different tables, being 9.A and 9.B, each representing the two dependent variables studied within the current research, being lean green innovation and environmental performance. Table 9.A is divided into four columns, each representing diverse regression models, while every row defines each independent variable whose influence is being evaluated towards lean green innovation, characterized by the just-explained four dependent variables. Moreover, in the table, the values of the chi-squared and the p-value are observed.

Starting from the first models that consider the green patent citation as the dependent variable, it can be noted that every independent variable has a high p-value, meaning that there is no evidence of heteroscedasticity. In fact, the null hypothesis in the Breusch-Pagan test is that the errors have a constant variance and, given that the null hypothesis cannot be rejected because of the high p-value, then the models result to be homoscedastic.

Moving forward to (3) and (4), they focus on identifying heteroscedasticity issues for the green patent count variable. Even here, the majority of the independent variables present high p-values that suggest the presence of homoscedasticity in the models. For the conversion rate and propensity to patent models, all the variables show the lowest p-values of the whole sample, indicating that the errors do not have a constant variance, and this could negatively influence the results and outcomes of the paper. In order to solve these problems, diverse regression models are run considering robust standard errors. In this way, correct estimates for the standard errors could be calculated even with the presence of heteroscedasticity. With the Stata option *vce(robust*), standard errors have been recalculated for the models in which the Breusch - Pagan test found heteroscedasticity issues, in order for coefficient estimates to be consistent and statistical findings to be robust. The coefficients do not change, while the standard errors are modified because adjusted for the heteroscedasticity.

Table 9.B instead focuses on analyzing the heteroscedasticity in the regression models that see environmental performance as the dependent variable and lean green innovation as the independent. As can be seen from the results of the Breusch – Pagan model, all the regressions present some heteroscedasticity issues because the low p-values lead to the rejection of the null hypothesis that supports the homoscedasticity. Consequently, as seen also for Table 9.A, the same regressions are run using the *vce(robust*) option that makes the standard errors robust and more reliable.

5.1.1.1 H1: Robust effect model with ESG

Table 10 focuses on presenting the regression results with robust standard errors that consider the impact of ESG on lean green innovation. The initial hypothesis seems to be confirmed, given that ESG still presents the positive coefficient as it was in H1, but with the following regression models the heteroscedasticity issue should be solved thanks to the introduction of the robust standard errors. The same thing happens with Table 11, referred to the environmental, social, and governance pillars that comprehensively explain the ESG score.

5.1.1.2 H2: Robust effect model with Environmental Performance

In Table 12, the effect of lean green innovation on environmental performance is analyzed. The initial hypothesis seems to be confirmed, given that the regressions still present the positive coefficients as it was in H2. The following regression models, though, permit to have robust standard errors in order to manage the heteroscedasticity issue.

5.1.1.3 H3: Robust effect model with R&D investments

Table 13's scope is to analyze the regression results with robust standard errors involving R&D investments and lean green innovation explained by conversion and propensity. In Table 13 it is possible to note that the conversion rate variable is still negative and not significant; however, there is an important change when talking about the propensity to new patents. In fact, in H3, the relationship between propensity to new patents and R&D investments was positive but not significant. This happened with the regression model that, out of the Breusch – Pagan test, had heteroscedasticity issues. With the following regression models, the heteroscedasticity issue should be solved thanks to the introduction of robust standard errors. Particularly, R&D investment now appears to be positive and significant at 5% for the propensity to new patents. Therefore, it can be stated that the problem in H3 was, indeed, related to the absence of homoscedasticity.

5.1.1.5 H4: Robust effect model with interaction term

From Table 14, it can be noted that the effect of the interaction term between R&D investments and lean green innovation on environmental performance is positive and significant, confirming what H4 proved, even though there were heteroscedasticity issues. In fact, the coefficients are positive and significant even in the model with robust standard errors. From Table 14 the positive and significant relationship between interaction term and environmental performance is confirmed.

5.1.2 PLACEBO TEST

In some empirical research, a placebo test is often used as a robustness check to ensure that the estimated effects in a study are not driven by unobservable omitted variables. A placebo test is typically based on the realization of a "fake" treatment group by randomly assigning a treatment variable that should not have an effective impact. If the outcome of the placebo test is significant, it suggests that the original findings might be biased. Otherwise, a non-significant result would strengthen the reliability of the original findings.

More precisely, following the approach by Yang et al., (2023) and Wang et al., (2023), in the current research, the placebo test was conducted two times in order to examine the robustness of the two main regressions run in the paper. Particularly, Table 15.A, and Table 15.B indicate the results of the placebo tests respectively for H1 and H2. It is based on generating a fake treatment variable and on regressing it against the dependent variable along with the control variables. Moreover, the test has been repeated 1000 times using the bootstrap method, in order to have robust results; nevertheless, one or more parameters could not be estimated in some bootstrap replicates, because standard error estimates include only complete replications. Particularly, the results of both placebo tests regard 955 replications for ESG and lean green innovation, and 945 for lean green innovation and environmental performance.

Initially, Table 15.A sees green innovation explained by citations and *fake_ESG* as the fake treatment variable. Table 15.B considers *EnvironmPerf* as the dependent and *fake_greeninnov* as the fake treatment variable. The results explain that the coefficient for the fake treatment (*b_fake*) is, for the two tests, respectively equal to -0.098 and -0.002, with standard errors of 0.289 and 0.004, and resulting in a z-value of -0.34 and -0.480 and a p-value of 0.736 and 0.628. This means that the fake treatment effect is not significant in both tests and, moreover, it is also negative, with a coefficient close to 0. This means that, besides being of the opposite sign with respect to the original regressions, the coefficients being close to 0 and the p-values, representing the non-reliability of the “fake” treatment group regressions, lead to confirm that the original sample’s results are likely due to the actual treatment rather than random variation.

Figures 2 and 3 show the distribution of the fake treatment coefficients. Their values are very close to zero meaning that there are no relevant variables omitted in the original models. This states that the impact of ESG on lean green innovation and lean green innovation’s influence on environmental performance are not random.

Hence, the placebo test provides a fundamental robustness check, strengthening the credibility of the original findings. It furtherly proved that the estimated effects are not driven by random correlations.

Figure 2

Density diagram for ESG and lean green innovation

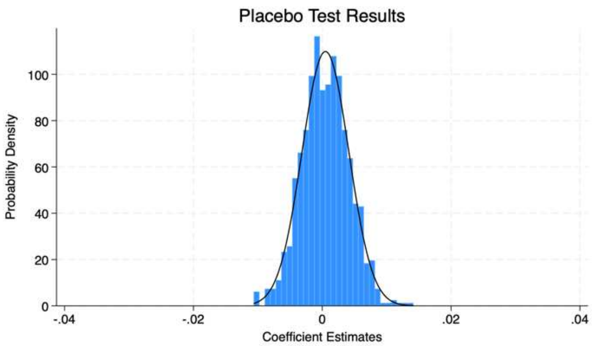

Figure 3

Density diagram for Lean green innovation and environmental performance

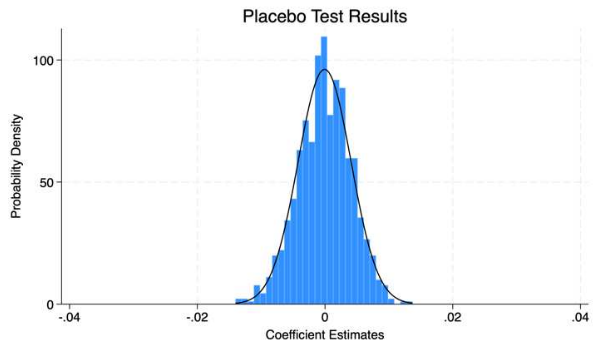

Figure 2 and Figure 3 represent the density diagram of coefficients, resulting from the placebo test that was run two times. More precisely, Figure 2 refers to the placebo test run considering lean green innovation as the dependent variable and a fake treatment ESG score. Figure 3 examines the results of the placebo test run considering environmental performance as the dependent variable and a fake treatment lean green innovation variable. In both figures the estimates of the coefficient are around the value of zero, meaning that no factors have been omitted from the original models.

