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Relation of Green Innovation Practices to Firm Performance: Evidence from BEEPS data

Master's thesis

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Abstract

Relation of Green Innovation Practices to Firm Performance: Evidence from BEEPS data

In view of the gap of consensus on how applying green innovation affects a firm's performance, this thesis investigates the impact of green innovation practices on firm performance in developing economies using the latest wave (2018-2020) of the World Bank Enterprise Surveys (formerly BEEPS). Employing 11 Ordinary Least Squares (OLS) regressions, our findings reveal a significant positive correlation between certain types of green innovations and improved firm performance. In particular, the implementation of vehicle upgrade and on-site climate-friendly energy generation emerged as a highly influential green innovation, boosting firm performance by 11.2% and 10.8% respectively. However, other green innovations such as water and waste management measures and machinery upgrades showed no significant impact. These results underscore the strategic importance of green innovations for operational efficiency and firm performance, providing insights for companies and policymakers to support sustainable practices.

Roheinnovatsioonipraktikate seos ettevõtete tulemuslikkusega BEEPS andmete põhjal

Ei ole ühest arusaama selle kohta, kuidas roheinnovatsioon mõjutab ettevõtte tulemuslikkust (ingl *firm performance*). Käesoleva väitekirja eesmärk on teada saada, kuidas arengumaade ettevõtete roheinnovatsioonipraktikad mõjutavad ettevõtete tulemuslikkust. Selleks kasutatakse töös World Bank Enterprise Survey (varemalt tuntud kui BEEPS) kõige uuemaid andmeid aastatest 2018-2020. Andmete statistiliseks analüüsiks kasutatakse harilikku vähimruutude meetodit. Töö analüüsi tulemusena leiti positiivseid korrelatsioone kindlate roheinnovatsioonipraktikate ja ettevõtte tulemuslikkuse vahel. Vaadeldud praktikatest osutusid kõige mõjusamateks roheinnovatsioonideks sõidukite uuendamine ja kohapealne kliimasõbralik energiatootmine, mis tõstavad ettevõtte tootlikkust vastavalt 11,2% ja 10,8%. Samas muud rohepraktikad, näiteks muudatused veemajanduses, jäätmekäitluses ja uute masinate kasutuselevõtt ei oma statistiliselt olulist seost ettevõtete tulemuslikkusega. Uurimistöö tulemused kinnitavad roheinnovatsiooni strateegilist olulisust ettevõtete tegevusedukusele ja ettevõtte tulemuslikkusele.

1. Introduction

In today's business landscape, adapting sustainable practices has become a strategic imperative for organizations worldwide. Among these practices, green innovation stands out as a powerful driver of both environmental responsibility and financial success. As companies grapple with the challenges posed by climate change, resource scarcity, and shifting consumer preferences, understanding the impact of eco-innovation on firm performance becomes crucial.

Green innovation, encompassing product, process, and organizational improvements with environmental benefits, has gained prominence in recent years (Triguero et al., 2013). When companies actively embrace eco-innovation, they commit to reducing the adverse impacts of their operations on the environment. This commitment extends beyond mere compliance with regulations; it involves rethinking production methods, supply chains, and product development (Hart, 1995; Gonzalez-Benito & Gonzalez-Benito, 2005).

External factors—such as customer demands, government policies, and market dynamics—play a pivotal role in shaping green innovation. Customers are increasingly conscious of the environmental impact of the products they consume. This shift in consumer behavior is driving businesses to innovate and develop green products (Burki et al., 2019). For instance, customer involvement has been found to have a positive impact on green innovation (Ma et al., 2022). Recent study by Nguyen et al., (2023) states that firms are also responding to customer pressures for greener practices, which can lead to process innovations and a positive relationship between external environmental factors and green product innovation. So, customer feedback does affect both product and process innovation. Another external factor, government policies, can significantly influence green innovation. For example, government policy has been found to have a direct promoting effect on green technology innovation (Wu et al., 2022). Policies can stimulate technological development by providing financial assistance, offering subsidies for green environmental innovation, and facilitating the transfer of knowledge and modern production systems (Farooq, 2023). Furthermore, environmental regulation encourages firms to carry out green technology innovation by increasing the environmental costs to non-green technology innovation firms and increasing the income of green technology innovation firms (Li et al., 2023). The dynamics of the market also play a crucial role in green innovation. Both domestic and foreign demand can foster the development of green innovation (Zheng et al., 2022) . However, the influence of demand considerations on green innovation can vary depending on the region and type of patent (Hou & Guo 2023). In conclusion, these external factors interact in complex ways to shape the trajectory of green innovation. It is important for businesses to understand and navigate these factors to successfully innovate in a way that is both profitable and sustainable.

Notably, these influences extend beyond the firm level; industry-wide and country-level innovation efforts can significantly impact a focal firm's performance (Hart & Ahuja, 1996). Findings (BEEPS 2013–2014 in the Balkans countries) show that investing in R&D, knowledge spillovers are positively related to firm innovation activities. The study concluded that knowledge spillovers have positive and statistically significant impact on performance, so it became evident that the firms in Balkan countries have improved their performance (Ramadani et al., 2017). Overall, these broader innovation initiatives often exert a more substantial influence than firm-level innovations (Hart & Ahuja, 1996).

The financial implications of environmental responsibility are equally compelling. Firms that proactively integrate environmental considerations into their business practices tend to achieve favorable financial results (Walley & Whitehead, 1994). Being a “green” firm is not just about altruism; it can lead to continuous innovation, access to new markets, and wealth creation.

However, the relationship between sustainability efforts and financial performance is nuanced. While many studies support the notion that eco-friendly initiatives enhance financial outcomes (Porter & Van der Linde, 1995; Gallego-Alvarez et al., 2015; Lee et al., 2015), some findings challenge this consensus. For instance, Chang and Kuo (2008) suggest that the impact varies based on a firm’s sustainability performance. Lower sustainability groups may not automatically translate sustainability practices into improved profitability. Telle (2006) even found that being environmentally friendly positively affects economic performance in specific industries, driven by consumer pressures.

Process innovation—referring to changes in production methods, supply chains, and operational procedures—holds immense potential. Yet, we lack a comprehensive understanding of which types of process innovation most significantly influence firms’ financial outcomes. Identifying these nuances is critical for strategic decision-making and sustainable business success. Despite the growing body of literature on green innovation and firm performance, a research gap persists. Previous studies have primarily focused on firm-level innovation, assuming that individual achievements and organizational leverage drive performance (give ref). However, the specific mechanisms through which process innovation affects annual performance remain less explored.

Despite the growing interest in green innovation and its impact on firm performance, there is a significant gap in understanding how different types of process innovation, particularly those related to green innovations, influence annual firm performance. Previous studies have primarily focused on firm-level innovation, assuming that individual achievements and organizational leverage drive performance. However, the specific mechanisms through which process innovation affects annual performance remain less explored. (Liu et al., 2024; Xue et al., 2019; Ha et al., 2023)

This thesis aims to fill this research gap by investigating the relation of various types of green innovation practices on firm performance. We delve into the unique characteristics of process-oriented changes and their implications for financial success. By analyzing empirical evidence and drawing insights from diverse industries, we seek to provide actionable recommendations for firms striving to balance environmental responsibility and profitability. Our study contributes to the existing body of knowledge by offering a nuanced understanding of the relationship between green innovation and firm performance.

We employ the Enterprise Surveys (ES) dataset constructed by the European Bank for Reconstruction and Development (EBRD), the European Investment Bank, and the World Bank Group. This dataset covers 2018-2020 and provides insights into the business environment and green management practices of enterprises within the EBRD's operational regions. Our dependent variable is firm performance, and our main explanatory variables are derived from eleven questions in the ES dataset capturing the green innovations of companies. We also control for various firm characteristics such as firm age, exporter status, possession of international quality certifications, ownership structure, the gender of the top manager, provision of employee training, and investment in R&D activities. Our empirical analysis extends to eleven OLS regressions. The results uncover a detailed view of how different types of green innovation are linked to company performance.

