

Mukhopadhyay, Nirupam; Nayak, Narayan Chandra

Article

Examining the relationship between green innovation dynamics and firm performance: a comparative study of BRICS and G7 countries

Cogent Business & Management

Provided in Cooperation with:

Taylor & Francis Group

Suggested Citation: Mukhopadhyay, Nirupam; Nayak, Narayan Chandra (2024) : Examining the relationship between green innovation dynamics and firm performance: a comparative study of BRICS and G7 countries, Cogent Business & Management, ISSN 2331-1975, Taylor & Francis, Abingdon, Vol. 11, Iss. 1, pp. 1-17,
<https://doi.org/10.1080/23311975.2024.2364836>

This Version is available at:

<https://hdl.handle.net/10419/326330>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by/4.0/>

Examining the relationship between green innovation dynamics and firm performance: a comparative study of BRICS and G7 countries

Nirupam Mukhopadhyay & Narayan Chandra Nayak

To cite this article: Nirupam Mukhopadhyay & Narayan Chandra Nayak (2024) Examining the relationship between green innovation dynamics and firm performance: a comparative study of BRICS and G7 countries, Cogent Business & Management, 11:1, 2364836, DOI: [10.1080/23311975.2024.2364836](https://doi.org/10.1080/23311975.2024.2364836)

To link to this article: <https://doi.org/10.1080/23311975.2024.2364836>



© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 05 Jul 2024.



[Submit your article to this journal](#)



Article views: 1606



[View related articles](#)



[View Crossmark data](#)



Citing articles: 1 [View citing articles](#)

Examining the relationship between green innovation dynamics and firm performance: a comparative study of BRICS and G7 countries

Nirupam Mukhopadhyay and Narayan Chandra Nayak

Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, Kharagpur, India

ABSTRACT

Green innovation entails the production assimilation or exploitation of unique methods of doing business that result in a decrease in environmental risks. Green innovation is a complex and multifaceted process, encompassing product, process, and organizational dimensions, each with unique factors influencing firm performance, business efficiency, and sustainable development. This research investigates the impact of eco-innovation on the financial performance of firms across 12 G7 and BRICS countries from 2013 to 2022. Considering 2100 listed firms, the study explores how process, product, and organizational eco-innovation dimensions affect business performance. Utilizing Feasible Generalized Least Square (FGLS) regression and System Generalized Method of Moments (GMM) models, the results indicate a positive impact of environmental innovation on firm performance. Further, in BRICS countries, process, and organizational eco-innovations have greater impacts, while in G7 countries, product eco-innovation gets precedence. The varying impacts reflect the unequal stages of development and priorities between the two groups. It also signifies that G7 countries possess more resources for green innovation, while BRICS countries are still evolving. The findings therefore underscore the importance of tailored regulations, monitoring, and support to facilitate the integration of eco-innovations into business processes. Moreover, there is a need for firms to adopt and execute green innovation-based economic activities that would make them financially efficient, and strengthen the growth imperatives of both the groups of countries. Collaboration between developed and emerging economies would go a long way fostering common goals across them.

ARTICLE HISTORY

Received 30 November 2023

Revised 8 April 2024

Accepted 23 May 2024

KEYWORDS

Firm performance; green innovation; organizational eco-innovation; product eco-innovation; process eco-innovation; BRICS; G7

REVIEWING EDITOR

Jeffrey Muldoon, Emporia State University, United States

SUBJECTS

Economics; Environmental Economics; Business, Management, and Accounting; Finance

1. Introduction

Of late, academics and corporate professionals widely agree on the need for considerable alterations to how businesses establish relationships with the natural and social environments that are integral to their operations and products (Cai & Li, 2018; Franceschini & Pansera, 2015; Lee & Min, 2015; López & Montalvo, 2015; Segarra-Oña et al., 2015; Vivanco et al., 2015). Amidst global ecological crises caused by pollution, environmental degradation, and resource scarcity, firms have started exploring diverse strategies to gain a competitive advantage and enhance performance (Cai & Li, 2018) while ensuring environmental sustainability. Amongst all, green innovation stands apart as a way forward for many firms across countries.