5.2 DIFFERENCE-IN-DIFFERENCES MODEL

As previously explained, the analyzed sample refers to the period going from 2002 to 2020. Considering that sustainability and environmental impact by the companies have been developing recently as fundamental topics, common sense suggests that, at the beginning of the millennium, the attention towards GHG emissions was undoubtedly minor than nowadays. Therefore, another subsequent analysis regards the division of the whole sample into two groups, that differentiate between themselves only for the period considered: the first group analyzes data from 2002 to 2015, while the second one goes from 2016 to 2020. This is done with the intention of understanding whether recent regulations regarding sustainability have brought to the reducing of the environmental impact by the U.S. companies. Consequently, an important evaluation has to be made towards the second group of data, going from 2016 to 2020. In fact, 2015 was a critical year for environmental regulations aimed at increasing the sensibilization towards sustainability. As an illustration, the Paris Agreement was issued by the United Nations in 2015. This agreement firstly recognized the need for an intervention due to the continuous threats related to climate change. According to it, countries and companies could be affected not only by climate change itself, but also by the repercussions that the natural disasters could have on people and businesses and what the actions taken in response to it could provoke. The agreement wanted, in fact, to acknowledge that climate change is indeed a common concern of humankind and that the parties should focus on this matter and address climate change, respect the environment, and promote practices, and activities to sensibilize people and other businesses (*“Paris Agreement”, 2016*). In order to examine the impact that the Paris Agreement had on the environmental performance of the firms analyzed in the sample of this research, the *Difference-in-Differences* (*DiD*) model was used in the study, following the approach by Guizani et. al, (2024). It represents a statistical technique used in econometrics to estimate the causal effect of a treatment by comparing the changes in outcomes over time between a group that is exposed to the treatment (the "*treatment group*") and a group that is not (the "*control group*"). In this case, the intervention would regard the Paris Agreement, while the treated group and the control one relate respectively to a group of companies affected by the agreement and a group of company that is not. The key assumption is that, in the absence of the treatment, the difference between the treated and control groups would have remained the same over time (parallel trends assumption). This means that any deviation from this trend after the treatment can be attributed to the treatment itself.

In the current research, the regression model for *DiD* is:

$$EnvironmPerf_{i,t} = \alpha + \beta_1 Post_t + \beta 2 Treatment_i + \beta 3 (Post_t \times Treatment_i) + \beta_4 \, CapIntensity_{i,t} + \beta_5 \, RevGro_{i,t} + \beta_6 \, Leverage_{i,t} + \beta_7 \, Age_{i,t} + \beta_8 \, Size_{i,t} + \beta_9 \, MV_{i,t} + \beta_{10} \sum InvYear_t + \beta_{11} \sum Industry_i + \varepsilon_{i,t}$$

Post is a dummy variable that equals 1 for the post-treatment period (after 2015) and 0 otherwise.

Treatment is a dummy variable that equals 1 for the treatment group (firms expected to be affected by the Paris Agreement) and 0 for the control group. *Post* × *Treatment* is the interaction term that captures the *DiD* estimate, showing the effect of the Paris Agreement. The coefficient of the interaction term provides the estimated effect of the Paris Agreement on the outcome variable. A positive and significant coefficient would suggest that the Paris Agreement had a positive impact on the dependent variable.

Delving into the details of the *DiD* model, the treatment group represents firms that are more engaged in sustainable, social, and environmental practices, while the control group consists of less engaged firms. In particular, *Env_Resp* defines a dummy variable that equals 1 if the investor is more engaged in environmental responsibility, defined when the environmental pillar variable is higher than 30%, while *Sust_Resp* defines a dummy variable that equals 1 if the investor is more engaged in sustainable responsibility, defined when the ESG score is higher than 30%. Eventually, the *Social_Resp* variable is another dummy variable equal to 1 when the CSR score is higher than 30%.

As from Table 16, the Differences-in-Difference model shows that after the Paris Agreement in 2015, firms with higher social responsibility experienced significant improvements in environmental performance. The interaction term "*Post2015 * Social_Resp*" is positive and significant, indicating the Paris Agreement's positive impact on these firms, with a coefficient equal to 0.158 and significant at 1%. In fact, the Paris Agreement wanted to sensitize companies and individuals on important topics regarding, for instance, climate change and GHG emissions. Similarly, the interaction term between *Post2015* and the sustainable responsibility (*Sust_Resp*) is positive, showing that firms with higher sustainable responsibility also improved, though slightly less so. In fact, the interaction term coefficient is equal to 0.104 and significant at 5%. Eventually, even for the environmental responsibility, the interaction term is positive and significant, with a coefficient equal to 0.066 and significant a 10%. Overall, this suggests that the Paris Agreement encouraged better environmental performance, reducing the emissions amount, and enhanced sustainable, social, and environmental responsibility.

5.3 HAUSMAN TEST

The decision to use the fixed effect model in the current research rather than the random effect one comes from the results of the Hausman test (*Hausman, 1978*). This test represents a statistical test implemented in various research, such as Su and Moaniba, (2017), with the scope of identifying which of the two models, the random effect (RE) or the fixed effect (FE) one, should be preferred in regressions. This evaluation depends on the relationship between the independent variables and the individual effects [9]. In the null hypothesis of the Hausman test, the independent variables result to be not correlated to the individual effects, meaning that the random effect model is preferred. Otherwise, if the p-value is low enough to permit the refusal of the null hypothesis, then the fixed effect model appears more suitable for the regression in question.

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[9] *https://www.sciencedirect.com*

Table 17 analyzes the results of the Hausman test. More precisely, this table is divided into two in order to analyze the regressions regarding the two dependent variables analyzed, namely lean green innovation and environmental performance. Table 17.A focuses on running the Hausman test for the regressions that see lean green innovation as the dependent variable. It is possible to see that the majority of the regression models actually prefers the fixed effect model, and for this reason, it was followed and kept throughout the whole paper. This happens for every model, except for the one that studies the impact of R&D investments on the green patent count and on propensity to patent, where, respectively, the p-value is equal to 0.548 and 0.265. Moreover, the same happens for the regression model that considers the governance pillar as the independent variable and propensity to patent as the dependent. For these few cases, it would be better to consider a random effect model, because their high p-values lead to the non-rejection of the null hypothesis, meaning that they prefer the random effect model. Table 17.B, instead, focuses on environmental performance as the dependent variable. Even here, the p-value is equal to 0.000 and, hence, the fixed effect model is preferred rather than the random effect one. Tables 18 and 19 analyze the regression models that preferred the random effect, in order to understand whether there is a big difference in the outcomes of the models with fixed effects.

5.3.1 Random effect model with R&D investments

Table 18 examines the effect of R&D investments on lean green innovation explained by green patent count and propensity to patent using a random effect model. In fact, from Table 17.A, it was found that it would have been preferable to implement a regression model with random effects. It is possible to note how, for the green patent count, the impact of R&D investments on lean green innovation stays positive and significant at 1%, confirming the hypothesis. The interesting aspect regards, instead, the relationship between propensity to patent and R&D investments. In fact, in H3, in the model with fixed effects, the influence of R&D investments was positive but not significant, whilst, integrating a random effect model, the influence becomes relevant at 1%, with also a smaller standard error.

