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THE RELATIONSHIP BETWEEN GREEN INNOVATION AND FINANCIAL PERFORMANCE: A STUDY ON EU FIRMS

YEŞİL İNOVASYON VE FİNANSAL PERFORMANS İLİŞKİSİ: AB FİRMALARI ÜZERİNE BİR ARAŞTIRMA [1]

Kubilay DÜZGİT [a*]***, Aslı AYBARS*** [b]

[a*]*Corresponder Author, Res. Assit., Yeditepe University,* kubilayduzgit@hotmail.com , *ORCID: 0000-0002-0941-0589*
[b]*Prof. Dr., Marmara University,* asli.aybars@marmara.edu.tr, *ORCID: 0000-0002-7899-2367*

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ABSTRACT

This research aims to comprehensively evaluate the impact of green innovation on the financial performance of firms operating within the European Union (EU). The study examines data from 105 real sector firms over the period between 2016 and 2022. Within this scope, a balanced panel dataset comprising 735 firm-year observations was constructed and analyzed. To determine the effect of green innovation on firms' financial performance, the study employed panel data analysis method. The results of the analysis reveal that green innovation practices had a significant and positive impact on firms' financial performance during the period under review. The study's unique contributions include incorporating green innovation intensity scores into the analysis, utilizing eight different models that account for lagged effects, and employing a balanced panel data structure. These features enable the research to offer valuable contributions to both the literature and the fields of applied economics and business management.

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ÖZET

Bu araştırma, Avrupa Birliği'nde (AB) faaliyet gösteren firmaların finansal performansı üzerinde yeşil inovasyonun etkisini kapsamlı bir şekilde değerlendirmeyi amaçlamaktadır. Çalışmada, 2016 ile 2022 yılları arasındaki döneme ilişkin 105 reel sektör firmasına ait veriler incelenmiştir. Bu kapsamda, 735 firma-yıl gözleminden oluşan dengeli bir panel veri seti oluşturulmuş ve analiz edilmiştir. Araştırmada, yeşil inovasyonun firmaların finansal performansı üzerindeki etkisini belirlemek amacıyla panel veri analizi yönteminden yararlanılmıştır. Analiz sonuçları, incelenen dönemde yeşil inovasyon uygulamalarının firmaların finansal performansını anlamlı ve pozitif yönde etkilediğini ortaya koymaktadır. Çalışmanın özgün katkıları arasında, yeşil inovasyon yoğunluk skorlarının analize dahil edilmesi, gecikmeli etkileri göz önünde bulunduran sekiz farklı modelin kullanılması ve dengeli bir panel veri yapısının tercih edilmesi yer almaktadır. Bu özellikler, araştırmanın hem literatüre hem de uygulamalı ekonomi ve işletme yönetimi alanlarına değerli bir katkı sunmasını sağlamaktadır.

1. INTRODUCTION

In the pursuit of sustainable development, green innovation plays a crucial role. To mitigate the adverse effects of economic activities, the development of innovative goods, processes, and services prioritizing the environment is imperative. Green innovation aims to minimize pollution, conserve vital resources, and promote the use of renewable energy sources by endorsing novel technologies and practices (Fussler & James, 1996).

Several factors drive the adoption of green innovation. Stringent environmental regulations compel companies to adhere to eco-friendly standards and reduce their environmental impact. Additionally, the growing demand from consumers for sustainable products acts as a compelling force. The availability of financial support for green innovation projects, the desire to enhance corporate social responsibility (CSR), and the recognition of economic benefits associated with sustainability also contribute to its promotion. Despite these driving factors, challenges persist in the realm of green innovation. High development and implementation costs of sustainable technologies pose a significant obstacle. Furthermore, limited awareness and understanding, particularly among small and medium-sized enterprises, hinder the adoption of green innovation. Cultural, social, and institutional barriers can also impede the transition to sustainable practices (Liu et al., 2021).

The benefits derived from green innovation are extensive, encompassing reduced environmental impact, improved resource efficiency, and enhanced competitiveness. Green innovation fosters the creation of new markets and business opportunities, especially in renewable energy and sustainable products. Moreover, it enhances the reputation of companies and strengthens their relationships with stakeholders such as customers, employees, and investors (Takalo & Tooranloo, 2021).

For organizations and communities, green innovation holds paramount significance in environmental management (Yang et al., 2016). In recent years, there has been a noticeable increase in studies conducted in this field. Due to the significant threat that environmental deterioration poses to human life, many organizations and communities have embraced green innovation as a means to simultaneously advance both environmental preservation and economic growth. According to Hur et al. (2013), green innovation enables businesses to achieve sustainable competitive advantages when both environmental sustainability and economic profitability are valued equally.

Green innovation has become a crucial tool for businesses to expand their market share and ensure long-term profitability. Successful green innovation initiatives not only enhance market standing but also foster customer loyalty, provide eco-friendly services, and confer a competitive edge. These advantages have sparked considerable interest among researchers and managers in diverse enterprises. Most innovation studies draw upon the Schumpeterian theory, asserting that green innovation addresses customer expectations regarding environmental preservation. In green innovation, new goods and technologies are developed with the intention of reducing environmental hazards, including pollution and resource depletion (Castellacci & Lie, 2017).

Innovation can be categorized into two subcategories: process or product design and service development. The ultimate goal of product and service innovation is to enhance how goods and services meet the needs of customers and clients. This innovation process improves cost-effectiveness and organizational flexibility, thereby reducing environmental risks, enhancing resource efficiency, creating opportunities for eco-conscious behaviors, reducing pollution, promoting recycling, and conserving energy. It also contributes to gaining competitive advantages, improving environmental performance, aligning with strategic goals, and enhancing overall company performance.