Green innovation, often called environmental or eco-innovation, entails the production, assimilation, or exploitation of unique methods of doing business that result in a decrease in environmental risks (Kemp & Pearson, 2007). It is a firm's considered response to external demands, which differs from the Schumpeterian notion of innovation that originates from within a firm and enters the marketplace to exploit or discover new markets (Bocken et al., 2014; Santos et al., 2017). Green innovation involves the potential disruption of an already existing production model, contributing to reducing adverse

CONTACT Nirupam Mukhopadhyay ✉ nirupamm@iitkgp.ac.in Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, Kharagpur 721302, India.

© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

environmental and social impacts (Kuo & Smith, 2018). Through its life cycle, environmental risks associated with resource use are also minimized (Kemp & Pearson, 2007). From a sustainability perspective, green innovation can be construed as a strategy for firms to sustain their long-term survival while enhancing their performance. It leads to the reconfiguration of resources to develop green capabilities of the firms to realize competitive advantages.

Green innovation encompasses diverse forms (OECD, 2005b), including product, process, organizational, and marketing. Evidently, different organizations seem to have adopted different eco-innovation programs with a common goal of becoming environmentally more responsible. Some such programs are service innovation, policy innovation, product service innovation, etc. (Santos et al., 2017).

For green innovation to proliferate, it is imperative that the firms espousing it stay financially sustainable and improve their performance. However, the impacts of green innovation are decidedly mixed. There is inconclusive evidence concerning the relationship between green innovation and firm performance across countries. It may be attributed, *inter alia* to varying regulatory and institutional frameworks across regions or industries, with numerous countries experiencing different stages of development (Nishitani et al., 2017; Santos et al., 2017). While there is evidence of eco-innovation improving firm performance (Atalay et al., 2013), many firms still have a fear of experiencing the possibility of market failure (Chiesa & Frattini, 2011), an imminent increase in production cost, and a decline in price-cost margins (Katsikeas et al., 2016). In emerging markets, though, there is no denying that increasing environmental risks tend to generate market opportunities for products and services, the low purchasing power amongst consumers and poor knowledge about eco-products limit the scope for their proliferation as people are extremely sensitive to high prices (Biswas & Roy, 2015).

Interestingly, the efforts to go green and the impacts thereof are not uniform across developed and developing countries. To be specific, the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the USA) pioneer the advocacy for net-zero emissions. They have shown their commitment to diversifying their energy portfolios to include green energy sources in their conventional energy basket (Murshed, 2020). Still, their dependence on non-renewable energy sources continues to remain high. The newly industrializing countries, on the other hand, are reportedly responsible for one-third of environmental technology innovations in recent years (Walz et al., 2017). The BRICS (Brazil, Russia, India, China, and South Africa) economies, in particular, are gradually moving toward green growth with a growing share of renewable energy sources in their energy mix (Zhao et al., 2021). However, the key to the sustenance of such efforts lies in cross-country collaborations. Of late, the G7 countries have started extending their support for green innovations in developing countries (Herman & Xiang, 2022).

Against this backdrop, this study examines the impact of green innovation on firm performance across G7 (developed) and BRICS (emerging economies) nations. Additionally, it empirically investigates separately the impact of three major dimensions of eco-innovation, namely process, product, and organizational, on firms' financial performances in these countries. We consider the firms operating in these countries, covering a span of ten years from 2013 to 2022. The basic objective of this research is to explore if the impact of green innovation varies according to the country groups and whether different forms of eco-innovation have differing roles in different countries. As the chosen groups of countries experience varying stages of development, their efforts toward green innovation are not necessarily uniform, and so could be their outcomes. Although empirical studies exist on green innovation and firm performance (Aldieri et al., 2020; Gonenc & Scholtens, 2017; Song et al., 2017), to the best of our knowledge, studies focusing on the roles of product, process, and organizational innovation in the context of both developed and emerging countries are limited. Moreover, there are also conflicting findings. This empirical study, while offering an insight into the dynamics of the G7 and BRICS countries, thus tries to fill this gap.