5.3.2 Random effect model with Governance pillar

Table 19 studies the effect of the governance pillar on lean green innovation explained by the propensity to patent using a random effect mode. It is possible to state that, for propensity, the impact of governance is still positive and significant on lean green innovation, confirming the initial hypothesis. Both F – statistics and R – squared confirm the significance of the model.

5.4 MULTICOLLINEARITY

Multicollinearity is defined as an issue related to the independent variable being accurately predicted by other variables. It is considered as an interdependency between *X* and *Y,* an effective threat to the regression models that want to analyze the relationship between the variables (*Farrar and Glauber, 1967*). In order to identify whether a regression model is characterized or not by multicollinearity, the literature aligns with the usage of the *Variance Inflation Factor*, otherwise called VIF, as a technique able to verify the presence of multicollinearity in the models. More precisely, Salmerón et al., (2020) suggest that the threshold value of the VIF, which defines the presence of multicollinearity, is 10. Therefore, if the VIF is under 10, this means that the model is either with no multicollinearity or, at least, manageable. If it goes over this threshold, the estimation of the coefficients and their significance and p-values are not reliable.

In Table 20, the VIF factor has been calculated for every independent variable considered throughout the regression models of the current paper, with the aim of identifying whether there is a multicollinearity problem or not. For this reason, as it happened for the Hausman, the Breusch – Pagan and the placebo tests, Table 20 has been divided into two different tables, each referring to a dependent variable, being lean green innovation and environmental performance. Both tables present, additionally, the value of 1/VIF. Looking at the models in Table 20.A, it can be noted that there are no relevant or high values of multicollinearity. The regression table has been constructed in a way in which every independent variable has its regression model toward lean green innovation, and they do not affect each other. The values of the VIF are all under 2, therefore it can be concluded that there is no model redundancy, meaning a slight multicollinearity issue. Moving forward to the analysis of the VIF values of the control variables present in every model, even in this case there is not a problematic situation that needs to be overlooked. VIF is less than two even for control variables.

Similar results are found in Table 20.B. In fact, here the regression models considered environmental performance as the dependent variable and lean green innovation as the independent. Neither the independent nor the control variables show relevant multicollinearity issues, given that the value of the VIF is under 2 for every variable, apart from the size variable., in the model with propensity to new patents as independent variable, that had a VIF equal to 2.038. These analyses confirm the robustness of all the regressions run within the paper, due to the VIF values not defining any relevant problems between independent and control variables.

6. CONCLUSIONS

This research focuses on understanding whether some corporate scores, such as ESG score, have an effect on a company's lean green innovation and how the latter affects the environmental performance of the investors. In line with recent literature, as per Carney et al., (2019) or Zulfiqar et al., (2020), lean green innovation is comprehensively explained by patents, represented either by the effective quantity of patents or by the citations that indicate the quality of the patents, and by the propensity to patent and conversion rate of R&D investments into successful patents. Everything is studied within the world of Corporate Venture Capital investments (CVC), considering a sample of global firms in a period from 2002 to 2020.

The paper demonstrates how these aforementioned scores influence the level of lean green innovations owned by a CVC investor, aligning with the literature, that had taken a side when talking about innovation since it was demonstrated that these scores positively affected it, but was unsure about the relation with lean green innovation. For instance, Cohen et al. (2020) discovered a controversial finding, according to which the companies with lower ESG scores actually had higher levels of innovation, especially green ones. Against this proof, Li and Li, (2024) proved that ESG performance eventually improved innovation. Moreover, the research wants to shed light on the impact of research and development investments, the ratio between R&D expenses over revenues, on lean green innovation, and its role as a mediating variable between environmental performance and lean green innovation.

The research is organized through the analysis of three hypotheses, with an additional one where an interaction term between two of the four independent variables is analyzed. In particular, firstly the effect of the ESG score on lean green innovation is studied. The outcomes present a positive and relevant influence of ESG towards lean green innovation. In fact, an increase in the ESG score brings an average enhancement of the lean green innovation by that specific investor. This finding is ulteriorly confirmed by the fact that the positive influence that ESG has on lean green innovation regards all four dependent variables explanatory of the lean green innovation, namely green patent count, citation, conversion rate, and propensity to patent.

Moreover, the first hypothesis analyzes also the impact of every single pillar, into which it is possible to divide the ESG score, namely Environmental, Social, and Governance, discovering a positive impact on lean green innovation. This is confirmed by the positive and significant relation that these pillars have towards every dependent variable. Eventually, the additional analyses representing the robustness check give even more strength to these outcomes, because there are no multicollinearity issues and heteroscedasticity is either absent for green patent count and citation or solved through the robustness of the standard errors for the propensity to new patent and conversion rate variables. Eventually, the results have additionally been confirmed by the placebo test, that considered a fake treatment ESG score variable using the bootstrap method; these random simulations have been repeated 1000 times in order to have more reliability in the results. It confirmed, that, since the coefficients are centered around the value of zero, the regression results do not produce a significant effect. Consequently, the treatment effect of the original regression is real and not due to some random chance or bias in the model.

Secondly, this research examines the impact of lean green innovation on environmental performance, finding out a positive influence of the former towards the latter. This means that the higher the investor's lean innovation, the higher its commitment to reducing greenhouse gas emissions. The relation is also significant at 1% for all the regression models, confirming the positive impact. Moreover, further analyses, run to give robustness to the already explained findings, confirm the positive results. Consequently, CVC firms should increment the level of green innovation not only to respect stakeholders' pressures but also because of the good impact that this would have on the firm's performance, particularly the environmental one. The relation between environmental performance and lean green innovation has ulteriorly been confirmed by the placebo test. It was run in the same way as the one presented for ESG and lean green innovation, giving, additionally, similar results regarding the coefficients. In fact, even in this case, they were mainly centered around zero. Consequently, the treatment effect of the original analysis is likely real. Moreover, the DiD model was run considering the 2015 Paris Agreement as the main intervention that brought the enhancement of firms' environmental performance, reducing the emissions amount, and enhancing sustainable, social, and environmental responsibility.

Moving forward to the next hypothesis, the influence of R&D investments on lean green innovation is studied. If the patent variables are analyzed, namely citation and count, it is possible to identify the positive impact that research and development expenditures have on lean green innovation, being the coefficient of the two regression models positive and significant. Nevertheless, the coefficients between R&D investments and propensity to patent and conversion rate are not significant. This may be due to heteroscedasticity or multicollinearity issues. Indeed, since both propensity and conversion rate are ratios that involve expenses in research and development and, considering that R&D investments are also defined as a ratio between R&D and revenues, the outcomes could be affected by this common component between the dependent variables and the independent one. This overlapping factor could be provoking instability in the results and bringing non-significant results, even though the positive and significant impact of R&D investments on lean green innovation has been confirmed with green patent count and citation. From the Breusch-Pagan test, R&D investments presented heteroscedasticity issues in the models analyzing its relationship with propensity to new patent and conversion rate. After running these models referring to robust standard errors, the conversion rate remained not significant, while propensity to patent acquired a 1% level relevance, confirming the positive relation with lean green innovation. This finding was further confirmed by the Hausman test, which affirmed that the relationship between R&D investments and green patent count and, additionally, with propensity to new patents, should have been analyzed using a random effect model, as seen from the high p-values that led to the non – rejection of the null hypothesis of the test. Consequently, after running a random effect regression model for these variables, green patent count and propensity to new patents results positively and significantly at 1% correlated to R&D investments.

Eventually, the current study wants to shed an ulterior light on the behavior of R&D investments toward environmental performance. In fact, the literature does not present any findings about a joint influence between R&D investments and lean green innovation on environmental performance. In fact, it has already been demonstrated how lean green innovation has a positive impact on environmental performance thanks to the findings of the second hypothesis, with positive and significant coefficients. This framework, instead, wants to understand whether the effect of increasing lean green innovation on environmental performance is strengthened by the increasing investments into R&D. The outcomes actually confirm this hypothesis, given that the interaction term presents a positive and significant impact on all the dependent variables. Moreover, these outcomes are further confirmed by the additional analyses run in the current research. In fact, from the Breusch – Pagan test, the regression models that considered green patent count, the propensity to new patents and conversion rate showed heteroscedasticity issues; after running the same models but with robust standard errors, the results were always positive and significant.