Therefore, green innovation serves as a crucial tool for achieving environmental sustainability in society, organizations, and businesses. It also plays a significant role in gaining a competitive edge (Chu et al., 2019), boosting economic performance, and addressing environmental concerns. Importantly, green innovation hampers imitation. Highlighting these aspects amplifies its influence on groups, businesses, and the wider community. However, implementing these factors comes with challenges, including environmental issues associated with green technologies, the risk of implementation failure, high research and development costs, data collection challenges, increased workload and job dissatisfaction for employees, insufficient funding for green projects, negative effects of external information, organizational aversion to risk, limited understanding of green projects, and ineffective government assistance. Overcoming these obstacles can facilitate the adoption of green innovation by organizations and communities.

The motivation behind this research stems from the growing recognition of the critical intersection between environmental sustainability and economic prosperity. As global concerns about climate change intensify, businesses are increasingly seen as both contributors to environmental challenges and pivotal agents for fostering a sustainable future. The transition toward green practices is no longer just a moral imperative but also a strategic necessity for firms aiming to secure long-term growth and competitiveness. In this context, firms operating within the European Union (EU) are uniquely positioned due to the region's progressive environmental policies and regulations. These include ambitious frameworks such as the European Green Deal, the Circular Economy Action Plan, and stricter emissions targets, which collectively push businesses toward adopting sustainable practices and innovations.

However, while these initiatives underline the importance of sustainability, there remains a significant gap in understanding the tangible financial benefits of such efforts. This disconnection creates a compelling need to explore how green innovation impacts the economic performance of firms. Does environmental responsibility align with shareholder value creation, or do the costs outweigh the benefits in the short term? This inquiry is especially relevant in the EU, where regulatory compliance often demands substantial investment in eco-friendly technologies, supply chain modifications, and resource efficiencies.

The need to bridge this gap serves as a driving force for this study. As the global business landscape evolves, the demand for empirical evidence that links green innovation to financial outcomes has never been more pressing. Such evidence is essential not only for guiding firms in their strategic decision-making but also for informing policymakers who design frameworks to incentivize sustainability. Furthermore, this research contributes to the broader discourse on sustainable business practices by examining the intersection of environmental responsibility and economic performance, offering insights that are critical for both academia and industry.

By focusing on a dataset encompassing 105 real-sector firms operating in the EU during the period from 2016 to 2022, this study aims to provide a nuanced understanding of how green innovation influences financial outcomes. The dataset captures a dynamic phase of regulatory shifts, technological advancements, and increasing societal expectations regarding corporate environmental responsibility. Through this lens, the research not only evaluates the direct financial implications of green innovation but also sheds light on its broader impact on corporate reputation, competitive advantage, and long-term value creation.

What sets this study apart is its distinctive contributions. The incorporation of green innovation intensity scores adds granularity to the assessment, allowing for a more nuanced understanding of the varying degrees of eco-friendly initiatives across firms. Furthermore, the study's commitment to a well-balanced panel data set ensures a comprehensive representation of the diverse economic landscape within the EU. The utilization of eight models that consider the lag effect adds a temporal dimension to the analysis, providing insights into the persistence and sustainability of the observed positive correlation over time.

In essence, this research aspires to offer valuable insights that extend beyond the academic realm. By shedding light on the financial implications of green innovation for companies in the EU, it aims to inform business leaders, policymakers, and stakeholders alike, fostering a more informed and sustainable approach to economic growth in the face of pressing environmental challenges.

2. LITERATURE REVIEW

The intersection of green innovation and financial performance has become an increasingly prominent area of interest in the fields of sustainability and business research. As the global community grapples with the urgent need for environmentally responsible practices and economic stability, understanding the intricate relationship between green innovation and financial performance is pivotal for both businesses and policymakers alike. In this comprehensive literature review, we will delve deeper into this relationship, shedding light on the studies that have reported positive outcomes as well as those that have presented mixed results. By doing so, we aim to provide a nuanced and holistic perspective on this crucial topic.

Green innovation encompasses a wide range of activities, including environmentally friendly product development, process improvements, and sustainable business practices. Its potential to impact an organization's financial performance is multifaceted and far-reaching. One of the most direct ways in which green innovation can enhance financial performance is through cost savings and efficiency gains. Numerous studies have demonstrated that firms investing in energy-efficient technologies, waste reduction measures, and sustainable supply chain management often experience significant reductions in operating costs (Liu et al., 2021). For example, Gluch et al. (2009) conducted a study in the construction industry and found that green practices led to substantial cost reductions, directly translating into improved financial performance.

Moreover, green innovation can also act as a catalyst for market differentiation and competitive advantage. Companies that develop eco-friendly products and services often tap into growing consumer demand for sustainability (Castellacci & Lie, 2017). Research by Hur et al. (2013) revealed that firms adopting environmental practices not only improved their financial performance but also gained a competitive edge through enhanced brand reputation and increased customer loyalty. This strategic advantage positions them favorably in the market, contributing to financial success.

Compliance with environmental regulations and proactive risk mitigation can exert a positive influence on financial performance. Firms that address environmental issues proactively and adapt to evolving regulatory landscapes can avoid costly fines and penalties (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013). Multiple studies have illustrated that environmental proactivity can lead to better financial outcomes, particularly in industries subject to stringent environmental regulations (Doran & Ryan, 2012). This further underscore the symbiotic relationship between responsible environmental practices and financial performance.

Beyond operational considerations, the relationship between green innovation and financial performance extends to investor and stakeholder relations. In recent years, investors have increasingly factored in environmental, social, and governance criteria when making investment decisions (Zheng et al., 2022). Companies with robust green innovation initiatives and transparent sustainability reporting often attract socially responsible investors. This heightened investor interest can translate into increased access to capital and improved financial performance (Chouaibi et al., 2022). In essence, businesses that prioritize environmental responsibility not only fulfill their ethical obligations but also attract investment opportunities that can fuel growth.