The study carries significance from the following standpoints. First, the emerging economies, in general, and the BRICS countries in particular, hold strategic significance due to their crucial roles in the global production chain, thanks to their economic and business predominance. They have become major contributors to global growth and, consequently, key players in international trade and investment. Their ever-expanding consumer base, natural resources, and growing industries make them attractive business destinations (Farooq et al., 2024; Gyedu et al., 2021; Stiglingh, 2015). Consequently, understanding the dynamics of eco-innovation and its concomitant impact on business performance in these economies

carries significance, especially for those seeking to navigate these evolving global business landscapes. Second, the developed and industrialized countries, and specifically, the G7 countries, have become frontrunners in innovations and shown a strong desire for eco-innovation (Gyedu et al., 2021). However, mere domestic eco-innovation is not enough. There is a need for technology transfer from developed countries to the rest, which entails cross-country collaborations on green growth and innovations in environmental technology (Herman & Xiang, 2022). In the absence of such collaborations, the impact of green innovation on firm performance may vary between developed and developing countries. Finding differential impacts on firm performance between G7 and BRICS would help one understand such dynamics better.

This firm-level study provides a more granular and detailed examination of the shared relationship between eco-innovation and firm performance. It allows for a closer examination of specific strategies, practices, and innovations implemented at the firm level and their direct impacts on performance outcomes. This empirical research can help refine existing frameworks regarding underlying mechanisms of eco-innovation and firm performance linkage (Cai & Zhou, 2014; Mondejar-Jimenez et al., 2015). It also creates the scope for a more targeted and actionable approach to identifying the mechanisms that link green innovation to positive business outcomes.

While previous studies have largely focused on country-level surveys to explore the association between eco-innovation and firm performance, this study employs a formative construct to measure eco-product, eco-process, and eco-organization and analyzes their influence on firm performance across different countries. Employing the feasible generalized least squares (FGLS) model, the findings ascertain the positive impact of green innovation on firm performance across all countries. However, the impact seems to vary between G7 and BRICS nations according to the dimensions. The findings contribute to the existing empirical research by ascertaining the significance of the stage of development of a country upon the strength of the association between eco-innovation and its impact on firm performance. Besides, the importance of the firm-specific characteristics as control, viz., age, size, social pillar score, and governance pillar score, is also highlighted.

Accordingly, the remainder of the paper is organized as follows: In [section 2](#), we review the extant literature highlighting the theoretical and empirical underpinning. In [section 3](#), we present a conceptual framework supporting the basis of this study. Consequently, the methods of data analysis are outlined, highlighting sample country selection, variable identification, model specification, etc. An integrated model is employed to assess simultaneously the effects of eco-innovation at product, process, and organizational levels on the financial performance of firms. In the penultimate section, the empirical results are presented and discussed. The final section concludes the study with necessary implications.

2. Literature review

2.1. Theoretical literature

Green innovation has gained prominence since the time of the third Industrial Revolution of the 1970s, with a focus on innovation and sustainability. The 'Limits to Growth' as propounded by the 'Club of Rome' and 'Our Common Future' by the UN have reaffirmed the need for sustainability while vouching for the effective utilization of limited resources for economic progress and well-being of future generations (Brundtland, 1987). Over time, the notion of green innovation has evolved, with a shift in its focus from mere enhanced economic growth to an improved quality of life for the present and future generations (Levidow et al., 2016).

The notion of eco-innovation involves innovation with a thrust on sustainability (Rennings, 2000). It is characterized by the creation of something new directed toward reducing adverse environmental impacts. There is also a predisposition to influence social attitudes and cultural and institutional norms (de Oliveira Brasil et al., 2016; OECD, 2005a). Eco-innovation is said to reduce the use of natural resources and decrease the discharge of harmful substances across the life cycle. From this standpoint, two pertinent points emerge. First, all the novel processes that involve efficient resource use can be called eco-innovation. Second, eco-innovation manifests itself as a critical assessment of environmental impacts and risks. It is also a major candidate for innovation policies that address societal challenges of climate

change, resource efficiency, and energy/resource scarcity (Kemp & Oltra, 2011). The development of environmental technologies, viz. pollution control technologies, cleaner process technologies, waste management equipment, etc., organizational innovations for the environment, viz. environmental management and auditing systems, chain management, etc., product and service innovation offering environmental benefits and green system innovation are some of the traits of eco-innovation (Kemp & Pearson, 2007).

The significance of green innovation has already been increasingly acknowledged in a growing body of literature. To operate in an ecologically friendly manner, all the business houses need to embrace green innovation practices at the organizational, process, and product levels (Hojnik & Ruzzier, 2016). A consensus on this has been arrived at in at least 11 out of the 17 United Nations (UN) sustainable development goals (SDGs) (Moratis & Melissen, 2019). The UN has already taken initiatives to endorse and promote environmental-friendly innovations through the 2030 plan for SDGs.