The results of this research aim to furtherly deepen the knowledge of lean green innovation and to understand which influencing corporate factors could be affecting it, without considering the financial ratios sphere. In fact, the literature is already aligned when analyzing the positive and significant relationship between financial performance, environmental performance, and green innovation (*Benkraiem et al., 2023*). What this current paper wants to underline is the importance of corporate scores such as ESG and the relevant role that the environmental performance covers when talking about lean green innovation. Investors should, indeed, introduce practices aimed at enhancing their lean green innovation because they would encounter positive consequences in different spheres: the financial one, the innovative one, on the environmental score and it would, additionally, be beneficial for the living and non – living natural systems within the globe.

Moreover, nowadays, even the stakeholders require the enhancement of the companies' environmental performance by lowering emissions; integrating problems, related to the environment, within the corporate business strategy plans characterizes an optimal technique to respect stakeholders' requests (*Tirkey et al., 2022*). In fact, transformations in the environmental or social spheres might denote ulterior motives to enhance companies' performance, given the fact that investors want to improve it across various fields (*Weber et al., 2016*).

Undoubtedly, these decisions to invest in ESG or environmental performance or lean green innovations, with the final scope of reducing greenhouse gas emissions and the general impact that these investors' decisions have on the environment, bring relevant costs with themselves. This aspect, sometimes, could represent the main reason why some firms stay behind with respect to others, since not everyone owns the financial background that is necessary in order to achieve these goals (*Wang et al., 2023*). This is the reason why there should be some forms of incentives that support companies in their efforts to diminish emissions of greenhouse gas, especially in less developed countries (*Rokhmawati et al., 2015; Rokhmawati et al., 2017*). Such measures would indeed not only mitigate environmental impact but also foster green innovation and encourage investments in sustainable technology, saving energy, preventing pollution, and promoting waste recycling (*Aguilera-Caracuel and Ortiz-de-Mandojana, 2013; Kraus et al., 2020*). Moreover, since there are companies that are less involved in this topic and whose pollution levels out–peak other companies', regulators should be able to assess the potential effect that green innovation has on firm performance. In this way, even the firms that were not initially moved by this would be more incentivized to reduce their GHG emission levels (*Chen et al., 2022; Hassan et al., 2022*).

Consequently, this current study's former aim is to make a noteworthy contribution to the already existing research concerning the corporate venture capital world, given the attention towards investments promoted in the CVC field. The goal is to understand how CVC investors' investment decisions could impact their level of lean green innovation and environmental performance. More precisely, the research wants to shed light on how companies' ESG scores could relate to lean green innovation and how the latter could be linked to their environmental performance. Nonetheless, this paper presents some limitations that have to be discussed in order to be solved by future studies. Firstly, the data sample to which this study refers consists of corporate venture capital investors. This suggests that there could be other research to be conducted in the future that might include more generic data. For instance, it could be beneficial to also include independent venture capital within the dataset, with the aim of better understanding the impact of environmental performance on lean green innovation. Secondly, the paper is centered on U.S. companies, therefore a territorial extension could be promoted in order to involve more geographical areas. In this way, the results could be either generalized, confirming the outcomes, or not, meaning that only U.S. firms actually present this pattern. Expanding the size of the group of the analyzed companies would also enhance the robustness and reliability of the outcomes. Another interesting research to be conducted regarding this matter is related to a wider temporal window; for instance, future studies could involve the behavior of investors prior to the new millennium, when sustainability issues were not heavily regarded as it, instead, happens nowadays. Lastly, as this paper was based on the relations between lean and green innovation, even though most of the literature aligned on the positive correlation between the two topics, there could be also some barriers and factors to be analyzed by future research that can impact the relation between lean and green innovation and other instruments affecting the positive influence that the lean green innovation has on environmental performance in the venture capital world.

APPENDIX

APPENDIX A.

Distribution of Industries

	Industry Frequency	Frequency (%)	Cumulative (%)
Basic Materials	46	5.049	5.049
Consumer Discretionary	52	5.708	10.757
Consumer Staples	175	19.210	29.967
Energy	53	5.818	35.785
Health Care	265	29.089	64.874
Industrials	170	18.661	83.535
Technology	104	11.416	94.951
Telecommunications	46	5.049	100
Total	911	100	
N	911		

Appendix A features the frequencies of each observation in relation to the industries to which they belong. From this table it can be seen that the majority of the observations refer to the healthcare sector, followed by consumer staples and industrials.

TABLE 1

Variable definitions

Variable	Definition
logCitG	Natural logarithm of (1 + total number of green citation)
logCouG	Natural logarithm of (1 + total number of green patents)
Conversion	Conversion rate of R&D into successful patents = Conversion / 1000. Conversion = Green patent citation / natural logarithm of R&D expenditures
Propensity	Propensity to patent = Propensity / 1000. Propensity = Green patent count / natural logarithm of R&D expenditures
EnvironmPerf	Environmental performance explained by the Emissions score from Refinitiv divided by 100

ESG	ESG score from Refinitiv divided by 100
E	Environmenal pillar from Refinitiv divided by 100
S	Social pillar from Refinitiv divided by 100
G	Governance pillar from Refinitiv divided by 100
RD	R&D investments = Natural Logarithm of R&D expenditures / Revenues.
MV	Market value = Common shares outstanding * Close Price of Fiscal year. MV = Market value / 100000
Leverage	Leverage = Total debt / Total assets.
RevGro	Revenue Growth = ($Revenue_t$ – $Revenue_{t-1}$) / $Revenue_{t-1.}$ Revenue data for year t and for the precedent year t-1 taken from the Compustat database.
CapIntensity	Capital Intensity = Capital Expenditures / Total Assets
Age	Age = Natural logarithm of the difference between 2020 and the year of foundation of the correspondent firm. ln(2020-founding year)
Size	Size = Total Assets / 100000

Table 1 comprehensively explains the dependent, independent, and control variables that are being used within the regression models. logCitG, logCouG, Conversion, Propensity, and EnvironmPerf represent the dependent variable; ESG, and RD are the independent ones; Size, Leverage, RevGro, CapIntensity, Age, and MV are the control variables that remain fixed through the regressions.

TABLE 2

Summary Statistics

	Mean	Median	SD	Min	Max	Skewness	Kurtosis
logCitG	5.950	6.346	2.530	0.000	11.397	-0.383	2.513
logCouG	5.145	5.375	1.958	0.000	9.429	-0.441	3.177
Conversion	0.437	0.079	1.064	0.000	10.437	5.022	35.010
Propensity	0.099	0.031	.202	0.000	1.375	3.626	16.890
EnvPerf	0.661	0.770	.295	0.000	1.000	-1.048	2.969

ESG	0.633	0.680	0.196	0.040	0.940	-0.786	2.890
E	0.598	0.680	0.270	0.000	0.970	-0.897	2.739
S	0.653	0.700	0.225	0.000	0.980	-0.607	2.518
G	0.629	0.670	0.208	0.080	0.990	-0.492	2.338
RD	-3.417	-3.285	1.430	-8.080	-0.422	-0.681	3.092
CapIntens	0.037	0.029	0.027	0.001	0.212	2.135	9.417
RevGro	0.054	0.045	0.154	-0.750	1.571	1.385	17.177
Size	0.738	0.311	1.125	0.011	7.978	3.460	17.820
MV	0.790	0.424	1.022	0.011	9.834	3.485	22.238
Age	4.316	4.522	0.742	2.565	5.384	-0.753	2.321

Table 2 defines the descriptive statistics of the variable observed within the dataset. The main types of measures indicated in the table are the central tendency, with mean and median, and the variability measure, with standard deviation, skewness and kurtosis, minimum and maximum.