While many studies have reported positive results, the relationship between green innovation and financial performance is not without its complexities and variations. Some studies have yielded mixed outcomes, suggesting that this relationship can be industry dependent. For instance, Khan et al. (2022) conducted a comprehensive study across multiple industries and found that the impact of green innovation on financial performance varied significantly between sectors. Industries with high environmental sensitivity, such as energy and chemicals, tended to benefit more from green innovation, while others experienced less pronounced improvements. This underscores the importance of considering industry-specific factors when assessing the link between green innovation and financial performance.

Another crucial dimension to consider is the temporal aspect of this relationship. Some studies have indicated that green innovation initiatives may involve short-term costs, including investments in research and development and the adoption of sustainable practices (De Azevedo Rezende et al., 2019). These initial expenses can temporarily offset financial gains, leading to mixed results in the short term. However, businesses that persevere in their green innovation efforts often reap substantial long-term benefits, such as enhanced brand value and reduced resource consumption (Przychodzen et al., 2019). This suggests that the timeline for assessing the impact of green innovation on financial performance should extend beyond immediate financial outcomes.

The size and resource constraints of firms also play a significant role in the mixed findings within literature. Smaller companies may encounter challenges in implementing green innovations due to limited resources and capacity (Lin et al., 2019). These resource constraints can hinder their ability to realize immediate financial gains from green initiatives, leading to mixed results in studies that encompass firms of different sizes. Recognizing these challenges, policymakers and researchers must consider how to support smaller businesses on their journey toward sustainable practices, ensuring that they can also benefit from green innovation over time.

Furthermore, variations in the environmental performance metrics used in different studies contribute to the mixed results in the literature. The choice of metrics and the manner in which they are measured can significantly impact the observed relationship between green innovation and financial performance (Tang et al., 2018). Some studies have employed comprehensive environmental performance measures that encompass a broad spectrum of sustainability aspects, while others have focused on specific indicators. These variations in measurement methodologies can influence the outcomes and conclusions drawn from the research, highlighting the importance of standardized and comprehensive approaches when evaluating the link between green innovation and financial performance.

Despite the growing body of literature exploring the intersection of green innovation and financial performance, several critical gaps remain unaddressed. One significant gap lies in the lack of consensus on the causal mechanisms linking green innovation to financial outcomes. While many studies highlight positive correlations, the precise pathways through which environmental initiatives translate into financial gains—such as operational efficiency, brand enhancement, or risk mitigation—remain underexplored, particularly across diverse industries. Additionally, the mixed results in the literature often stem from variations in methodological approaches, with inconsistencies in the metrics used to measure green innovation and financial performance. This creates a need for standardized frameworks that can yield comparable and robust results. Another key gap involves the temporal aspect of green innovation's impact; few studies have longitudinally examined how short-term costs and long-term benefits interact over time, particularly in dynamic regulatory and economic environments like the European Union. Addressing these gaps is essential for developing actionable insights that cater to the diverse realities of businesses striving to align profitability with sustainability.

In conclusion, the extensive body of literature on the relationship between green innovation and financial performance is marked by both positive findings and mixed results. While numerous studies suggest that green innovation can positively influence financial performance through cost savings, market differentiation, regulatory compliance, and investor attraction, the nuances of this relationship become evident when considering factors such as industry-specific variations, temporal dimensions, firm size, and environmental performance metrics. As we navigate the complex landscape of sustainability and economic growth, it is imperative that businesses, policymakers, and researchers continue to explore and understand the multifaceted interplay between green innovation and financial performance, ultimately working towards a more sustainable and prosperous future for all.

3. HYPOTHESIS DEVELOPMENT

In recent years, businesses across various industries have embraced green practices and placed an increasing focus on environmental sustainability. This trend towards green innovation is a response to growing stakeholder expectations, regulatory demands, and environmental concerns. Green innovation has several advantages, including a reduced impact on the environment and increased Corporate Social Responsibility (CSR), but its effects on financial performance are still under study and debate. The hypothesis developed in this section will investigate the connection between green innovation and financial performance.

The Resource-Based View (RBV) provides a theoretical framework for understanding the connection between financial success and green innovation. RBV asserts that businesses can achieve a lasting competitive advantage by creating and utilizing distinctive and valuable resources (Wernerfelt, 1984). The adoption of environmentally friendly practices, technology, and processes can be viewed in the context of green innovation as strategic resources that support a firm's competitive advantage. With the use of these tools, businesses may distinguish their goods and services, cut costs through increased operational efficiency, expand into new markets, and enhance their reputation and brand value.

According to stakeholder theory (Donaldson & Preston, 1995), businesses must consider the interests of various stakeholders, such as clients, workers, communities, and the environment, to succeed in the long run.

From the viewpoint of stakeholders, implementing green innovation may benefit businesses. Customers who care about the environment and are willing to pay more for sustainable goods or services may be drawn to green innovation. Additionally, it may help businesses avoid reputational risks, comply with ever-stricter environmental rules, and cultivate effective connections with stakeholders. These satisfying stakeholder outcomes are likely to lead to better financial performance.

While numerous studies have explored the relationship between green innovation and financial performance, it is essential to consider the potential lag effect that may exist in this relationship. The lag effect refers to the time delay between the implementation of a particular action or strategy and the subsequent realization of its effects. In the context of green innovation and financial performance, the lag effect suggests that the benefits and impact of adopting green practices may not be immediately evident or reflected in a firm's financial performance. Instead, there might be a time gap before the positive outcomes of green innovation materialize and become apparent in financial indicators.