The rest of the paper is organized as follows. Chapter 2 provides a literature review, discussing the theoretical frameworks that underpin our study. Chapter 3 details the data and methodology used in our research. Chapter 4 presents the results of our empirical analysis. Finally, Chapter 5 concludes the paper, summarizing our findings and discussing their implications for both theory and practice.

Keywords: green innovation, firm performance, green process innovation, eco-innovation, sustainable business practices

CERCS: S180 Economics, econometrics, economic theory, economic systems, economic policy

2. Literature review

2.1. Green innovation and firm performance

In academic literature, “**green innovation**”, “**eco-innovation**”, “environmental innovation” and “sustainable innovation” have been used interchangeably. For instance, it has been propose that the terms can be employed interchangeably, despite sustainable innovation encompassing both ecological and social dimensions (Clark & Charter, 2007; Schiederig et al., 2012; Halila & Rundquist, 2011). Despite the varied definitions, the overarching emphasis remains on optimizing resource utilization while mitigating environmental harm (Johansson & Magnusson, 1988; Lanjouw & Mody, 1996; Pickman, 1998).

As a company embraces eco-innovation and actively strives to minimize the adverse impacts of its activities on the environment, various elements of current production, procedures, and product advancement must be reconsidered (Hart, 1995; Gonzalez-Benito & Gonzalez-Benito, 2005). External factors, such as customer demands, government regulations, and market changes, play a pivotal role in shaping green innovation. Nguyen et al. (2023) explored these influences and their impact on green product innovation. Their findings revealed a positive relationship between external environmental factors and green innovation. (Hart & Ahuja, 1996) underscore the potential benefits of adopting proactive environmental strategies. According to their research, firms that actively incorporate environmental considerations into their business practices are more likely to achieve favorable financial results. This positive correlation implies that environmental responsibility can be aligned with, and even contribute to, broader corporate success. Being a green firm is a way to get to continuous innovation, new markets, and to create wealth (Walley & Whitehead, 1994). A recent study by Liu (2023) examined the correlation between corporate green innovation and its positive impacts by analyzing firm-level data from the S&P 500 spanning the years 2001 to 2022. The study found that implementing green innovation leads to a reduction in volatility of a company's stock and credit risk, while also enhancing firm value and emission performance.

On the other hand, the relationship between sustainability efforts and financial performance is nuanced and varies depending on the sustainability performance of the firm. In the case of lower sustainability groups (firms in the lower sustainability group may not effectively allocate resources towards sustainable practices), the observed negative influence implies that simply engaging in sustainability practices may not automatically lead to improved profitability (Chang & Kuo, 2008). Green innovation have a significant impact on firm performance for larger, foreign-owned firms, firms with high labour productivity and for companies in low-technology industries. However, the impact on the performance of small, local firms, and companies in high and medium technology industries is likely to be minimal (Siedschlag & Yan, 2023). For instance, in certain industries, such as pulp and paper, being environmentally friendly can positively impact economic performance due to consumer pressures (Telle, 2006). In addition to the findings, other studies have also explored the relationship between sustainability efforts and financial performance. For instance, a study on Corporate Sustainability (CS)[1] and Financial Performance (CFP) in family and nonfamily firms found that higher CS rates are negatively associated with family firms' performance. However, this negative relationship within family firm subsamples is positively moderated by the presence of more executive members on the board of directors of family companies. (Tenuta & Cambrea, 2022).

Moreover, it is difficult for investors to understand how a company's sustainability efforts affect financial performance due to the lack of a clear link between sustainability and strategy. This suggests that companies can make the ESG[2]-to-value case more clearly (Gelb et al., 2023). Furthermore, the influence of environmental regulations on business innovation has been examined. The findings show that environmental performance is positively linked to corporate compliance with environmental legislation, as well as to corporate environmental innovation (Trevlopoulos et al., 2021). Overall, the conclusion that it pays to be green is considered premature, and replacing traditional environmental regulations with informational policies may not be effective. While, majority of the studies, including (Porter & Van der Linde, 1995), (Gallego-Alvarez et al., 2015), (Lee et al., 2015), agreed that companies can attain improved financial results by implementing eco-friendly initiatives.

These sources provide a broader understanding of the mechanisms through which sustainability efforts can influence financial performance, including the role of environmental regulations, the impact of green innovation, and the importance of linking sustainability initiatives to financial performance. It is important to note that the relationship between sustainability and financial performance can be complex and may vary depending on the specific context and industry. Therefore, firms should carefully consider their sustainability strategies and practices to ensure they are effectively contributing to their financial performance. Firms that possess unique and valuable environmentally friendly practices, technologies, or processes may gain a competitive edge. This perspective sets the stage for exploring how a firm's commitment to sustainability, reflected in its environmental strategies, can become a source of distinctiveness in the marketplace (Barney, 1991). For the good of the environment and achieving higher performance, firms need to assemble their resources and control capabilities for a long-term focus on profits instead of short-term for the favor of the environment. The application of sustainable business practices and products can assist firms to achieve an advantage in the market (Hart, 2005), (Hart and Dowell, 2011).

The backgrounds, experiences, and psychological characteristics of top management significantly shape organizational decision-making, particularly regarding environmental responsibility (Wu & Tham, 2023). Executives' personal attributes at the highest levels of leadership play a vital role in

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[1] Corporate sustainability is a concept that is still evolving, but it can be defined around its environmental, social, and economic constitutive pillars with the purpose to provide equal opportunities to future generations (Pazienza et al., 2022). It is a holistic approach to conducting business while achieving long-term environmental, social, and economic sustainability (Vanderbilt University, 2023).

[2] According to Vanderbilt University, (2023) ESG IS core components or fundamental aspects of corporate sustainability are commonly referred to as environmental, social, and governance.

formulating and executing a firm's approach to sustainability initiatives. Therefore, fostering a culture of environmental responsibility and innovation within top management is essential for achieving sustainable business success. (Hambrick & Mason, 1984)

Managers who prioritize environmental concerns are likely to invest more time, attention, and resources in green initiatives. This heightened focus on sustainability could enhance the potential for green innovations to positively influence company performance, as suggested by Bansal & Roth (2000), Papagiannakis & Lioukas (2012), and Papagiannakis et al. (2014). As we already know that firm performance and green innovation are positively linked (Mulaessa & Lin, 2021) the resource-based theory encourages firms to engage in green innovation practices which also may lead to higher profit. While proactive environmental strategies alone may not directly impact firm performance, the significant role of technological eco-innovation as a mediator suggests that firms' effective utilization of capabilities in developing eco-innovations contributes to improved performance, emphasizing the importance of integrating such innovations into business activities for sustained competitive advantage (Ryszko, 2016).

While the resource-based theory encourages firms to engage in green innovation practices, the effect on performance and profits may vary due to several factors. For instance, the degree of market acceptance of green products can significantly influence the profitability of these innovations (Chen et al., 2006). Moreover, when we consider innovations that result in decreased energy and resource usage, it’s clear that being eco-friendly is financially beneficial. However, when we shift our focus to innovations designed to minimize externalities like harmful substances and pollution of air, water, noise, and soil, it appears that being eco-friendly doesn’t immediately translate into profits. While these eco-friendly measures may become profitable over time as environmental regulations improve, they don’t provide immediate financial returns when such regulations are viewed as external constraints (Ghisetti & Rennings, 2014). Furthermore, it has also be indicated that innovations that don’t enhance a company’s resource efficiency don’t yield profitable returns. Conversely, innovations that boost a company’s resource efficiency - measured in terms of material or energy use per output unit - positively influence profitability. This beneficial outcome is observed for both innovations prompted by regulations and those that are voluntary. However, the impact is more pronounced for innovations driven by regulatory requirements (Rexhäuser & Rammer, 2014).

Overall, it can be said that green innovation captures competitive advantage, which ultimately improves firm performance (Clarkson et al., 2011). Sustainable development makes firms innovative with the improvement of environmental and economic performance (Triguero et al., 2013). For conclusion, managerial concern moderates the relationship between green process innovation and firm performance positively (Tang et al., 2018).