TABLE 3

Correlation matrix

	logCitG	logCouG	Conversion	Propensity	ESG	E	S	G	EnvPerf	RD	CapIntens	RevGro	Size	MV	Age
logCitG	1														
logCouG	0.798***	1													
Conversion	0.566***	0.518***	1												
Propensity	0.524***	0.646***	0.758***	1											
ESG	-0.0583	0.195***	-0.0191	0.135***	1										
E	-0.0302	0.219***	0.00813	0.198***	0.873***	1									
S	-0.0725*	0.186***	-0.0352	0.0782*	0.896***	0.738***	1								
G	-0.0364	0.0851*	0.00401	0.105**	0.710***	0.473***	0.417***	1							
EnvPerf	0.0149	0.236***	0.0388	0.153***	0.802***	0.870***	0.717***	0.441***	1						
RD	0.368***	0.409***	0.0898**	0.0977**	0.0732*	0.0320	0.158***	-0.0992**	0.0745*	1					
CapIntens	0.0849*	0.0687*	0.0796*	0.140***	-0.106**	-0.0488	-0.178***	0.00450	-0.0590	-0.236***	1				
RevGro	0.0759*	-0.00175	0.0552	0.00823	-0.214***	-0.196***	-0.214***	-0.119***	-0.140***	0.0259	0.113***	1			
Size	0.290***	0.431***	0.351***	0.506***	0.231***	0.283***	0.189***	0.117***	0.165***	-0.0645	0.0540	-0.0567	1		
MV	0.232***	0.374***	0.202***	0.241***	0.250***	0.284***	0.227***	0.131***	0.228***	0.0480	0.000903	-0.0111	0.602***	1	
Age	0.0312	0.0246	0.0931**	0.103**	0.0773*	0.0861**	0.0796*	0.0525	0.0481	-0.111***	-0.0585	-0.0945**	0.241***	0.226***	1

*Table 3 studies the correlation matrix between the variables considered within the regression models. *, **, and *** represent the significance to respectively the 1%, 5%, and 10% statistical level.*

TABLE 4

Regression results for ESG on lean green innovation

	(1) Citation	(2) Count	(3) Conversion	(4) Propensity
ESG	0.981***	1.474***	0.495***	0.094***
	(0.330)	(0.299)	(0.173)	(0.030)
Leverage	-0.812	0.060	0.530*	0.035
	(0.577)	(0.522)	(0.303)	(0.052)
CapIntensity	5.790**	8.170***	2.265	1.021***
	(2.643)	(2.392)	(1.388)	(0.239)
RevGro	-0.005	-0.260	-0.054	-0.025
	(0.372)	(0.337)	(0.195)	(0.034)
Size	0.255***	0.246***	0.242***	0.064***
	(0.073)	(0.066)	(0.038)	(0.007)
MV	0.583***	0.546***	0.106***	0.011
	(0.075)	(0.068)	(0.039)	(0.007)
Age	0.068	0.043	0.076*	0.010
	(0.083)	(0.075)	(0.043)	(0.007)
Constant	7.480***	4.971***	0.828	-0.047
	(1.034)	(0.936)	(0.543)	(0.093)
Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.613	0.471	0.396	0.506
Observations	911	911	911	911
F-statistics	43.547	24.444	18.018	28.156

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 studies the influence of CVC investors' ESG score on lean green innovation. In models (1), (2), green innovation is measured through patent citation and count, while in (3), (4) through conversion rate of R&D expenditures into good patents and propensity to patent. All models are evaluated with fixed effects. The model the R – squared, observations and F-statistic.

TABLE 5

Regression results for G on lean green innovation

	(1) Citation	(2) Count	(3) Conversion	(4) Propensity	(5) Citation	(6) Count	(7) Conversion	(8) Propensity	(9) Citation	(10) Count	(11) Conversion	(12) Propensity
E	0.644**	1.030***	0.341***	0.076***								
	(0.250)	(0.226)	(0.131)	(0.023)								
S					1.208***	1.410***	0.514***	0.073***				
					(0.292)	(0.265)	(0.154)	(0.027)				
G									0.207	0.728***	0.264*	0.090***
									(0.268)	(0.244)	(0.141)	(0.024)
Leverage	-0.770	0.118	0.550*	0.038	-1.041*	-0.179	0.439	0.024	-0.705	0.262	0.600**	0.052
	(0.577)	(0.522)	(0.303)	(0.052)	(0.578)	(0.525)	(0.305)	(0.053)	(0.579)	(0.526)	(0.304)	(0.052)
CapIntensity	5.681**	8.002***	2.209	1.009***	6.473**	8.946***	2.550*	1.059***	5.627**	7.727***	2.107	0.972***
	(2.646)	(2.397)	(1.389)	(0.239)	(2.637)	(2.393)	(1.389)	(0.240)	(2.659)	(2.416)	(1.394)	(0.239)
RevGro	-0.050	-0.316	-0.074	-0.027	0.038	-0.268	-0.049	-0.029	-0.147	-0.411	-0.102	-0.028
	(0.371)	(0.336)	(0.195)	(0.033)	(0.370)	(0.335)	(0.195)	(0.034)	(0.371)	(0.338)	(0.195)	(0.033)
Size	0.258***	0.250***	0.243***	0.064***	0.260***	0.253***	0.244***	0.064***	0.260***	0.248***	0.242***	0.064***
	(0.073)	(0.066)	(0.039)	(0.007)	(0.073)	(0.066)	(0.038)	(0.007)	(0.074)	(0.067)	(0.039)	(0.007)
MV	0.576***	0.531***	0.101**	0.010	0.574***	0.547***	0.105***	0.012*	0.615***	0.587***	0.119***	0.013*
	(0.076)	(0.069)	(0.040)	(0.007)	(0.074)	(0.068)	(0.039)	(0.007)	(0.074)	(0.068)	(0.039)	(0.007)
Age	0.064	0.037	0.074*	0.010	0.050	0.024	0.068	0.009	0.075	0.059	0.081*	0.012
	(0.083)	(0.075)	(0.043)	(0.007)	(0.082)	(0.075)	(0.043)	(0.007)	(0.083)	(0.076)	(0.044)	(0.007)
Constant	7.745***	5.361***	0.960*	-0.024	7.532***	5.151***	0.879	-0.031	7.699***	5.026***	0.834	-0.072
	(1.029)	(0.932)	(0.540)	(0.093)	(1.025)	(0.930)	(0.540)	(0.093)	(1.047)	(0.951)	(0.549)	(0.094)

Year F. E	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.613	0.469	0.395	0.507	0.617	0.473	0.398	0.505	0.610	0.462	0.393	0.509
Observations	911	911	911	911	911	911	911	911	911	911	911	911
F-statistics	43.370	24.234	17.946	28.233	44.204	24.667	18.171	27.995	42.886	23.556	17.779	28.395

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5 studies the influence of the three pillars into which the ESG score is sub - classified on lean green innovation. In models (1), (2), (5), (6), (9), (10) green innovation is measured through patent citation and count, while in (3), (4), (7), (8), (11), (12) it is analyzed through conversion rate of R&D expenditures into good patents and propensity to patent. All models are evaluated with fixed effects. The model also shows the value of the R – squared, the number of observations and the value of the F-statistic, that explains the overall significance of the model.