After an extensive review of the related literature, the lag effect up to a 3-year period is also taken into account in the empirical analysis to evaluate the link between green innovation and financial performance. Cainelli et al. (2015) explained that green innovations take longer to yield positive results as they are more complex in nature compared to non-green innovations. Additionally, the learning curve process and the optimization of newly developed technologies are two other factors that support the idea of a lagged relationship between green innovation and financial performance (Aragón ‐ Correa & Leyva ‐ de la Hiz, 2016).

Studies by Przychodzen et al. (2019) and Tang et al. (2022) both examined the lag effect of green innovation on financial performance over a 2-year period. Additionally, the work of De Azevedo Rezende et al. (2019) examined this effect over a 3-year period. All of these studies found a positive and statistically significant lag effect of green innovation on financial performance. Furthermore, Tang et al. (2022) observed the highest effect in the 2nd year, whereas De Azevedo Rezende et al. (2019) found that the effect becomes markedly higher, with the peak being in the 3rd year. The literature suggests that the effect of green innovation on financial performance has a lag, and this effect is observed to be highest in the 2nd and 3rd years.

Based on the conceptual background and the theoretical frameworks presented, the following hypotheses are constructed:

Model 1: There is a positive and statistically significant relationship between green innovation intensity score of the latest fiscal year and return on assets.

Model 2: There is a positive and statistically significant relationship between green innovation intensity score of the previous fiscal year and return on assets.

Model 3: There is a positive and statistically significant relationship between green innovation intensity score of the two years before the last fiscal year and return on assets.

Model 4: There is a positive and statistically significant relationship between green innovation intensity score of the three years before the last fiscal year and return on assets.

Model 5: There is a positive and statistically significant relationship between green innovation intensity score of the latest fiscal year and return on equity.

Model 6: There is a positive and statistically significant relationship between green innovation intensity score of the previous fiscal year and return on equity.

Model 7: There is a positive and statistically significant relationship between green innovation intensity score of the two years before the last fiscal year and return on equity.

Model 8: There is a positive and statistically significant relationship between green innovation intensity score of the three years before the last fiscal year and return on equity.

4. RESEARCH DESIGN

In this section, the empirical research design will be addressed. Firstly, the data collection process and the decisions on which variables will be used in the analysis are explained. Then, the abbreviations and definitions of the variables utilized in the study are presented in a table format. Lastly, the methodology used in the study is described in detail.

4.1. Data and Variables

We utilize data from two key sources: the PATSTAT database and the Eikon database to test the hypothesis that there is a positive and statistically significant association between green innovation and financial performance. The Eikon database provides information on business size, debt, and past-year performance, along with financial performance indicators like ROA and ROE. Furthermore, the PATSTAT database supplies patent information, which acts as a proxy for green innovation.

The Eikon database is a comprehensive financial database that includes information on various financial indicators for publicly traded companies worldwide. It offers reliable and widely used metrics for evaluating financial performance, making it suitable for our research. On the other hand, the PATSTAT database is a renowned source for patent information, covering patents from multiple countries and regions. By using these two databases, we were able to gather information on the firms with respect to the study’s main variables of interest, namely, financial performance and green innovation.

ROA and ROE are the study's dependent variables. The financial indicator, namely ROA, gauges a company's profitability by evaluating its capacity to generate profits from its assets. In contrast, ROE measures a company's profitability by contrasting its net income with the equity contributed by shareholders. In the literature, these two metrics are frequently employed as measures of financial performance (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Asni & Agustia, 2022; Chouaibi et al., 2022; De Azevedo Rezende et al., 2019; Duque-Grisales et al., 2020; Khan et al., 2022).

Green innovation serves as the explanatory variable in our analysis and is represented by patent data gathered from the PATSTAT database. Patents act as a valuable indicator of a company's commitment to and investment in environmentally friendly technology. The assessment of a company's level of green innovation involves examining the quantity and types of patents related to eco-friendly technology.

To compute green innovation intensity, we use IPC Green Inventory codes. Patents with any codes included in the IPC Green Inventory are considered green patents. Therefore, we collect data on the total patents issued and the green patents issued by European companies within the scope and time period of our research. The green patents are then divided by the total patents issued to calculate the green innovation intensity of the companies.

Control variables are also included to account for other factors that may influence financial performance. These variables encompass firm size, leverage, and prior-year performance. Firm size is typically measured by the natural logarithm of total assets (Ali & Camp, 1993) and is included to capture the effect of company size on financial performance. Leverage, measured by the ratio of total liabilities to total assets (Akhtar et al., 2012), reflects the degree of financial risk and is expected to impact financial performance (Yoon & Jang, 2005). Prior-year performance, represented by the lagged values of ROA and ROE (Hammond & Slocum, 1996), helps control for the effect of prior-year financial performance on current-year financial performance (Payne et al., 2009).

The selection of variables in this study is rooted in their relevance and established use in the literature for evaluating the relationship between green innovation and financial performance. Return on Assets (ROA) and Return on Equity (ROE) were chosen as dependent variables because they are widely recognized as robust indicators of financial performance, effectively capturing a firm's efficiency in utilizing assets and equity to generate profits. Their frequent application in prior research ensures comparability and enhances the study’s alignment with existing academic frameworks. Green innovation, the explanatory variable, is represented through patent data, as patents are a concrete measure of a company's commitment to environmentally friendly technology. The use of the IPC Green Inventory codes to compute green innovation intensity provides a nuanced metric that reflects the proportion of a company's innovation efforts dedicated to sustainability, offering a comprehensive view of its green innovation activities.