2.2. Effects of green process innovation on firm performance

Process innovation refers to the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment, and/or software. Process innovation can lead to more efficient resource use, reduction of waste, and improved quality of products, all of which can enhance firm performance. It's important to note that process innovation is closely linked to product innovation. As firms innovate and improve their processes, they often develop new and improved products as a result. This is because the enhanced processes can enable the creation of products that were previously impossible to produce, or improve the quality of existing products (OECD, 2005). Furthermore, the efficiency gains from process innovation can reduce production costs, allowing firms to invest more in product innovation (Jain, 2023). Therefore, product and process innovation are interconnected, each driving the other in a virtuous cycle of continuous improvement and competitive advantage.

The relationship between process innovation and firm performance has been widely studied and has been found out that process innovation positively affects firm performance by improving efficiency and productivity (Evangelista and Vezzani, 2010; Gunday et al., 2011). In addition to process innovation, green product innovation also affects firm performance positively (Tang et al., 2018). In the context of green innovation, process innovation can take the form of implementing new or improved methods of production that are environmentally friendly. Such innovations can lead to reduced environmental impact and improved efficiency, which can in turn enhance firm performance. For example, Horbach (2008) found that eco-innovations, particularly those related to process innovation, can lead to cost savings and improved environmental performance. However, the relationship between green process innovation and firm performance is not always straightforward. It can be influenced by various factors such as firm size, industry, and market conditions. The impact of green process innovation on economic performance is more significant for large firms than for small and medium-sized enterprises (SMEs) (Cainelli et al. (2012). At the same time, it has been indicated that product, process, marketing, and organizational innovations were all positively and significantly associated with the performance of micro and small manufacturing firms (Ayinaddis, 2023). Among these, product innovation exhibited the most pronounced positive impact on firm performance, followed by process and organizational innovations, respectively.

Recent studies have provided further evidence of the positive relationship between process innovation and firm performance. A study conducted on a sample of Chinese A-share-listed firms from 2010 to 2021 found that both substantive and strategic green innovations significantly impact firms' financial and environmental performance. Specifically, substantive green innovation leads to a significant improvement in financial performance, while strategic green innovation weakens financial performance (Liu et al., 2024). Moreover, the effect of green process innovation on firm performance can also be contingent on the firm's strategic orientation. Firms with a proactive environmental strategy[3] are more likely to benefit from green process innovation (Aragón-Correa & Sharma, 2003). This suggests that the alignment of green process innovation with the firm's overall strategy is crucial for realizing its potential benefits.

While green process innovation can potentially enhance firm performance, its impact can vary depending on various factors. Therefore, firms need to carefully consider these factors when implementing process innovations.

[3] The organization that implements environmental protection measures with its motivation, it is considered as a proactive environmental strategy (Forés, 2019; Hunt & Auster 1990).

3. Data and Methodology

3.1. Data

To conduct the research, we employ the Enterprise Surveys (ES) dataset constructed by the European Bank for Reconstruction and Development (EBRD), the European Investment Bank, and the World Bank Group. This dataset is the latest wave of the Business Environment and Enterprise Performance Surveys and covers 2018-2020. The aim of the ES is to obtain insights from enterprises within the EBRD's operational regions (and beyond) regarding the environment where these enterprises conduct their business. Interviews conducted with companies in the manufacturing and services sectors help to capture their perceptions of the main barriers to company growth. In addition to the questions that enable measuring different company characteristics, the survey also provides insights into the effects of a country's business environment on its international competitiveness. The ES develops reliable indicators of the business environment which are compatible across various countries. An important factor that makes the ES dataset suitable for our study is that it introduces a new Green Economy module which enables capturing green innovation practices of companies.

Following the previous literature (Muravyev et al., 2010; Al-Matari et al., 2014; Asogwa & Chike, 2023;), the dependent variable of our study capturing firm performance is labor productivity. We have constructed the dependent variable by dividing the total annual sales of a company by the number of its permanent, full-time employees and then taking the natural logarithm. As the main explanatory variables, we utilize eleven questions from the ES dataset capturing the green innovation practices of companies. Specifically, seven of these explanatory variables concern whether, during the last three years, companies have adopted on-site green energy generation, energy management, waste minimization, recycling and waste management, measures controlling air pollution, other pollution control measures, water management, and energy efficiency measures. The remaining four main explanatory variables are derived from the questions on whether the firms have improved their heating and cooling systems or upgraded their machinery, vehicles, and lighting systems during the last three years.

We also check various company characteristics that could influence firm performance. In this spirit, we account for the age of the firm, measured in logs, since older companies may benefit from accumulated experience and established market presence, leading to enhanced performance (Coad et al., 2013; Rossi, 2015; Williams et al., 2016; Coad et al., 2018). A binary variable of exporter status is another control variable, as companies that export products and services often enjoy a productivity boost from exposure to international markets and competition, which contributes to improved performance (Abor, 2011; Pham, 2015; Munch & Schaur, 2018). We further consider whether a firm possesses international quality certifications because it might indicate superior quality and operational standards, thereby elevating firm reputation and performance (Islam et al., 2016; Hernandez-Vivanco et al., 2019; Ali & Yusuf, 2021).

The inclusion of ownership structure, distinguishing foreign and domestic ownership, is vital as foreign-owned companies may have access to richer resources, cutting-edge technology, and management practices, all of which can be positively associated with improved firm performance (Aydin et al., 2007; Weche Gelubcke, 2013; Williams et al., 2016; Carney et al., 2019; Siedschlag & Yan, 2023). Additionally, the gender of the top management is taken under consideration, recognizing that leadership diversity, including the presence of female managers, can contribute to firm performance by bringing different viewpoints and approaches to management styles (Smith et al., 2006; Dezsö & Ross, 2012; Khalife & Chalouhi, 2013; Peni, 2014; Liu et al., 2014; Arora, 2022).

We also control for employee training as it can significantly boost employee skills and productivity, contributing to better firm performance (Bartel, 1994; Molina & Ortega, 2003; Elnaga & Imran, 2013; Colombo & Stanca, 2014). Finally, investment in research and development (R&D) activities is also taken into account because R&D plays a vital role in driving a firm's success by enabling technological advancements and improving products and processes, thereby enhancing company performance (Belderbos et al., 2004; Sharma, 2012; Rahman & Howlader, 2022; Tung et al., 2022).

Table 1 provides comprehensive details about the variables utilized in this study, including their descriptions and any modifications made to the original values. After the underlying selection of variables, the dataset is cleaned by removing the observations where the values of selected variables were either "Don't know" or "Does not apply". The cleaning process resulted in the refined dataset including 3 801 observations.

Table 1. Detailed description of the variables.

Variable	Description
	Dependent variable
Firm Performance (in logs)	Logarithm of the establishment's total annual sales divided by the number of its permanent, full-time employees at the end of last fiscal year.
	Explanatory variables
Vehicle Upgrade (dummy)	Over last 3 years, whether the establishment adopted upgrades of vehicles, vessels, aircraft in the fleet. 1="YES", 0="NO".
Machinery Upgrade (dummy)	Over last 3 years, whether the establishment adopted machinery upgrades. 1="YES", 0="NO".
Heating & Cooling Improvements (dummy)	Over last 3 years, whether the establishment adopted heating and cooling improvements. 1="YES", 0="NO".
Ecoenergy Generation (dummy)	Over last 3 years, whether the establishment adopted more climate-friendly energy generation on-site. 1="YES", 0="NO".
Energy Management (dummy)	Over last 3 years, whether the establishment adopted energy management. 1="YES", 0="NO".
Waste Management (dummy)	Over last 3 years, whether the establishment adopted waste minimization, recycling and waste management. 1="YES", 0="NO".