Green innovation is usually understood as a firm's response to external demands, and it may be in contrast to innovation as understood by Schumpeter. He contends that innovation primarily originates from within a firm and gradually explores new markets (Bocken et al., 2014; Santos et al., 2017). As Kemp and Pearson (2007) argue, green innovation can be attained when a business uses a product or resource in a manner that reduces its contributions to pollutants, thereby reducing environmental risk. The notion of green innovation seems to have evolved to demonstrate that innovation may be not only sustainable but also ecological (Hellström, 2007; Levidow et al., 2016).

From the perspective of the firms, eco-innovation may have mixed impacts on their performance. As the neoclassical theory suggests, green innovation, if tied to environmental regulations, may cause an increase in cost (Palmer et al., 1995; Walley & Whitehead, 1994). However, there are positive effects as well that may offset such impacts (Porter & van der Linde, 1995). According to the natural resource-based view, there are many competitive advantages a pro-active environmental behavior can generate, yielding positive economic returns. As it ascertains, a positive financial effect can result from the development of distinct bundles of resources and capabilities within the firm (Hart & Dowell, 2011). A firm could find it profitable to invest in eco-innovation if it can efficiently associate its internal skills (e.g. physical, financial, labor, and organizational resources) with environmental objectives. These efforts could mitigate future regulatory costs and improve the effectiveness of the production processes (Kemp & Pearson, 2007).

Further, it may be important to state that familiarity with the eco-innovation types that complement one another is critical to achieving higher productivity and greater competitiveness. At the same time, as the theory of socio-technical systems argues, the execution of innovations must include social issues and management systems so that corporate performance is optimized (de Oliveira Brasil et al., 2016). The association between eco-innovation and performance signifies not just a mere reduction in environmental risks but in cost reduction, an increase in sales with product differentiation, and a rise in profit margins, brand value, and firm reputation (Klewitz et al., 2012).

There is a need for a robust policy directed toward promoting green innovation. The need for such a policy emanates from two important problems: market failure and system failure. The former is a neo-classical approach, which suggests that eco-innovation has to address the public good nature of knowledge leading to an appropriability problem. There are also uncertainties about the benefits and costs of eco-innovation. Further, the external costs of environmentally unfriendly alternatives are usually not internalized. Rather, they are transferred to the society and environment (Kemp & Oltra, 2011). System failure involves problems, such as infrastructure constraints and technological rigidities, knowledge and institutional barriers, and competition with old products, which hinder innovation. There is a need for proper policy interventions to address these twin problems (Nelson, 2009).

2.2. Empirical literature

To add to the debate over the relationship between green innovation and firm performance, several empirical studies have been carried out in different countries and contexts (Bocken et al., 2014; Lin et al., 2014). Recently, there has been an emphasis on eco-innovation among the firms of the G7 countries, which has significantly contributed to enhancing their performance. These countries have made

substantial investments in research and development, trademarks, and patents, demonstrating their commitment to innovation (Sesay et al., 2018; Stiglingh, 2015). They are also recognized for their knowledge production, driven by historical developments and high growth rates (Inglesi-Lotz & Pouris, 2013).

A firm's financial performance is considered a key indicator when one examines its green innovation efforts. Investors analyze a firm's current and future financial performance to make investment decisions. Existing studies have focused on evaluating a firm's financial performance, particularly its bottom-line results (Bitencourt et al., 2020; Hojnik & Ruzzier, 2016; Przychodzen & Przychodzen, 2013). These studies have primarily focused on accounting-based metrics, such as Return on Assets (ROA) and Return on Equity (ROE), and found that investing in green innovation leads to improved ROA and ROE. The proactive approach to spending is construed as an important prerequisite as companies need to be constructive rather than reactive to benefit from green innovation (Przychodzen & Przychodzen, 2013).

The empirical findings on the impact of green innovation on firm performance are, however, distinctly mixed. While some of the studies have established a positive relationship (Aldieri et al., 2020; Song et al., 2017; Wagner, 2010), some others have observed a negative relationship (Gonenc & Scholtens, 2017; Rassier & Earnhart, 2010). Many existing studies have yielded mixed findings (Cheng et al., 2014) or indicated only specific categories of green innovation having effects on financial performance (de Oliveira Brasil et al., 2016). There is also evidence of an inverted U-shaped relationship between green innovation and firm performance (Misani & Pogutz, 2015; Wagner, 2010). A positive linkage between green innovation and firms' financial performance is established in Poland and Hungary. Following the accounting-based metrics, it is proven that investing in green innovation leads to improved ROE and ROA. A recent report based on 153 surveyed companies ascertains an increase in sales and a reduction in manufacturing costs (Pure Strategies Report, 2017).