Additionally, the inclusion of control variables—firm size, leverage, and prior-year performance—serves to account for external factors that could influence financial outcomes. Firm size is included because larger firms often possess more resources to invest in innovation and achieve economies of scale, which could impact financial performance. Leverage reflects financial risk and operational constraints that can influence profitability, while prior-year performance controls for the persistence of financial outcomes, ensuring that the analysis isolates the impact of green innovation. Together, these variables were chosen to provide a robust, multifaceted framework for analyzing the intricate relationship between green innovation and financial performance within the European context, ensuring the study's findings are both reliable and actionable.

Below in Table 1 there are the detailed definitions regarding the calculation of the variables and associated abbreviations used in the analysis:

Table 1. The Abbreviations and the Definitions of the Variables Used in the Study

Variable	Abbreviation	Definition
Dependent Variables		
Return on Assets	ROA_{it}	Net Income / Total Assets for Firm i at Year t
Return on Equity	ROE_{it}	Net Income / Total Equity for Firm i at Year t
Explanatory Variables		
Green Innovation Intensity for Fiscal Year-0	$GIIFY0_{it}$	Green Patents Issued / Total Patents Issued for Firm i at Year t
Green Innovation Intensity for Fiscal Year-1	$GIIFY1_{i(t-1)}$	Green Patents Issued / Total Patents Issued for Firm i at Year t-1
Green Innovation Intensity for Fiscal Year-2	$GIIFY2_{i(t-2)}$	Green Patents Issued / Total Patents Issued for Firm i at Year t-2
Green Innovation Intensity for Fiscal Year-3	$GIIFY3_{i(t-3)}$	Green Patents Issued / Total Patents Issued for Firm i at Year t-3
Control Variables		
Firm Size	$SIZE_{it}$	Natural Logarithm of Total Assets for Firm i at Year t
Leverage	$LEVERAGE_{it}$	Total Liabilities / Total Assets for Firm i at Year t
Prior Year Return on Assets	$PRIORROA_{i(t-1)}$	Net Income / Total Assets for Firm i at Year t-1
Prior Year Return on Equity	$PRIORROE_{i(t-1)}$	Net Income / Total Equity for Firm i at Year t-1

The models that are generated in the hypothesis development section and used in the analysis are defined in formulas below using the variables and their abbreviations.

Model 1: $ROA_{it}=\beta_0+\beta_1 GIIFY0_{it}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROA_{i(t-1)}+u_{it}$

Model 2: $ROA_{it}=\beta_0+\beta_1 GIIFY1_{i(t-1)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROA_{i(t-1)}+u_{it}$

Model 3: $ROA_{it}=\beta_0+\beta_1 GIIFY2_{i(t-2)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROA_{i(t-1)}+u_{it}$

Model 4: $ROA_{it}=\beta_0+\beta_1 GIIFY3_{i(t-3)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROA_{i(t-1)}+u_{it}$

Model 5: $ROE_{it}=\beta_0+\beta_1 GIIFY0_{it}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROE_{i(t-1)}+u_{it}$

Model 6: $ROE_{it}=\beta_0+\beta_1 GIIFY1_{i(t-1)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROE_{i(t-1)}+u_{it}$

Model 7: $ROE_{it}=\beta_0+\beta_1 GIIFY2_{i(t-2)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROE_{i(t-1)}+u_{it}$

Model 8: $ROE_{it}=\beta_0+\beta_1 GIIFY3_{i(t-3)}+\beta_2 SIZE_{it}+\beta_3 LEVERAGE_{it}+\beta_4 PRIORROE_{i(t-1)}+u_{it}$

The data has undergone thorough examination to determine the sample that will be used. To ensure reliable and statistically significant analysis results, priority is given to a strongly balanced dataset, meaning there is no missing data, and a high number of firm-year observations are sought. Based on the objectives and priorities, the data is narrowed down to 105 companies, and the time period is set to cover the years from 2016 to 2022. Tables detailing the sample distribution across countries and the descriptive statistics of the selected variables are provided in Appendix 1 and 2, respectively.

4.2. Methodology

The decision to employ panel data analysis in this research is driven by its unique advantages in studying the relationship between green innovation and financial performance. Panel data, which combines cross-sectional and time-series dimensions, allows for a more comprehensive analysis by observing multiple firms over a specified period. This method is particularly well-suited for this study, as it enables the assessment of dynamic changes in green innovation efforts and their financial outcomes across a diverse set of firms operating in the European Union from 2016 to 2022. Panel data analysis also helps control unobservable heterogeneity factors specific to individual firms that may influence financial performance but are not directly measurable—by leveraging fixed or random effects models. This ensures that the results are not biased by firm-specific characteristics, such as management quality or organizational culture, that remain constant over time.

Moreover, panel data analysis enhances the statistical power and efficiency of the model by utilizing a larger number of observations, which is crucial for identifying nuanced relationships between variables. It also allows for the examination of lagged effects, such as the delayed financial impact of green innovation efforts, which aligns with the study's focus on the temporal aspects of this relationship. By capturing both firm-specific and time-varying influences, panel data analysis provides a robust framework for generating actionable insights into how green innovation contributes to financial performance, making it an ideal methodological choice for this research.

The selected methodology for testing the eight hypotheses mentioned above involves panel data analysis on a dataset comprising 105 European enterprises for the years between 2016 and 2022. STATA statistical analysis software is employed to conduct the analysis.

To address the potential issue of multicollinearity, Variance Inflation Factor (VIF) testing is utilized in the initial stages of the study. Multicollinearity, which can distort models, occurs when there is a substantial correlation between the selected explanatory and control variables. The obtained VIF values are found to be lower than 5 (VIF < 5), indicating the absence of multicollinearity. This is a significant finding, as multicollinearity can compromise the validity of results by complicating the identification of underlying correlations between variables (López, 2021).