Air Pollution Control (dummy)	Over last 3 years, whether the establishment adopted air pollution control measures. 1=”YES”, 0=”NO”.
Water Management (dummy)	Over last 3 years, whether the establishment adopted water management. 1=”YES”, 0=”NO”.
Lighting Improvements (dummy)	Over last 3 years, whether the establishment adopted improvement of lighting systems. 1=”YES”, 0=”NO”.
Other Pollution Control Measures (dummy)	Over last 3 years, whether the establishment adopted other pollution control measures. 1=”YES”, 0=”NO”.
Energy Efficiency (dummy)	Over last 3 years, whether the establishment adopted any measures to enhance energy efficiency. 1=”YES”, 0=”NO”.
	Control variables
Firm Age (in logs)	Logarithm of the number of years since when the establishment began to operate.
R&D (dummy)	During last fiscal year, whether the establishment spent on R&D (excluding market research), 1=”YES”, 0=”NO”.
Foreign Ownership (dummy)	Company is considered as a foreign-owned company, if at least 10% of the company’s equity shares are owned by private foreign individuals, companies or organizations.
International Certification (dummy)	Does establishment have an internationally-recognized quality certification? 1=”YES”, 0=”NO”.
Training (dummy)	Formal training programs for permanent, full-time employees in last fiscal year. 1=”YES”, 0=”NO”.
Female Manager (dummy)	Is the top manager female? 1=”YES”, 0=”NO”.
Exporter (dummy)	If direct exports of the company are bigger than 0%, then Exporter = 1. Otherwise, Exporter = 0.

Table 2 contains descriptive statistics for the variables in the refined dataset. Around half of the companies in the dataset reported that they have adopted green innovation practices, such as upgrading vehicles or machinery, improving heating and cooling, adopting energy and waste management measures, and enhancing their energy efficiency. The most popular green innovation practice employed by companies is upgrading machinery, as 71% of firms reported. On the other hand, only 24% of companies reported adopting more eco-friendly energy generation on-site and control measures for other pollution than air pollution. Adopting air pollution control measures was the third least popular green innovation practice among companies, as slightly less than one-third of companies reported adopting the underlying control measures. Table 2 further reveals that the dataset predominantly consists of domestic companies, as the portion of foreign-owned firms is only 12%. Around 47% of companies possess internationally recognized quality certificates, and 44% have exporter status. Companies in which the top manager is female constitute only 15% of the observations.

Table 2. Descriptive statistics of the variables.

Variables/Statistics	N	Mean	Standard Deviation	Min	Max
Firm Performance (logs)	3 801	13.39	2.54	5.54	25.85
Vehicle Upgrade	3 801	0.52	0.50	0	1
Machinery Upgrade	3 801	0.71	0.46	0	1
Heating & Cooling Improvements	3 801	0.55	0.50	0	1
Ecoenergy Generation	3 801	0.24	0.42	0	1
Energy Management	3 801	0.52	0.50	0	1
Waste Management	3 801	0.57	0.50	0	1
Air Pollution Control	3 801	0.28	0.45	0	1
Water Management	3 801	0.36	0.48	0	1
Lighting Improvements	3 801	0.67	0.47	0	1
Other Pollution Control Measures	3 801	0.24	0.43	0	1
Energy Efficiency	3 801	0.56	0.50	0	1
R&D	3 801	0.52	0.50	0	1
Training	3 801	2.84	0.77	0	1
Firm Age (logs)	3 799	0.55	0.50	0.00	5.32
Exporter	3 801	0.44	0.50	0	1
International Certification	3 801	0.47	0.50	0	1
Foreign Ownership	3 801	0.12	0.33	0	1
Female Manager	3 801	0.15	0.36	0	1

Figure 1, the clustered bar plot of mean green innovation practices by industry, reveals distinct engagement patterns across different sectors. Each bar cluster represents a specific green innovation practice, showing the proportion of firms engaged in that practice within the top five industries. The least common green innovation practices across all industries are adopting more eco-friendly energy generation on-site and other pollution control measures. Meanwhile, upgrading machinery, improving lighting systems, and managing waste are the green innovation practices companies engage with the most in the rubber and plastics products and manufacturing industries. In the non-metallic mineral products industry, firms adopted measures to improve energy management and efficiency alongside vehicle and machinery upgrades, lighting system improvements, and waste minimization. In the food and beverages industry, companies demonstrate a high engagement with waste and water management, while the adoption rates of pollution control measures remain comparatively lower. This visualization provides valuable insights into the varying priorities and challenges different industries face in adopting green innovation practices.

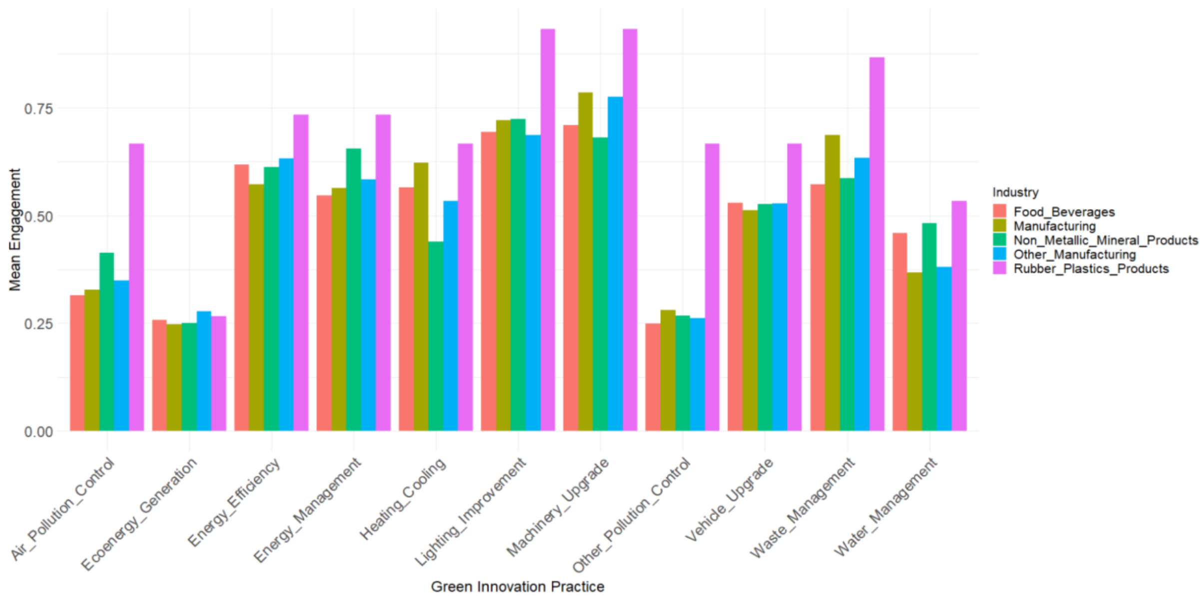

Figure 1. Clustered bar plot of mean green innovation practices by industry.

3.1.1. Correlation matrix

The correlation matrix presented in Figure 2 illustrates the correlation coefficients between the variables of the study.