The studies establishing a positive relationship provide a broad range of explanations, including the increased demand for 'green firm products' due to product differentiation and market expansion (García-Granero et al., 2018), cost reduction due to pollution-reducing measures or increasing efficiency in resource use (Dangelico et al., 2017), and increased competitiveness attributable to an improved corporate image (Testa et al., 2011). Dangelico et al., (2017). A positive relationship can also emanate if environmental innovation is tied to robust regulations (Tsireme et al., 2012). Arguably, strong financial resources are critical to fostering green innovation, and a hands-on approach to monitoring spending patterns helps firms benefit from green innovation (Przychodzen & Przychodzen, 2013).

Those studies establishing a negative relationship between green innovation and firm performance attribute it *inter alia* to the absence of necessary information (Berchicci & King, 2007) and difficulties in comprehending the cost-saving potential of green innovation (Horbach, 2008). The possibilities of a non-linear relationship may signify that initially, environmental measures become expensive, but after a threshold, the costs are compensated (Barnett & Salomon, 2012).

It may be significant to state that the firm performance could vary according to the types of eco-innovation. Both process and product environmental innovations have markedly different positive effects on a firm's environmental performance (Cai & Li, 2018). However, there is inadequate evidence regarding the impact of organizational innovation (Chiou et al., 2011). The contrasting findings according to countries and contexts, and inadequate focus on various dimensions of eco-innovation, warrant the need for examining the effects of eco-innovation in all its stages - from product development to the process and beyond.

Nonetheless, emerging economies reportedly face several challenges to sustainable economic growth. They need to find a balance between the current utilization of natural resources and preserving them for future generations. Simultaneously, they must prioritize the well-being of their citizens alongside economic development. By adopting sustainable practices and incorporating eco-innovation into their growth strategies, these countries can work toward achieving a harmonious integration of economic growth, environmental sustainability, and societal well-being (Davidescu et al., 2015; Jabbour et al., 2015; Przychodzen & Przychodzen, 2015).

Compared to emerging economies, advanced economies often exhibit significant institutional differences. The varying institutional contexts of the latter concerning regulatory framework, governance structure, and market dynamics shape the priorities of their businesses and governments. Addressing

these differences could be critical while designing effective strategies concerning their specific needs and opportunities (Hojnik & Ruzzier, 2016; Kijek, 2015; Lee & Min, 2015).

Given a lack of empirical consensus and limited studies, there is perhaps a need for further investigation concerning eco-innovation in both developed and emerging economies. This would help broaden our understanding of the role of eco-innovation in different country contexts (Díaz-García et al., 2015). To the best of our knowledge, studies examining the impact of green innovation on firm performance in emerging economies, especially BRICS, and a comparison between the advanced and emerging countries are seldom found. There are also limited cross-country analyses, focusing specifically on green innovation at the firm level. It is important to recognize that eco-innovation is context- and country-driven. Hence, understanding the context while delving into specific countries can provide valuable insights into the challenges, opportunities, and dynamics associated with eco-innovation in different country settings (Kemp & Oltra, 2011). The comparisons whatsoever made so far have predominantly focused on aggregate indicators rather than examining individual dimensions and firms (Davidescu et al., 2015).

3. Data and methodology

3.1. Data

The present study is based on secondary data collected from two major sources, namely Refinitiv database (Thomson Reuters) and Bloomberg database. Our analysis considers the publicly listed firms of G7 and BRICS countries. The sample comprises 2100 firms across twelve countries covering a period of ten years from 2013 to 2022. The original dataset had 4000 listed firms from which 2100 firms having a market capitalization of above US\$3 billion were chosen for the present purpose. Details of variables, their sources, and their operationalization are furnished in Table 1.