TABLE 6

Regression results for lean green innovation on environmental performance

	(1) EnvironmPerf	(2) EnvironmPerf	(3) EnvironmPerf	(4) EnvironmPerf
logCitG	0.024***			
	(0.005)			
logCouG		0.035***		
		(0.006)		
Conversion			0.048***	
			(0.010)	
Propensity				0.262***
				(0.060)
Leverage	0.233**	0.209**	0.188**	0.204**
	(0.092)	(0.091)	(0.092)	(0.092)
CapIntensity	-0.638	-0.782*	-0.607	-0.765*
	(0.424)	(0.422)	(0.423)	(0.428)
RevGro	-0.145**	-0.132**	-0.143**	-0.139**
	(0.059)	(0.058)	(0.059)	(0.059)
Size	-0.038***	-0.040***	-0.043***	-0.048***
	(0.012)	(0.012)	(0.012)	(0.012)
MV	0.059***	0.053***	0.068***	0.070***
	(0.012)	(0.012)	(0.012)	(0.012)
Age	0.016	0.016	0.014	0.015
	(0.013)	(0.013)	(0.013)	(0.013)
Constant	0.067	0.064	0.208	0.260
	(0.170)	(0.166)	(0.165)	(0.165)
Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.271	0.284	0.273	0.270
Observations	911	911	911	911

F-statistics	10.204	10.863	10.294	10.166

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 focuses on analyzing the influence of firms' lean green innovation on financial performance (emissions score). In the model, fixed effects for investment year and industry are considered; it also shows the value of the R – squared, the number of observations and the value of the F-statistic, that explains the overall significance of the model.

TABLE 7
Regression results for R&D investments on lean green innovation

	(1) Citation	(2) Count	(3) Conversion	(4) Propensity
RD	0.803***	0.677***	-0.016	0.009
	(0.058)	(0.054)	(0.034)	(0.006)
Leverage	-2.188***	-1.043**	0.603*	0.026
	(0.535)	(0.496)	(0.310)	(0.053)
CapIntensity	4.870**	7.352***	2.249	1.004***
	(2.408)	(2.233)	(1.395)	(0.240)
RevGro	-0.112	-0.464	-0.143	-0.041
	(0.335)	(0.311)	(0.194)	(0.033)
Size	0.418***	0.387***	0.242***	0.066***
	(0.068)	(0.063)	(0.039)	(0.007)
MV	0.487***	0.487***	0.126***	0.013*
	(0.068)	(0.063)	(0.039)	(0.007)
Age	0.032	0.015	0.078*	0.010
	(0.075)	(0.070)	(0.044)	(0.008)
Constant	11.081***	8.242***	0.944*	0.025
	(0.964)	(0.894)	(0.559)	(0.096)
Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.679	0.539	0.391	0.502

Observations	911	911	911	911
F-statistics	58.147	32.125	17.610	27.693

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7 highlights the impact of firms' R&D investments, on lean green innovation. In the model, there are fixed effects for investment year and industry; it also shows the number of observations, together with the value of the R – squared and the value of the F-statistic, that explains the overall significance of the model.

TABLE 8

Regression results for interaction term between R&D and lean green innovation on environmental performance

	(1) EnvironmPerf	(2) EnvironmPerf	(3) EnvironmPerf	(4) EnvironmPerf
RD	-0.096*** (0.017)	-0.139*** (0.018)	-0.021** (0.010)	-0.032*** (0.010)
logCitG	0.082*** (0.011)			
RD * logCitG	0.015*** (0.015)			
logCouG		0.142*** (0.015)		
RD * logCouG		0.029*** (0.004)		
Conversion			0.296*** (0.047)	
RD * Conversion			0.083*** (0.015)	
Propensity				3.455*** (0.390)
RD * Propensity				1.078*** (0.130)

Leverage	0.349***	0.321***	0.225**	0.175*
	(0.094)	(0.091)	(0.093)	(0.091)
CapIntensity	-0.533	-0.708*	-0.539	-0.250
	(0.417)	(0.409)	(0.417)	(0.417)
RevGro	-0.125**	-0.115**	-0.126**	-0.088
	(0.058)	(0.057)	(0.058)	(0.057)
Size	-0.047***	-0.047***	-0.025**	0.004
	(0.012)	(0.012)	(0.012)	(0.014)
MV	0.069***	0.066***	0.073***	0.073***
	(0.012)	(0.012)	(0.012)	(0.012)
Age	0.021	0.024*	0.015	0.013
	(0.013)	(0.013)	(0.013)	(0.013)
Constant	-0.411**	-0.546***	0.099	0.154
	(0.188)	(0.180)	(0.168)	(0.164)
Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.299	0.331	0.297	0.324
Observations	911	911	911	911
F-statistics	10.979	12.766	10.882	12.347

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 concentrates on the impact of the interaction term between the lean green innovation and R&D investments on environmental performance. In particular, the table wants to understand whether R&D investments could act as a moderating variable between green innovation and environmental performance, and, if so, how impacted on the overall model with respect to the one without interaction term. In the current model, there are fixed effects for investment year and industry; it also shows the number of observations, together with the value of the R – squared and the value of the F-statistic, that explains the overall significance of the model.

TABLE 9.A

Breusch - Pagan

	logCitG		logCouG		Conversion		Propensity	
	χ2 (1)	p-value (2)	χ2 (3)	p-value (4)	χ2 (5)	p-value (6)	χ2 (7)	p-value (8)
ESG	0.090	0.765	0.910	0.339	1558.34	0.000	1408.48	0.000
E	0.130	0.722	2.030	0.154	1547.13	0.000	1396.28	0.000
S	0.010	0.912	0.020	0.882	1591.57	0.000	1493.01	0.000
G	0.010	0.917	0.330	0.563	1525.38	0.000	1310.46	0.000
RD	0.000	0.996	0.060	0.804	1544.98	0.000	1427.80	0.000

Table 9.A presents the results of the Breusch – Pagan test for H1 and H3. It is used with the intention of measuring whether these regression models present any heteroscedasticity issues or not. The Breusch – Pagan test considers as null hypothesis the homoscedasticity of the model. The refusal of the null hypothesis leads to the refusal of homoscedasticity, an important assumption for the OLS regressions.

TABLE 9.B

Breusch - Pagan

	χ2 (1)	p-value (2)
logCitG	127.49	0.000
logCouG	135.08	0.000
conversion	89.47	0.000
propension	86.73	0.000
logCitg* RD	111.51	0.000
logCouG* RD	137.97	0.000
conversion* RD	70.63	0.000
propension* RD	70.44	0.000

Table 9.B presents the results of the Breusch – Pagan test for H2 and H4. It is used with the intention of measuring whether these regression models present any heteroscedasticity issues or not. The Breusch – Pagan test considers as null hypothesis the homoscedasticity of the model. The refusal of the null hypothesis leads to the refusal of homoscedasticity, an important assumption for

the OLS regressions.

TABLE 10

Regression results for ESG on conversion and propensity with robust standard errors.

	(1) Conversion	(2) Propensity
ESG	0.495^{***}	0.094^{***}
	(0.189)	(0.025)
Leverage	0.530^{**}	0.035
	(0.256)	(0.058)
CapIntensity	2.265^{*}	1.021^{***}
	(1.197)	(0.265)
RevGro	-0.054	-0.025
	(0.197)	(0.037)
Size	0.242^{***}	0.064^{***}
	(0.037)	(0.008)
MV	0.106^{**}	0.011
	(0.050)	(0.008)
Age	0.076^{**}	0.010^{*}
	(0.036)	(0.006)
Constant	0.828	-0.047
	(0.554)	(0.053)
Year Time F. E	YES	YES
Industry F. E	YES	YES
R-squared	0.396	0.506
Observations	911	911
F-statistics	12.897	15.369

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10 concentrates on the impact of ESG on lean green innovation, explained by green patent count and propensity to new patents, and considering a model with robust standard errors. Coefficients are not expected to change, only the standard errors should because considered as robust. Model with fixed effects.