Proceeding to the next step, the presence of unit and time effects in the model is examined through the Likelihood-ratio test. The Likelihood-ratio test is a statistical method used to evaluate whether the inclusion of unit and time effects significantly enhances the model's fit. The results of this test reveal the existence of both unit and time effects, suggesting that these factors play a substantial role in shaping the dependent variable (Tatoğlu, 2020).

The Hausman test is conducted to refine the model and determine the most suitable estimator for use. This test helps to ascertain whether the model should be executed as a fixed effects model or a random effects model. According to the results of the Hausman test, the model is identified as a two-way fixed effects model with both unit and time effects. This implies that the model considers both the time-specific characteristics and the unique properties of the units in the panel data (Tatoğlu, 2020).

Following that, several tests are performed to evaluate whether the model deviates from the fundamental assumptions of the panel data model. One such test is the Jarque-Bera normality test, which assesses whether the distribution of the dataset adheres to a normal distribution. The outcomes of this test indicate that the dataset follows a normal distribution. This adherence to normality is crucial for many statistical models, enabling the application of various estimation techniques and hypothesis testing procedures (Longhi & Nandi, 2014).

Heteroskedasticity, the presence of varying levels of dispersion in the error term across observations, is examined using the Wald test. The Wald test provides insights into whether heteroskedasticity is present in the model (López, 2021). The findings of this test support the presence of heteroskedasticity, indicating that the variability of the error term is not constant across observations. This can have implications for the efficiency and reliability of the estimated coefficients, necessitating the selection of appropriate estimators for the final eight models to be conducted.

To address the issue of cross-sectional independence, three alternative tests—Pesaran test, Friedman test, and Frees test—are conducted, specifically designed for assessing cross-sectional independence in the panel data model. The results of these tests reveal that the model fails to satisfy the assumption of cross-sectional independence, indicating that the observations are not independent from one another. This finding is crucial as it highlights potential issues related to the violation of this assumption (Tatoğlu, 2020).

Moving on, tests for autocorrelation are executed using the Durbin-Watson test and Baltagi's LBI test. Autocorrelation refers to the correlation between error terms of observations at different time periods.

The results of these tests indicate the presence of autocorrelation in the model, suggesting that errors in the model are not independent across time periods. Autocorrelation can introduce bias in the estimated coefficients and lead to inefficiency in the model's predictions (Longhi & Nandi, 2014).

Therefore, the panel data model is estimated using Driscoll-Kraay standard errors to account for these departures from the assumptions. This reliable estimation method accommodates cross-sectional dependency, autocorrelation, and heteroskedasticity (Tatoğlu, 2020). The model makes an effort to mitigate the effect of these variations and offer more trustworthy and accurate estimations by using Driscoll-Kraay standard errors.

The approach used in this study considers the unique properties of panel data, such as balanced data, time and unit fixed effects, heteroskedasticity, autocorrelation, and cross-sectional independence. To generate accurate and effective parameter estimates, the fixed effects estimation approach, robust standard errors, and suitable techniques to address autocorrelation and cross-sectional independence are employed.

5. EMPRICAL FINDINGS

In this section, the results of the panel data analysis are presented. As mentioned in the preceding subsection, Driscoll-Kraay standard errors are employed in the analysis to account for any potential deviations from assumptions. The tables showcasing the results of the panel data analyses for all models performed include information such as the number of observations, the number of groups, the F-statistic, and the related probability (p-value) for the overall model's significance. Additionally, the coefficients, standard errors, and t-statistics for each independent variable are presented.

The findings of Model 1, Model 2, Model 3, and Model 4, which aim to investigate the link between green innovation and the dependent variable ROA, along with our control variables, are provided in Table 2.

As evident from Model 1, the relationship between the selected financial performance indicator and the current year green innovation intensity, denoted by GIIFY0, is found to be statistically insignificant with a t-statistic of 1.38. This finding contradicts our hypothesis of a positive relationship between ROA and the green innovation intensity score of the latest fiscal year. Despite contradicting our hypothesis, this finding aligns with the study by De Azevedo Rezende et al. (2019). In their research, De Azevedo Rezende et al. (2019) also explored the effects of green innovation on financial performance, considering the influence of lag effects. They discovered that there was no statistically significant relationship between green innovation and financial performance in the immediate year, similar to the results of our Model 1.

The results of Model 2 support our hypothesis, indicating a significant relationship between the green innovation intensity score of the previous fiscal year and return on assets. Additionally, the findings are consistent with Przychodzen et al. (2019), who investigated first-mover advantages in green innovation and its relationship with financial performance. Their study also revealed a statistically significant and positive impact of green innovation with a one-year lag, aligning with our results.

In Model 3, the outcomes suggest that return on assets (ROA) is significantly influenced by GIIFY2, thus supporting the hypothesis of Model 3. This evidence is in line with the study by Tang et al. (2022), where they explored the effect of green technology innovation on financial performance. Their results indicated a positive impact of green technology innovation, strongest two years after its issuance.

The findings of Model 4 align with the associated hypothesis, indicating a positive relationship between ROA and the green innovation intensity score with a three-year lag. This result is also supportive of the study by De Azevedo Rezende et al. (2019), which examined the impact of green innovation on financial performance, accounting for lag effects. Their study found a statistically significant and positive relationship between green innovation and financial performance, with the strongest effect observed in the third year.

Regarding the control variables, LEVERAGE negatively and significantly affects financial performance, while PRIORROA positively and significantly influences financial performance. SIZE has been found to have no statistically significant impact for Model 1, Model 2, Model 3, and Model 4.