Table 1. Operationalization of the variables.

| Dependent variable | Operationalization | Data source | References |
|--|---|--------------------------------------|---|
| TQ—Tobin's Q (FPE) | Equity market value + Liabilities market value/Equity book value + Liabilities book value | Bloomberg database | McNamara & Bromiley, 1999; Rahman et al., 2022 |
| Independent variable | | | |
| Product eco-innovation (PDEI) Index formed using PCA of three indicators. | Environmental products/services/activities | Thomson Reuters (Refinitiv) database | García-Granero et al., 2020; Johl & Toha, 2021 |
| | Environmental design of the product | Thomson Reuters (Refinitiv) database | |
| | Clean energy product | Thomson Reuters (Refinitiv) database | |
| Process eco-innovation (PCEI) Index formed using PCA | Reduce the use of energy (Resource reduction score) | Thomson Reuters (Refinitiv) database | García-Granero et al., 2020; Johl & Toha, 2021 |
| | Keep energy use to a minimum (target energy efficiency score) | Thomson Reuters (Refinitiv) database | |
| | Policy energy efficiency score | Thomson Reuters (Refinitiv) database | |
| | Renewable energy (Resource Use score) | Thomson Reuters (Refinitiv) database | |
| Organizational eco-innovation (OGEI) Index formed using PCA | EMS or ISO 14000 certified | Thomson Reuters (Refinitiv) database | García-Granero et al., 2020; Johl & Toha, 2021 |
| | Environmental management training | Thomson Reuters (Refinitiv) database | |
| | Equator Principle | Thomson Reuters (Refinitiv) database | |
| Overall eco-innovation (OVEI) | TRESENPIS or Environmental Innovation Score | Thomson Reuters (Refinitiv) database | Thomson Reuters (Refinitiv) database |
| Control variable | | | |
| Social Pillar Score (SPS) | Social Pillar Score data from the ESG statistics | Thomson Reuters (Refinitiv) database | Grund & Westergaard-Nielsen, 2008; Ergun et al., 2022 |
| Governance Pillar Score (GPS) | Governance Pillar Score data from the ESG statistics. | Thomson Reuters (Refinitiv) database | |
| Firm size (SIZE) | Natural log of each company's total assets | Bloomberg database | |
| Firm age (AGE) | Years of firms' existence (current year–year of incorporation) | Bloomberg database | |

PCA: principle component analysis was used to construct different indices.

3.2. Conceptual framework

There are two theoretical dispositions that offer insights into the interconnection between a firm's resources and its competitive advantage. They are the resource-based view and the new resource-based view. The former emphasizes internal resources and capabilities, highlighting their roles in gaining a long-term comparative edge over competitors, while the latter extends this perspective by recognizing the importance of rare, inimitable, and non-substitutable strategic resources for sustained competitive advantage. In essence, both frameworks provide a theoretical foundation for understanding the relationship across resources, environmental innovation, and firm performance (García-Granero et al., 2020; Munodawafa & Johl, 2019). They are instrumental in comprehending the role of resources in driving innovation, analyzing green capabilities, and creating competitive advantages. By directing managerial attention toward internal resources, both approaches aim to identify a firm's strengths, skills, and competencies that can give it a comparative edge.

Accordingly, three main dimensions of green innovation, namely product, process, and organization, emanate. These dimensions cover both internal and external eco-innovations. Product eco-innovation (PDEI) focuses on designing and developing goods and services that minimize their overall environmental impact. It puts a thrust on eco-design, introducing novel or substantially enhanced products. Process eco-innovation (PCEI) involves the implementation of new or improved production and delivery methods in terms of techniques, equipment, and software to minimize adverse environmental impacts. It aims to decrease material use, lower risks, and achieve cost savings. Compared to the above, organizational eco-innovation (OGEI) involves investments in eco-friendly equipment and embracing innovative production technologies. It requires firms to develop specific resources and capabilities to implement technological eco-innovations successfully. Overall, firms need to invest in green innovation across these dimensions to address environmental challenges and make effective progress toward sustainability (Cai & Li, 2018; Cai & Zhou, 2014; García-Granero et al., 2020).

3.3. Variable description

The present study aims to examine how green innovation affects firms' financial performance across G7 and BRICS nations. While delving into that, we examine the impact of overall green innovation as well as its individual dimensions on the financial performance of the firms (Figure 1). While analyzing the relationship, we consider other relevant firm-level variables as control. A brief discussion regarding the dependent and independent variables is made as follows:

3.3.1. Firm performance

The firm performance is measured by Tobin's Q. Tobin's Q provides insights into how the market perceives a firm's green innovation efforts and assigns values to them (Atan et al., 2018; Saygili et al., 2022).