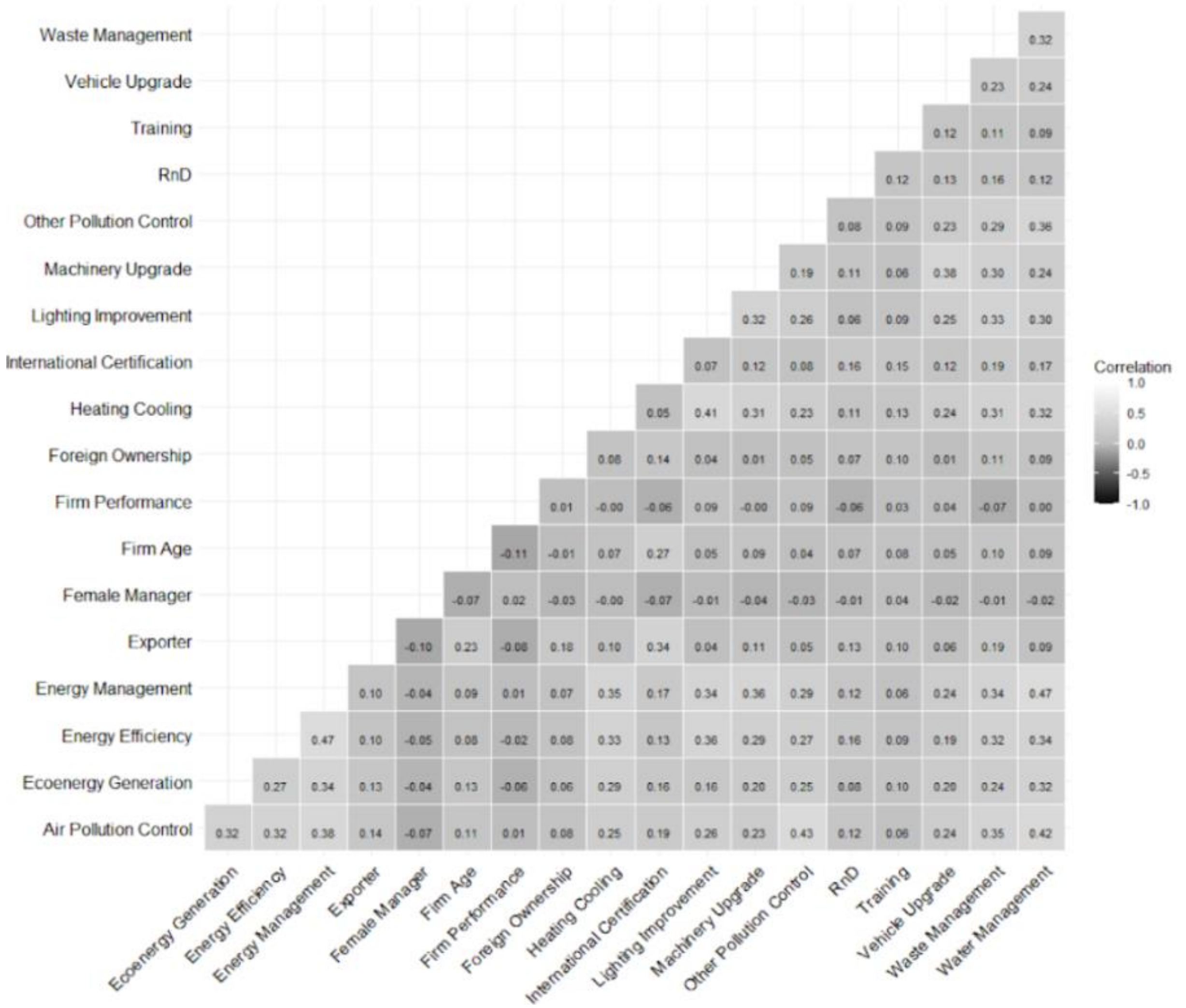

Figure 2. Correlation coefficient heatmap.

The fact that the absolute values of correlation coefficients are below 0.5 suggests the absence of multicollinearity between the variables.

3.1.2. Green innovation practices by country

Significant variations in adopting different green innovation practices across various countries were observed, as illustrated in Figure 3.

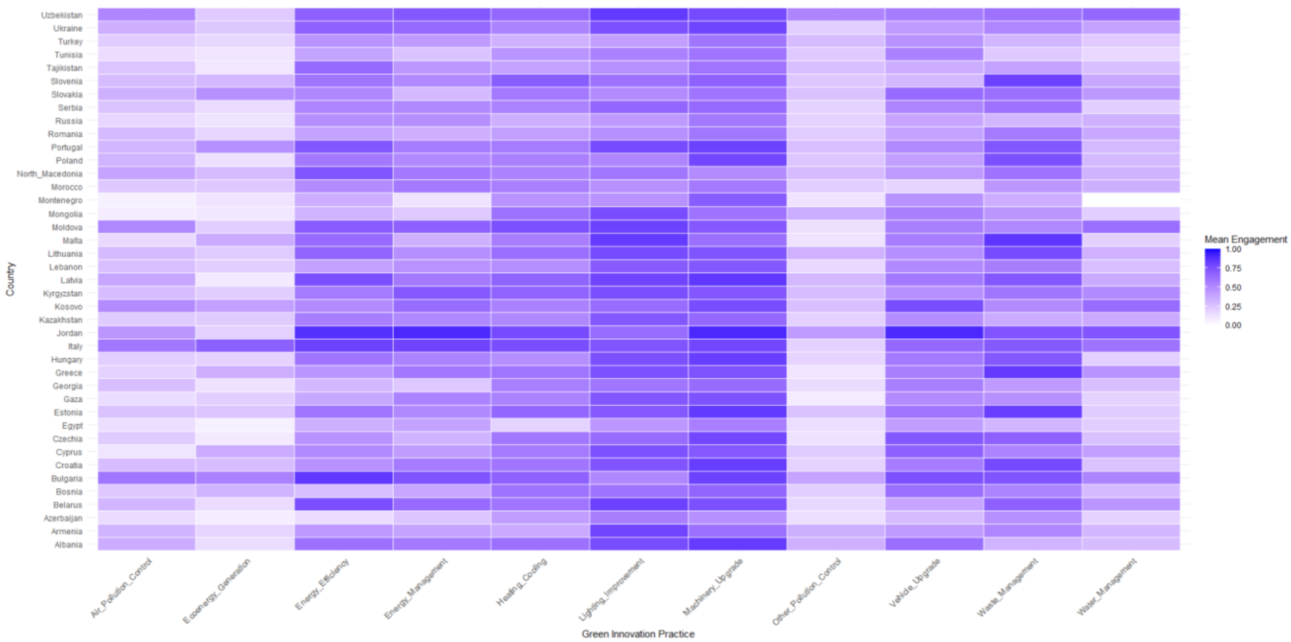

Figure 3. Heatmap of mean green innovation practices by country.

Measures taken to control air pollution, generate eco-friendly energy on-site, and efficiently manage water consumption are the least common among all countries compared to other green innovation practices. Conversely, companies in many countries primarily focus on upgrading their machinery and vehicles, improving lighting systems and enhancing energy efficiency, to reduce their environmental footprint. Improvements in heating and cooling systems, energy management, and waste minimization also tend to be common across countries, with many showing moderate to high engagement in these practices. Overall, the heatmap in Figure 3 further highlights the diversity in green innovation practices across countries, with some excelling in specific areas while others lag

3.2. OLS

We have selected the Ordinary Least Squares (OLS) as the analytical technique to conduct our estimations due to its relevance and ease of interpretation. OLS is particularly well-suited for handling both continuous and dummy variables within the ES dataset, making it suitable for exploring the relationship between green innovation practices and firm performance. This approach enables us to account for various characteristics at the firm level and derive insightful conclusions. While potential issues such as endogeneity, which we acknowledge in the Conclusion section, might challenge the results of our estimations, OLS provides a starting point for our investigation. The models estimated using OLS are structured as follows:

$$Log(Firm\ Performance_{i,j}) = \beta_0 + \beta_1 X_{m.ij} + \beta_2 Y_{i.j} + \beta_3 C_{i.j} + \beta_4 Z_{i.j} + \varepsilon_{m,ij}$$

In the analytical expression given above β_0 represents the intercept. Indices i and j point to company i in country j. $X_{m,ij}$, where m changes from 1 to 11, corresponds to the aforementioned eleven main explanatory variables of our study of various green innovation practices of companies. $Y_{i.j}$ denotes company-level control variables, which are firm age (in logs), R&D, training, exporter, international certification, foreign ownership and female manager. Variables $C_{i.j}$ and $Z_{i.j}$ capture country and industry dummies we have introduced to control for country and industry level effects, respectively. $\varepsilon_{k,ij}$ represents the error term.

3.3. KDE

To demonstrate how firm performance is distributed among companies involved in green innovation practices compared to those that are not, we will use The Kernel Density Estimate (KDE). To conduct this comparison, companies were considered engaged in green innovation practices if they had implemented at least one type of such practices in the past three years. Conversely, companies that had not adopted any of the green innovation practices were classified as not engaged.