Table 2. The Panel Data Analysis Results of Model 1, Model 2, Model 3 & Model 4

Regression with Driscoll-Kraay standard errors							
Dependent Variable: ROA							
Variable	**Coefficient**	**Standard Error**	**T Statistics**	**Variable**	**Coefficient**	**Standard Error**	**T Statistics**
Model 1				**Model 3**			
GIIFY0	0,0922	0,0666	1,38	GIIFY2	0,0528**	0,0197	2,67

SIZE	-0,0009	0,0038	-0,25	SIZE	-0,0008	0,0038	-0,22
LEVERAGE	-0,0343*	0,0155	-2,21	LEVERAGE	-0,0378**	0,0121	-3,12
PRIORROA	0,5483***	0,1193	4,59	PRIORROA	0,5949***	0,098	6,07
Constant	0,0512	0,0455	1,13	Constant	0,0531	0,0345	1,54
Model 2				**Model 4**			
GIIFY1	0,0423**	0,0161	2,62	GIIFY3	0,0928**	0,0327	2,84
SIZE	-0,0009	0,0039	-0,25	SIZE	0,0004	0,0038	0,13
LEVERAGE	-0,0405**	0,0144	-2,81	LEVERAGE	-0,0298***	0,0078	-3,82
PRIORROA	0,5875***	0,0855	6,87	PRIORROA	0,5687***	0,1072	5,3
Constant	0,0577	0,0351	1,64	Constant	0,032	0,038	0,84
Legend	**p<0,1; **p<0,05; ***p<0,01*						

The results of Model 5, Model 6, Model 7, and Model 8, aiming to explore the relationship between green innovation and the dependent variable ROE, alongside our control variables, are outlined in Table 3.

In Model 5, the findings indicate no statistically significant relationship between green innovation and return on equity (ROE) in the immediate year. Contrary to our hypothesis, which posited a positive relationship between ROE and the green innovation intensity score of the latest fiscal year, this result contradicts the hypothesis, mirroring the outcome observed in Model 1.

Model 6 results suggest a positive relationship between GIIFY1 and ROE, aligning with the evidence in Model 2 and the study of Przychodzen et al. (2019), where they identified a positive impact of one-year lagged green innovation scores on financial performance.

Similar to the observations in Model 3, where ROA is the dependent variable, the hypothesis of Model 7 is accepted. The results align with Tang et al.'s (2022) findings, indicating a positive relationship between green innovation and financial performance, with the highest impact observed with a two-year lag.

Table 3. The Panel Data Analysis Results of Model 5, Model 6, Model 7 & Model 8

Regression with Driscoll-Kraay standard errors

Dependent Variable: ROE

Variable	Coefficient	Standard Error	T Statistics	Variable	Coefficient	Standard Error	T Statistics
Model 5				**Model 7**			
GIIFY0	0,1603	0,088	1,82	GIIFY2	0,1143**	0,038	3,01
SIZE	0,0188*	0,0081	2,31	SIZE	0,0188*	0,0082	2,3
LEVERAGE	-0,0372	0,0594	-0,63	LEVERAGE	-0,0455	0,0484	-0,94
PRIORROE	0,5015**	0,1491	3,36	PRIORROE	0,5137**	0,1451	3,54
Constant	-0,1088	0,0698	-1,56	Constant	-0,1006	0,0578	-1,74
Model 6				**Model 8**			
GIIFY1	0,0978**	0,0316	3,09	GIIFY3	0,1310**	0,0515	2,54
SIZE	0,0185*	0,0079	2,35	SIZE	0,0209**	0,0072	2,9
LEVERAGE	-0,0483	0,0584	-0,83	LEVERAGE	-0,0411	0,0482	-0,85
PRIORROE	0,5101**	0,1461	3,49	PRIORROE	0,5060**	0,1459	3,47
Constant	-0,0939	0,0549	-1,71	Constant	-0,1257*	0,0527	-2,38
Legend	**p<0,1; **p<0,05; ***p<0,01*						

The results of Model 8 indicate that GIIFY3 has a positive effect on ROE, suggesting that higher green innovation scores are associated with better return on equity. This finding aligns with the hypothesis of Model 8, positing a positive relationship between ROE and the green innovation intensity score with a three-year lag. It is also consistent with the study by De Azevedo Rezende et al. (2019), where they explored the impact of green innovation on financial performance, considering the influence of lag. Their findings revealed a statistically significant and positive relationship between green innovation and financial performance, with the strongest impact observed in the third year, supporting the results of Model 8.

Regarding the control variables, the findings show that SIZE and PRIORROE significantly and positively affect financial performance, while LEVERAGE has no statistically significant influence in Model 5, Model 6, Model 7, and Model 8.

In summary, the results suggest that green innovation enhances financial performance after the first year for both ROA and ROE indicators. In the immediate year, no statistically significant result was observed concerning the relationship between green innovation and financial performance (De Azevedo Rezende et al., 2019). However, as the lag effect was tested, the results indicated a long-term positive effect of green innovation on financial performance, which increases significantly (De Azevedo Rezende et al., 2019; Przychodzen et al., 2019; Tang et al., 2022). Additionally, prior-year performance proves to be a significant predictor of the current year's financial performance, with statistically significant and positive results for both ROA and ROE (Bharadwaj, 2000; Gürbüz et al., 2016; Kordestani et al., 2010; Ojimadu, 2022).

Leverage negatively impacts financial performance in models using ROA as the dependent variable (Bagirov & Bagirov, 2019; Enekwe et al., 2014; Zheng et al., 2022). However, in models using ROE as the dependent variable, leverage yields statistically insignificant results. Furthermore, for models using ROA as the dependent variable, there is no statistical evidence supporting a relationship between firm size and financial performance. On the other hand, the analysis results for models with ROE as the dependent variable indicate a statistically significant and positive relationship between firm size and financial performance (Andries & Faems, 2013; Tariq et al., 2019; Zheng et al., 2022).