TABLE 11

Regression results for E, S, G on conversion and propensity with robust standard errors.

	(1) Conversion	(2) Propensity	(3) Conversion	(4) Propensity	(5) Conversion	(6) Propensity
E	0.341**	0.076***				
	(0.138)	(0.021)				
S			0.514**	0.073***		
			(0.206)	(0.028)		
G					0.264*	0.090***
					(0.149)	(0.023)
Leverage	0.550**	0.038	0.439*	0.024	0.600**	0.052
	(0.258)	(0.058)	(0.239)	(0.055)	(0.261)	(0.058)
CapIntensity	2.209*	1.009***	2.550**	1.059***	2.107*	0.972***
	(1.194)	(0.265)	(1.214)	(0.265)	(1.160)	(0.256)
RevGro	-0.074	-0.027	-0.049	-0.029	-0.102	-0.028
	(0.200)	(0.037)	(0.200)	(0.038)	(0.201)	(0.037)
Size	0.243***	0.064***	0.244***	0.064***	0.242***	0.064***
	(0.036)	(0.008)	(0.036)	(0.008)	(0.037)	(0.008)
MV	0.101**	0.010	0.105**	0.012	0.119**	0.013
	(0.049)	(0.008)	(0.049)	(0.008)	(0.052)	(0.008)
Age	0.074**	0.010	0.068**	0.009	0.081**	0.012**
	(0.036)	(0.006)	(0.034)	(0.006)	(0.037)	(0.006)
Constant	0.960*	-0.024	0.879	-0.031	0.834	-0.072
	(0.538)	(0.048)	(0.547)	(0.055)	(0.564)	(0.053)
Year Time F. E	YES	YES	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES	YES	YES
R-squared	0.395	0.507	0.398	0.505	0.393	0.509
Observations	911	911	911	911	911	911
F-statistics	12.739	15.755	13.403	14.573	12.589	15.521

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11 concentrates on the impact of E, S, G on lean green innovation, explained by green patent count and propensity to new patents, and considering a model with robust standard errors. Model with fixed effects. R-squared and F-statistics ulteriorly confirms the relevance of the model.

TABLE 12

Regression results for lean green innovation on environmental performance, robust standard errors

	(1) EnvironmPerf	(2) EnvironmPerf	(3) EnvironmPerf	(4) EnvironmPerf
logCitG	0.024***			
	(0.007)			
logCouG		0.035***		
		(0.007)		
Conversion			0.048***	
			(0.008)	
Propensity				0.262***
				(0.046)
Leverage	0.233***	0.209**	0.188**	0.204**
	(0.083)	(0.084)	(0.085)	(0.084)
CapIntensity	-0.638	-0.782	-0.607	-0.765
	(0.514)	(0.520)	(0.522)	(0.526)
RevGro	-0.145**	-0.132*	-0.143**	-0.139**
	(0.072)	(0.071)	(0.070)	(0.070)
Size	-0.038***	-0.040***	-0.043***	-0.048***
	(0.009)	(0.009)	(0.010)	(0.010)
MV	0.059***	0.053***	0.068***	0.070***
	(0.010)	(0.010)	(0.010)	(0.011)
Age	0.016	0.016	0.014	0.015
	(0.015)	(0.015)	(0.015)	(0.014)
Constant	0.067	0.064	0.208	0.260
	(0.190)	(0.180)	(0.185)	(0.173)

Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.271	0.284	0.273	0.270
Observations	911	911	911	911
F-statistics	10.118	10.837	10.680	10.045

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12 concentrates on the impact of lean green innovation, explained by green patent count and propensity to new patens, on environmental performance, defined by emissions score, and considering a model with robust standard errors. Model with fixed effects. R-squared and F-statistics ulteriorly confirms the relevance of the model.

TABLE 13

Regression results for R&D investments on conversion and propensity with robust standard errors

	(1) Conversion	(2) Propensity
RD	-0.016	0.009**
	(0.029)	(0.004)
Leverage	0.603**	0.026
	(0.282)	(0.062)
CapIntensity	2.249*	1.004***
	(1.171)	(0.263)
RevGro	-0.143	-0.041
	(0.208)	(0.039)
Size	0.242***	0.066***
	(0.037)	(0.008)
MV	0.126**	0.013
	(0.054)	(0.008)
Age	0.078**	0.010
	(0.037)	(0.006)
Constant	0.944*	0.025
	(0.561)	(0.057)
Year Time Fixed Effects	YES	YES

Industry Fixed Effects	YES	YES
R-squared	0.391	0.502
Observations	911	911
F-statistics	13.323	15.405

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13 concentrates on the impact of R&D investments on lean green innovation, explained by green patent count and propensity to new patents, and considering a model with robust standard errors. Coefficients are not expected to change, only the standard errors should because considered as robust. Model with fixed effects.

TABLE 14

Regression results for interaction term between R&D and lean green innovation on environmental performance, robust standard errors

	(1) EnvironmPerf	(2) EnvironmPerf	(3) EnvironmPerf	(4) EnvironmPerf
RD	-0.096***	-0.139***	-0.021*	-0.032***
	(0.019)	(0.023)	(0.012)	(0.012)
logCitG	0.082***			
	(0.014)			
RD * logCitG	0.015***			
	(0.003)			
logCouG		0.142***		
		(0.020)		
RD * logCouG		0.029***		
		(0.005)		
Conversion			0.296***	
			(0.043)	
RD * Conversion			0.083***	
			(0.015)	
Propensity				3.455***
				(0.396)

RD * Propensity				1.078***
				(0.130)
Leverage	0.349***	0.321***	0.225***	0.175**
	(0.085)	(0.085)	(0.087)	(0.084)
CapIntensity	-0.533	-0.708	-0.539	-0.250
	(0.516)	(0.516)	(0.503)	(0.514)
RevGro	-0.125*	-0.115*	-0.126*	-0.088
	(0.069)	(0.067)	(0.069)	(0.067)
Size	-0.047***	-0.047***	-0.025***	0.004
	(0.009)	(0.009)	(0.009)	(0.012)
MV	0.069***	0.066***	0.073***	0.073***
	(0.012)	(0.010)	(0.012)	(0.011)
Age	0.021	0.024*	0.015	0.013
	(0.014)	(0.014)	(0.014)	(0.014)
Constant	-0.411*	-0.546***	0.099	0.154
	(0.221)	(0.204)	(0.225)	(0.178)
Year Time F. E	YES	YES	YES	YES
Industry F. E	YES	YES	YES	YES
R-squared	0.299	0.331	0.297	0.324
Observations	911	911	911	911
F-statistics	10.425	12.901	11.484	12.939

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14 concentrates on the impact of the interaction term between R&D investments and lean green innovation on environmental performance, explained by green patent count and propensity to new patents, and considering a model with robust standard errors. Model with fixed effects.

TABLE 15.A

Placebo test – green innovation as dependent and fake_ESG as the fake treatment variable

	Observed		Bootstrap		Normal-based		
	coefficient	std. error	z	P>z	[95%	conf.	interval]
b_fake	-0.098	0.289	-0.340	0.736	-0.665	0.469	

Table 15.A describes the placebo test run for the regression model that considers lean green innovation as the dependent variable and ESG as the independent. In order to run his test, a fake treatment variable has been created, fake_ESG, and run this model for 1000 times in order to strengthen the outcomes. These results ulteriorly confirm the positive relation between ESG score and a CVC firm's lean green innovation, because of the non – significance of the results of the coefficients of the placebo test.