4. Results

4.1. OLS

Our empirical analysis extends to eleven OLS regressions, with the findings detailed in Table 3. The results uncover a detailed view of how different green innovation practices are linked to company performance. To begin with, firms that have upgraded their vehicles, vessels, or aircraft in the last three years exhibit the most substantial performance boost of 11.2%. This highlights the benefits of fuel efficiency, lower emissions, and better logistics from newer transport means, which in turn enhance company performance. Similarly, the implementation of on-site climate-friendly energy generation is linked to a noticeable and statistically significant 10.8% improvement in firm performance. This improvement is likely due to lower energy expenses, less reliance on external energy supplies, and a better public image thanks to the use of renewable energy, all contributing to better firm performance.

The adoption of energy management practices and air pollution control measures also led to significant gains in performance, 9.8% and 9%, respectively. The introduction of other pollution control measures is associated with an 8.6% rise firm performance, which is statistically significant at the 10% level. These outcomes emphasize the comprehensive advantages of optimizing energy consumption and minimizing environmental harm. The positive effects observed may be attributed to enhanced operational efficiency, healthier workspaces, and improved reputation, each aiding in increased labor productivity and, thereby, company performance.

Firms that focus on boosting energy efficiency and enhancing their lighting systems can anticipate increases in performance of 7.9% and 8.7%, respectively. These improvements are likely due to the direct savings on energy costs. Moreover, better lighting can lead to higher worker productivity through improved working conditions. Investments in better heating and cooling systems is linked with a statistically significant 7.1% increase in labor productivity, underscoring the importance of optimal climate control for employee comfort and potential productivity boosts.

Interestingly, our analysis shows no significant relationship between firm performance and the implementation of water and waste management strategies or machinery upgrades. The lack of significance in the coefficient of machinery upgrades is particularly surprising because fleet vehicle upgrades contribute the most to firm performance. The discrepancy in the significance levels between vehicle and machinery upgrades could be due to their definitions in the ES dataset. Specifically, the ES dataset defines a vehicle as a "machine that transports people or cargo", covering a wide range of vehicles including motor vehicles, rail vehicles , watercraft, wagons, bicycles, and aircraft. In contrast, machinery upgrades are described as the modernization of compressed air systems and other industry-specific production process optimizations. The relatively narrow scope of machinery upgrades compared to the broad categorization of vehicle upgrades might explain the insignificant coefficient obtained for machinery upgrades.

Table 3. OLS estimation results.

Dependent Variable: Firm Performance											
Machinery Upgrade	0.069 (0.042)										
Vehicle Upgrade		0.112*** (0.039)									
Air Pollution Control Measures			0.09** (0.044)								
Lighting Improvements				0.087** (0.041)							
Heating & Cooling					0.071* (0.039)						
Energy Management						0.098** (0.04)					
Water Management							0.036 (0.041)				
Other Pollution Control Measures								0.086* (0.045)			
Ecoenergy Generation									0.108** (0.046)		
Waste Management										0.035 (0.041)	
Energy Efficiency											0.079** (0.04)
R&D	-0.008 (0.039)	-0.014 (0.039)	-0.010 (0.039)	-0.008 (0.039)	-0.009 (0.039)	-0.010 (0.039)	-0.006 (0.039)	-0.009 (0.039)	-0.007 (0.039)	-0.007 (0.039)	-0.013 (0.039)
Firm Age	0.053** (0.027)	0.053** (0.027)	0.051* (0.027)	0.053* (0.027)	0.052* (0.027)	0.051* (0.027)	0.053* (0.027)	0.053* (0.027)	0.052* (0.027)	0.055** (0.027)	0.052* (0.027)
Training	0.095** (0.04)	0.089** (0.04)	0.094** (0.04)	0.091** (0.04)	0.091** (0.04)	0.091** (0.04)	0.095** (0.04)	0.093** (0.04)	0.09** (0.04)	0.095** (0.04)	0.091** (0.04)
Exporter	0.129*** (0.044)	0.128*** (0.044)	0.127*** (0.044)	0.131*** (0.044)	0.127*** (0.044)	0.128*** (0.044)	0.13*** (0.044)	0.13*** (0.044)	0.127*** (0.044)	0.13*** (0.044)	0.13*** (0.044)
International Certification	0.25*** (0.044)	0.244*** (0.044)	0.244*** (0.044)	0.25*** (0.044)	0.255*** (0.044)	0.243*** (0.044)	0.25*** (0.044)	0.249*** (0.044)	0.248*** (0.044)	0.251*** (0.044)	0.249*** (0.044)
Foreign Ownership	0.429*** (0.059)	0.429*** (0.059)	0.421*** (0.059)	0.424*** (0.059)	0.421*** (0.059)	0.419*** (0.059)	0.423*** (0.059)	0.423*** (0.059)	0.421*** (0.059)	0.424*** (0.059)	0.421*** (0.059)

Dependent Variable: Firm Performance											
Female Manager	-0.138** (0.054)	-0.139*** (0.054)	-0.137** (0.054)	-0.136** (0.054)	-0.138*** (0.054)	-0.14*** (0.054)	-0.14*** (0.054)	-0.137** (0.054)	-0.137** (0.054)	-0.14*** (0.054)	-0.137** (0.054)
Countries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	12.103*** (0.363)	12.103*** (0.362)	12.145*** (0.361)	12.094*** (0.363)	12.134*** (0.362)	12.126*** (0.361)	12.163*** (0.362)	12.148*** (0.361)	12.143*** (0.361)	12.132*** (0.363)	12.136*** (0.362)
Observations	3799	3799	3799	3799	3799	3799	3799	3799	3799	3799	3799
R2	0.806	0.807	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806
Adjusted R2	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803
Residual Std. Error (df=3728)	1.13	1.129	1.13	1.13	1.13	1.129	1.13	1.13	1.13	1.13	1.13
F Statistic	221.774***	222.191***	221.885***	221.903***	221.820***	222.016***	221.631***	221.841***	221.977***	221.631***	221.864***

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Standard errors are provided in parentheses.

4.2. KDE

The KDE plot shown in Figure 4.

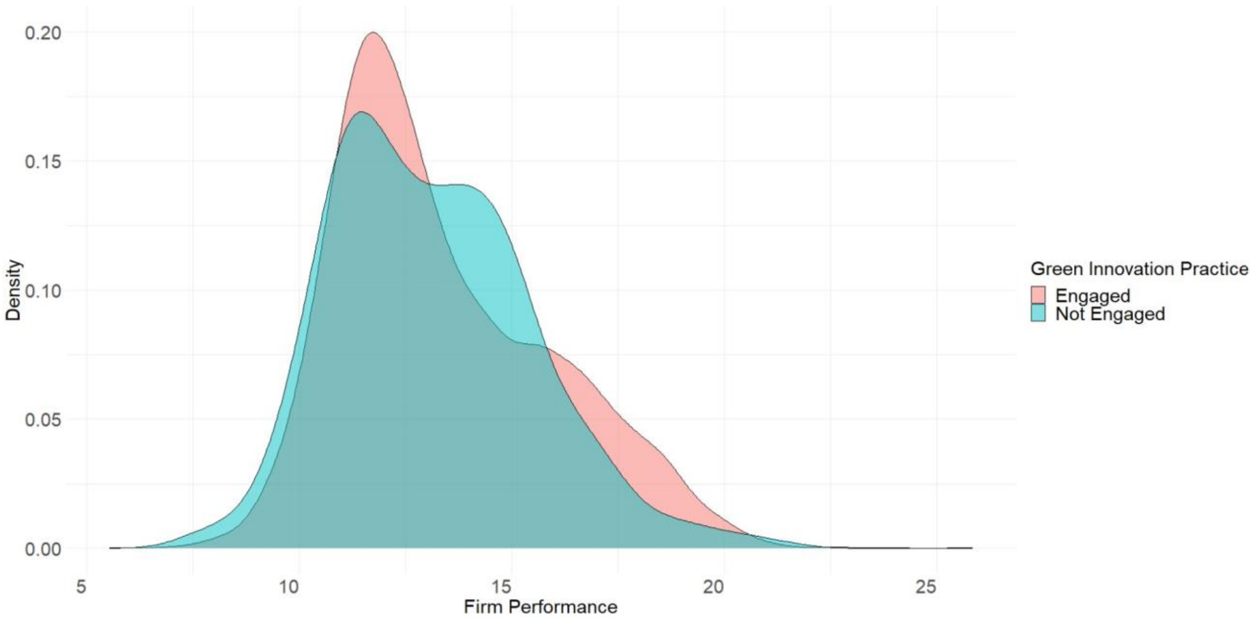

Figure 4. KDE plot of firm performance.