6. CONCLUSIONS

This study employs panel data analysis to investigate the impact of green innovation on the financial performance of 105 EU-based companies between 2016 and 2022. The findings establish a significant and sustained positive relationship between green innovation and financial performance, with measurable benefits emerging after the first year of implementation. Both ROA and ROE demonstrate continued improvement over time, affirming that green innovation not only provides immediate gains but also fosters long-term financial success.

The positive financial outcomes are primarily driven by three key mechanisms: cost savings, enhanced brand reputation, and market opportunities. Companies adopting green innovation practices—such as energy-efficient technologies, waste reduction measures, and sustainable supply chain strategies—achieve operational efficiencies that translate into significant cost reductions (Calof & Viviers, 1995). Simultaneously, eco-conscious initiatives strengthen brand loyalty and attract environmentally aware customers, leading to higher sales and improved market positioning (Castellacci & Lie, 2017). Additionally, the shift toward sustainability opens new business avenues, enabling companies to capitalize on growing demand for green products and services, ultimately diversifying revenue streams and expanding market presence (Hur et. al., 2013).

Based on the findings, the following recommendations are proposed for organizations aiming to enhance financial performance through green innovation:

- **Foster an Innovation-Driven Culture:** Companies should cultivate a corporate culture that rewards sustainability initiatives by creating dedicated teams, providing training, and incentivizing innovative solutions.
- **Conduct Regular Environmental Audits:** Periodic assessments can identify areas for improvement, monitor progress toward sustainability goals, and uncover opportunities for further innovation.
- **Leverage Collaborative Partnerships:** Organizations should collaborate with stakeholders, including suppliers, customers, and industry partners, to accelerate green innovation through shared knowledge, resources, and best practices.
- **Enhance Transparency in Communication:** Clear communication of sustainability goals, initiatives, and outcomes can bolster stakeholder trust, attract eco-conscious customers, and reinforce the company's reputation.
- **Invest in Research and Development (R&D):** Continuous investment in R&D is critical for developing cutting-edge, economically viable green technologies, ensuring long-term competitive advantage and financial performance.

To build on the findings of this study, future research should address the following:

- **Broaden Performance Metrics:** Investigate how green innovation influences other organizational outcomes, such as market value, return on investment, or employee productivity.
- **Industry-Specific Analysis:** Conduct comparative studies across different industries to identify sector-specific drivers and challenges associated with green innovation.
- **Examine Mediating Factors:** Explore how variables such as corporate culture, leadership, or regulatory frameworks mediate the relationship between green innovation and financial performance.
- **Incorporate Qualitative Methods:** Use case studies, interviews, and focus groups to gain deeper insights into the processes and motivations underlying green innovation initiatives.
- **Study Contextual Influences:** Assess the role of regional policies, cultural norms, and market conditions in shaping the impact of green innovation on financial outcomes.
- **Replicate in Diverse Contexts:** Validate the study's findings across different markets, timeframes, and geographic locations to ensure their generalizability and robustness.

In conclusion, this research provides compelling evidence that green innovation positively influences financial performance after the first year of implementation. By adopting green practices, companies can achieve cost savings (Calof & Viviers, 1995; Hur et al., 2013), strengthen brand recognition (Castellacci & Lie, 2017), foster customer loyalty, and unlock new business opportunities (Takalo & Tooranloo, 2021). The findings underscore the dual benefits of green innovation for both financial and environmental sustainability. Organizations that embrace these strategies can enhance their market competitiveness while contributing to broader sustainability goals. Implementing the outlined recommendations and pursuing further research will be instrumental in advancing the understanding and application of green innovation in driving financial and environmental success.

Ethics Committee Declaration
Ethics committee declaration is not required for the study.

Author Contribution Rate Declaration
The data were collected by Kubilay Düzgit. The analysis was carried out by Kubilay Düzgit & Aslı Aybars.

Conflict Statement
There is no conflict of interest between the authors.

Declaration of Support
No support was received from any organization for this study.

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8. APPENDIX

Appendix 1. The Country Breakdown of the Analysis Sample by Percentage and Numbers

Country	Percentage	Number of Companies
Germany	18,10%	19
France	13,33%	14
Finland	11,43%	12
Sweden	10,48%	11
United Kingdom	10,48%	11
Denmark	9,52%	10
Switzerland	9,52%	10
Belgium	8,57%	9
Austria	8,57%	9
Total	**100%**	**105**

Appendix 2: The Descriptive Statistics of the Analysis Sample

	Mean	Maximum	Minimum	Standard Deviation
$\mathbf{ROA_{it}}$	0,0632	0,6700	-0,4474	0,0750
$\mathbf{ROE_{it}}$	0,1438	3,2327	-1,3146	0,2185
$\mathbf{GIIFY0_{it}}$	0,0962	1	0	0,1622
$\mathbf{GIIFY1_{i(t-1)}}$	0,0940	1	0	0,1696
$\mathbf{GIIFY2_{i(t-2)}}$	0,0939	1	0	0,1786
$\mathbf{GIIFY3_{i(t-3)}}$	0,1027	1	0	0,1970
$\mathbf{SIZE_{it}}$	9,9461	11,7519	7,7081	0,7890
$\mathbf{LEVERAGE_{it}}$	0,6081	1,2914	0,0372	0,1725
$\mathbf{PRIORROA_{i(t-1)}}$	0,0612	0,6700	-0,5248	0,0769
$\mathbf{PRIORROE_{i(t-1)}}$	0,1438	3,2327	-1,3146	0,2111