TABLE 15.B

Placebo test – environmental performance as dependent and fake_greeninnov as the fake treatment variable

	Observed		Bootstrap		Normal-based		
	coefficient	std. error	z.	P>z	[95%	conf.	interval]
b_fake	-0.002	0.004	-0.480	0.628	-0.010	0.006	

Table 15.B describes the placebo test run for the regression model that considers environmental performance as the dependent variable and lean green innovation as the independent. In order to run his test, a fake treatment variable has been created, fake_greeninnov, and run this model for 1000 times in order to strengthen the outcomes. These results ulteriorly confirm the positive relation between lean green innovation and a CVC firm's environmental performance, because of the non – significance of the results of the coefficients of the placebo test.

TABLE 16

DiD Regression results

	(1) EnvironmPerf	(2) EnvironmPerf	(3) EnvironmPerf
Social_Resp	0.447^{***} (0.026)		
Post2015 * Social_Resp	0.158^{***} (0.052)		

Sust_Resp		0.521***	
		(0.027)	
Post2015 * Sust_Resp		0.104**	
		(0.043)	
Env_Resp			0.563***
			(0.020)
Post2015 * Env_Resp			0.066*
			(0.038)
Post2015	-0.191	0.273	-0.029
	(0.175)	(0.172)	(0.139)
Leverage	0.146**	0.271***	0.209***
	(0.067)	(0.077)	(0.061)
CapIntensity	-0.488	-0.256	-0.384
	(0.392)	(0.358)	(0.289)
RevGro	-0.061	-0.094*	-0.045
	(0.050)	(0.054)	(0.043)
Size	-0.033***	-0.034***	-0.032***
	(0.006)	(0.008)	(0.005)
MV	0.044***	0.056***	0.039***
	(0.007)	(0.009)	(0.007)
Age	-0.001	-0.002	-0.005
	(0.011)	(0.012)	(0.009)
Constant	0.362**	-0.186	0.233*
	(0.177)	(0.174)	(0.142)
Year F.E.	YES	YES	YES
Industry F.E	YES	YES	YES
R-squared	0.465	0.465	0.643
Observations	911	911	911
F-statistics	51.364	51.364	65.520

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16 presents the results of a Difference-in-Differences (DiD) analysis examining the impact *of two treatment variables on environmental performance, particularly the Environmental Responsibility and Sustainable Responsibility. The two interaction terms comprehensively explain the effect of the Paris agreement on the affected firms.*

TABLE 17.A

Hausman test

	logCitG		logCouG		Conversion		Propensity	
	χ2 (1)	p-value (2)	χ2 (1)	p-value (2)	χ2 (1)	p-value (2)	χ2 (1)	p-value (2)
ESG	203.788	0.000	23.771	0.001	108.117	0.000	18.498	0.000
E	204.376	0.000	26.995	0.000	111.807	0.000	26.356	0.000
S	207.967	0.000	27.814	0.000	111.993	0.000	15.494	0.030
G	184.568	0.000	13.382	0.063	104.986	0.000	11.820	0.107
RD	184.36	0.000	5.930	0.548	106.235	0.000	8.838	0.265

Table 17.A presents the result of the Hausman test for H1 and H3. It is used with the intention of measuring whether these regression models present better results with random effect models or with fixed effect models. The Hausman test considers as null hypothesis the random effect model. The refusal of the null hypothesis leads to the refusal of random effect model. Only the regression models that study the effect of RD on green patent count and on propensity and the effect of the Governance pillar on propensity preferred the random effect model.

TABLE 17.B

Hausman test

	χ2 (1)	p-value (2)
logCitG	79.471	0.000
logCouG	78.775	0.000
conversion	80.697	0.000
propension	79.887	0.000
logCitG* RD	82.502	0.000
logCouG* RD	84.833	0.000
conversion* RD	75.996	0.000
propension* RD	80.694	0.000

Table 17.B presents the result of the Hausman test for H2 and H4. It is used with the intention of measuring whether these regression models present better results with random effect models or with fixed effect models. The Hausman test considers as null hypothesis the random effect model. The refusal of the null hypothesis leads to the refusal of random effect mode. No regression model in this table preferred the random effect.

TABLE 18

Regression results with random effect model for R&D investments on patent and propensity to patent

	(1) Count	(2) Propensity
RD	0.620^{***}	0.025^{***}
	(0.036)	(0.004)
Leverage	-1.480^{***}	-0.057
	(0.459)	(0.052)
CapIntensity	10.230^{***}	1.083^{***}
	(1.950)	(0.220)
RevGro	-0.179	0.025
	(0.326)	(0.037)
Size	0.705^{***}	0.106^{***}
	(0.058)	(0.006)
MV	0.222^{***}	-0.025^{***}
	(0.062)	(0.007)
Age	-0.083	0.006
	(0.071)	(0.008)
Constant	6.868^{***}	0.068^{*}
	(0.326)	(0.037)
R-squared	0.418	0.306
Observations	911	911
F-statistics	92.630	56.760

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18 concentrates on the impact of R&D investments on lean green innovation, considering a random effect model. The impact of R&D investments on lean green innovation is positive and significant both for green patent count and for propensity to new patent.

TABLE 19

Regression results with random effect model for Governance pillar on patent and propensity to patent

	(1) Propensity
G	0.056**
	(0.028)
Leverage	-0.085
	(0.053)
CapIntensity	0.741***
	(0.217)
RevGro	0.042
	(0.038)
Size	0.103***
	(0.007)
MV	-0.022***
	(0.007)
Age	0.001
	(0.008)
Constant	-0.009
	(0.040)
R-squared	0.281
Observations	911
F-statistics	50.374

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19 concentrates on the impact the Governance pillar on lean green innovation, considering a random effect model. The impact of Governance pillar on lean green innovation is positive and significant for the propensity to new patent, as also explained by the R-squared and F-statistics.

TABLE 20.A

***Variance inflation factor** on lean green innovation*

	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
ESG	1.163	0.860								
E			1.177	0.850						
S					1.182	0.846				
G							1.035	0.966		
RD									1.100	0.909
Size	1.697	0.596	1.709	0.585	1.690	0.592	1.690	0.592	1.696	0.590
MV	1.669	0.599	1.672	0.598	1.674	0.598	1.633	0.612	1.640	0.610
Leverage	1.109	0.902	1.107	0.904	1.125	0.889	1.088	0.919	1.094	0.914
Age	1.095	0.913	1.095	0.913	1.095	0.913	1.094	0.914	1.110	0.901
RevGro	1.068	0.936	1.063	0.941	1.066	0.938	1.040	0.962	1.027	0.974
CapIntensity	1.053	0.950	1.047	0.955	1.069	0.936	1.047	0.955	1.118	0.895
Mean VIF	1.265		1.267		1.271		1.233		1.255	

Table 20.A presents the results of the multicollinearity test for H1 and H3. It is used with the intention of measuring whether these regression models present multicollinearity issues or not. The test considers the value of 10 as the threshold over which it is possible to talk about multicollinearity. No variable in this table presents multicollinearity.

TABLE 20.B

***Variance inflation factor** on environmental performance*

	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
logCitG	1.275	0.784						0.491
logCouG			1.336	0.749				
Conversion					1.24	0.806		
Propensity							1.395	0.717
Size	1.803	0.555	1.820	0.549	1.858	0.538	2.038	0.491
MV	1.586	0.630	1.615	0.619	1.558	0.642	1.556	0.643
Leverage	1.177	0.849	1.142	0.876	1.117	0.895	1.114	0.898
Age	1.090	0.917	1.094	0.914	1.083	0.923	1.083	0.923
CapIntens	1.038	0.964	1.036	0.965	1.036	0.965	1.051	0.952
RevGro	1.025	0.976	1.023	0.977	1.028	0.973	1.028	0.973
Mean VIF	1.285	.	1.295	.	1.274	.	1.324	.

Table 20.B presents the results of the multicollinearity test for H2 and H4. It is used with the intention of measuring whether these regression models present multicollinearity issues or not. No variable in this table presents multicollinearity.

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