Figure 4 indicates that the density peak for companies engaged in green innovation practices is higher and more concentrated around a performance value of roughly 12, implying that a larger fraction of such companies achieve performance levels near this value. In contrast, companies not engaged in green innovation practices have a lower density peak at the same performance level, indicating a wider range of firm performance outcomes. The right tail of the distribution for companies adopting green innovation practices extends further, suggesting that some of these firms achieve significantly higher performance levels than their non-engaged counterparts. This indicates that adopting green innovation practices is associated with a concentration of companies at higher performance levels, including a few that reach very high performance levels. On the other hand, companies not involved in green innovation practices have a more diverse range of performance levels, with fewer demonstrating higher performance.

Additionally, the KDE plots of the residuals from each OLS model, as shown in Figure 5, indicate that the residuals are symmetrically distributed around zero with single peaks and smooth tails. This suggests that the residuals are approximately normally distributed. The normality of residuals corroborates the validity of our OLS assumptions, indicating that our models are well-fitted and the observed relationships between green innovation practices and firm performance are reliable. The absence of extreme deviations or multiple peaks in the KDE plots further reassures that our results are not driven by outliers or model misspecifications.

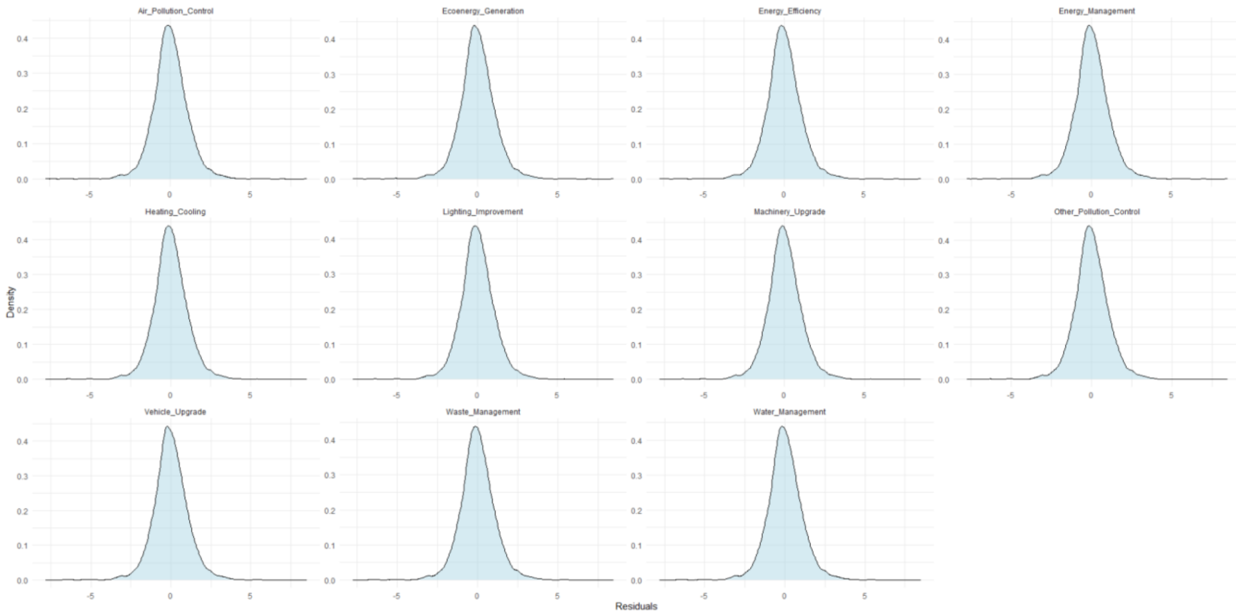

Figure 5. Kernel density plot of residuals for each OLS model.

4.3. Interaction Effects

We estimated additional OLS models with different interaction terms to deepen our understanding of how various combinations of green innovation practices jointly relate to firm performance. Variables capturing green innovation practices were grouped for interaction based on their inherent synergies and the potential for enhanced benefits when combined. Notably, we investigated the interactions between eco-friendly energy generation on-site, energy management, and energy efficiency (results are in Table 4 under Appendices), upgrades to machinery and vehicles (Table 5), practices of waste management alongside water management (Table 6), and efforts in air pollution control paired with other pollution control measures (Table 7). Despite the logical foundation for the underlying interactions, none of the interaction terms produced statistically significant coefficients in our estimations.

The triplet of eco-friendly energy generation, energy management, and energy efficiency was expected to significantly boost firm performance, as each has independently shown a positive link to company performance. The absence of a significant interaction implies that the underlying practices may have overlapping benefits, resulting in diminishing returns when implemented jointly. Firms might see optimal performance improvements by undertaking one of these practices, making additional practices redundant to be implemented together.

Regarding the interaction between machinery and vehicle upgrades, it was anticipated that concurrent upgrades in both machinery and vehicles would boost operational efficiency and productivity. The finding of a non-significant interaction coefficient might suggest that the advantages derived from updating machinery and vehicles are independent and do not synergize to produce additional performance gains for companies. This could be due to the distinct operational areas influenced by each type of upgrade, with machinery focusing on production processes and vehicles on logistics and transportation.

When analyzing the interaction between waste and water management, the expectation was that a holistic approach to resource management would significantly elevate firm performance. The failure to find a significant interaction coefficient might indicate the independent benefits of waste and water management practices. While each may contribute to cost reductions and compliance with regulations on its own, their simultaneous implementation might not yield benefits beyond those achievable through individual practices.

Lastly, the interaction between air pollution control and other pollution control measures was explored to assess if a comprehensive approach to pollution management would be positively linked to firm performance. The absence of a significant interaction term coefficient suggests that, although each pollution control measure is advantageous by itself, their collective application does not relate to significantly enhanced performance. This may be because different pollution control approaches target varied environmental issues, and their benefits do not necessarily accumulate when combined.

Despite the absence of significant joint effects, these observations underscore the complexity inherent in implementing multiple green innovation practices. While individual practices can be beneficial, their combined effects do not always align straightforwardly. Future investigations could delve deeper into these dynamics, examining various contexts and strategies for implementing green innovation practices to understand their interactions better.

5. Conclusion

This research has explored the relationship between firm performance and different types of green innovation practices, utilizing the comprehensive ES dataset spanning from 2018 to 2020. Our OLS regression analysis has revealed that certain types of green innovation practices are more positively and significantly associated with firm performance than others. Notably, upgrades to vehicles, vessels, or aircraft, alongside implementation of on-site climate-friendly energy generation, have emerged as the most influential green innovation practices, boosting firm performance by 11.2% and 10.8%, respectively. On the other hand, initiatives undertaken to enhance energy efficiency and improve heating and cooling systems have revealed comparatively smaller positive effects on firm performance – 7.9% and 7.1%, respectively. Moreover, the adoption of water and waste management measures, and machinery upgrades did not demonstrate statistically significant links to firm performance, underscoring the varying efficacy of different types of green innovation practices in enhancing company performance. Furthermore, the analysis of interactions between various types of green innovation practices revealed statistically insignificant relationships with firm performance, underscoring the complex interplay between the underlying practices.

Overall, our findings highlight the business case for sustainability, demonstrating that green innovations are not just ethical choices but strategic business decisions that can lead to improved firm performance. By prioritizing green initiatives that are most closely aligned with enhanced performance outcomes, companies can leverage these insights to optimize their green innovation practices. Policymakers can use the results to create supportive frameworks and incentives that encourage firms to adopt more sustainable practices, contributing to broader environmental objectives while enhancing economic competitiveness.

Nevertheless, we also acknowledge several limitations of our study, such as the reliance on self-reported data from the ES dataset, which could introduce biases, as firms may overstate their commitment to green practices. Future research could utilize more accurate and unbiased data sources to explore the link between green innovation practices and firm performance. Additionally, while the current study examined the interaction of green innovation practices, future studies could enrich our understanding by exploring these interactions across various contexts and utilizing more granular data. As an example, subsequent research might investigate the role of regional policies in influencing the outcomes of the interactions between green innovation practices. Employing qualitative research methodologies such as case studies could be another suggestion for future studies and help deepen the understanding of the mechanisms through which green innovation practices are pronounced in company performance. Moreover, by utilizing longitudinal data, further studies could shed light on the long-term relationship between green innovation practices and firm performance. Furthermore, the results of this study might face challenges due to possible endogeneity, wherein unobserved factors might influence both the adoption of green innovation practices and firm performance. For instance, companies with a proactive corporate mindset may be more predisposed to adopt green innovation practices and, at the same time, achieve higher performance, leading to a misleading association. Future studies could tackle this potential issue by utilizing instrumental variable regression to control for unobserved factors.

In conclusion, our study emphasizes the mutual benefits of environmental stewardship and economic efficiency. As the global community continues to tackle climate change and resource scarcity, our empirical findings offer a path forward for corporates to leverage sustainability as a competitive advantage. Businesses can improve their performance by adopting strategic green innovation practices, while contributing to a more sustainable future.

Appendices

Table 4. Interaction effects of energy management, ecoenergy generation, and energy efficiency on firm performance.

Dependent variable: Firm Performance	
Energy Management	-0.012 (0.073)
Ecoenergy Generation	0.193 (0.136)
Energy Efficiency	-0.014 (0.062)
Energy Management x Ecoenergy Generation	-0.096 (0.185)
Energy Management x Ecoenergy Efficiency	0.146 (0.097)
Ecoenergy Generation x Energy Efficiency	-0.114 (0.19)
Energy Management x Ecoenergy Generation x Energy Efficiency	0.059 (0.236)
R&D	-0.016 (0.039)
Firm Age	0.049* (0.027)
Training	0.087** (0.04)
Exporter	0.127*** (0.045)
International Certification	0.238*** (0.044)
Foreign Ownership	0.414*** (0.059)
Female Manager	-0.141*** (0.054)
Countries	Yes
Industries	Yes
Constant	12.125*** (0.362)
Observations	3,799
R2	0.807
Adjusted R2	0.803
Residual Std. Error	1.129 (df = 3722)
F Statistic	204.652*** (df = 76; 3722)

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Standard errors are provided in parentheses.
Source: Authors' calculations.

Table 5. Interaction effects of machinery and vehicle upgrades on firm performance.	
Dependent variable: Firm Performance	
Machinery Upgrade	0.006 (0.054)
Vehicle Upgrade	0.046 (0.083)
Machinery Upgrade x Vehicle Upgrade	0.074 (0.095)
R&D	-0.016 (0.039)
Firm Age	0.052* (0.027)
Training	0.088** (0.04)
Exporter	0.127*** (0.044)
International Certification	0.243*** (0.044)
Foreign Ownership	0.43*** (0.059)
Female Manager	-0.138** (0.054)
Countries	Yes
Industries	Yes
Constant	12.099*** (0.363)
Observations	3,799
R2	0.807
Adjusted R2	0.803
Residual Std. Error	1.129 (df = 3726)
F Statistic	215.978*** (df = 72; 3726)

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Standard errors are provided in parentheses.
Source: Authors' calculations.

Table 6. Interaction effects of waste and water managements on firm performance.	
Dependent variable: Firm Performance	
Water Management	-0.041 (0.075)
Waste Management	-0.001 (0.049)
Water Management x Waste Management	0.101 (0.089)
R&D	-0.009 (0.039)
Firm Age	0.053* (0.027)
Training	0.092** (0.04)
Exporter	0.129*** (0.045)
International Certification	0.248*** (0.044)
Foreign Ownership	0.42*** (0.059)
Female Manager	-0.14*** (0.054)
Countries	Yes
Industries	Yes
Constant	12.150*** (0.363)
Observations	3,799
R2	0.806
Adjusted R2	0.803
Residual Std. Error	1.130 (df = 3726)
F Statistic	215.481*** (df = 72; 3726)

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Standard errors are provided in parentheses.
Source: Authors’ calculations.

Table 7. Interaction effects of air and other pollution control measures on firm performance.

Dependent variable: Firm Performance	
Air Pollution Control	0.095 (0.058)
Other Pollution Control	0.097 (0.068)
Air Pollution Control x Other Pollution Control	-0.084 (0.097)
R&D	-0.012 (0.039)
Firm Age	0.05* (0.027)
Training	0.092** (0.04)
Exporter	0.126*** (0.045)
International Certification	0.243*** (0.044)
Foreign Ownership	0.419*** (0.059)
Female Manager	-0.137** (0.054)
Countries	Yes
Industries	Yes
Constant	12.139*** (0.361)
Observations	3,799
R2	0.807
Adjusted R2	0.803
Residual Std. Error	1.130 (df = 3726)
F Statistic	215.756*** (df = 72; 3726)

Note: *p < 0.1; **p < 0.05; ***p < 0.01. Standard errors are provided in parentheses.

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Resümee

Pealkiri: Roheinnovatsioonipraktikate seos ettevõtete tulemuslikkusega BEEPS andmete põhjal

Selles väitekirjas uuritakse, kuidas on arengumaade roheinnovatsioonipraktikad seotud sealsete ettevõtete tulemuslikkusega. Selleks kasutatakse World Bank Enterprise Surveys andmeid aastatest 2018 kuni 2020. Seoste uurimiseks kasutati 11 harilikku vähimruutude regressiooni. Andmeanalüüsi tulemil leiti, et roheinnovatsioon oluliselt suurendab ettevõtete tulemuslikkust. Nimelt, suurima mõjuga roheinnovatsioonipraktikad leiti olevat sõidukite vahetamine uuemate vastu ning kliimasõbraliku energiatootmise rakendamine, mis suurendavad ettevõtete tulemuslikkust vastavalt 11,2% ja 10,8%. Samas teised praktikad nagu vee- ja prügimajandus ning seadmete uuendamine ei demonstreerinud märgatavat mõju.

Uurimusest tuleb välja roheinnovatsiooni strateegiline olulisus, mis muutub üha aktuaalsemaks klientide nõudluse, seadusandluse ja turudünaamika tõttu. Et kliendid muutuvad üha rohkem keskkonnateadlikumaks, peavad ettevõtted arendama keskkonnasõbralikke tooteid ja protsesse. Valitsused samuti stimuleerivad roheinnovatsiooni arendust, pakkudes rahalist tuge, tehes teavitustööd ning toetades üleminekut moodsatele tootmissüsteemidele. Kuigi varasemad uurimused on näidanud, et püüdlused olla jätkusuutlikumad võivad tulemuslikkust suurendada, siis nende püüdluste täpne seos on keeruline, varieeruv ja sõltub roheinnovatsioonitüübist.

See uurimus demonstreerib konkreetseid seoseid rohepraktikate ja tulemuslikkuse vahel. Leiud üldiselt viitavad sellele, et strateegiline roheinnovatsioon suurendab tulemuslikkust. Ettevõtted ja seadusloojad saavad seda teadmist kasutada, et edendada keskkondlikku jätkusuutlikkust. Edasised uuringud peaksid analüüsima seoste potentsiaalseid ebakõlasid ja roheinnovatsioonipraktikate pikaaegseid mõjusid.

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