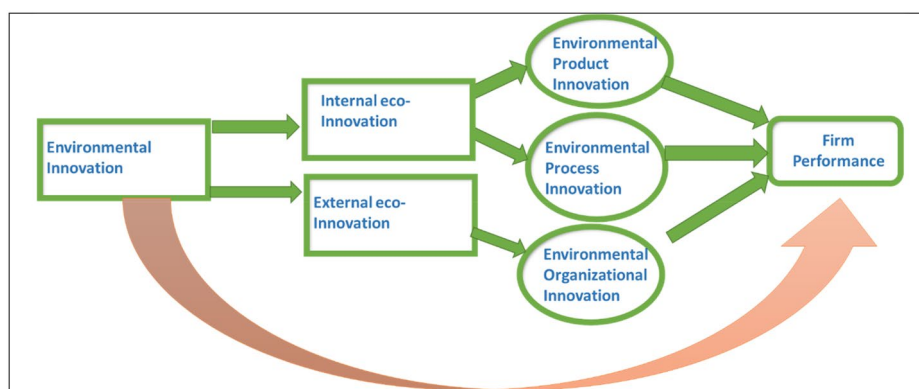


Figure 1. A conceptual framework depicting the relationship between environmental innovation and firm performance.

Source: By author.

While ROA is relevant in considering the costs associated with environmental innovation, Tobin's Q can reflect the subsequent market responses, if any. While some researchers consider ROA more reliable, we consider Tobin's Q as a performance indicator for the present purpose as it is a measure to capture market trends and the value attributed to firms. The data for the estimation of Tobin's Q is collected from the Bloomberg database. Tobin's Q can be estimated as

$$\text{Tobin's } Q = \frac{\text{Equity Market Value} + \text{Liabilities Market Value}}{\text{Equity Book Value} + \text{Liabilities Book Value}}$$

3.3.2. Green innovation

Green innovation relates to green practices and policies the firms implement. In the present study, we formulate an index of green innovation (García-Granero et al., 2020). The purpose is to check how green innovation affects firm performance and how each dimension matters. Drawing upon previous studies (García-Granero et al., 2020; Kuo & Smith, 2018; Marcon et al., 2017; OECD, 2005a), we consider three different dimensions: (a) PDEI, (b)PCEI, and (c) OGEI. PDEI comprises three indicators, namely environment-friendly products/services/activities, clean energy products, and environment-friendly design products (García-Granero et al., 2020). PCEI comprises four indicators. They are the resource use score, resource reduction score, policy energy efficiency score, and target energy efficiency score (Dalhammar, 2015; Johnstone et al., 2010; Rodriguez & Wiengarten, 2017). OGEI considers three items viz. environmental management system (EMS) or ISO 14000 certified, environmental management training, and equator principle (De Jesús Pacheco et al., 2016; Frosch, 1994). We have formulated individual indices for the above three dimensions as well as an overall index of green innovation considering all three dimensions together. To construct the index, we have employed the principal component analysis (PCA). We have employed the environmental innovation score data of Thomson Reuters for the said purpose.

3.3.3. Control variables

While examining the effects of green innovation on firm performance, following earlier studies, we consider four firm-level variables as control (Ergun et al., 2022; Grund & Westergaard-Nielsen, 2008). They are firm size, age, social pillar score (SPS), and governance pillar score (GPS). Firm-specific features seem to affect the magnitude and/or thematic content of ecological exposure provided in business financial reports. To prudently detect whether changes in these disclosures are related to changes in ecological performance, we control for these additional features. More precisely, bigger and older firms are inclined to release more extensive financial and environmental information. Similarly, larger corporations tend to exhibit greater transparency and prioritize societal welfare (Ergun et al., 2022; Grund & Westergaard-Nielsen, 2008; Pattern, 1992, 2002). In addition, environmental social governance (ESG) of individual forms also has a bearing on their performance. ESG comprises two different scores, namely the social pillar score (SPS) and the governance pillar score (GPS). While SPS signifies how socially responsible a firm is, the GPS represents the governance structure of a firm (Senadheera et al., 2021) For the present purpose, the data on size and age are sourced from Bloomberg and the data on ESG is sourced from Thomson Reuters.

3.4. Methodology

To examine the association between green innovation and firms' financial performance across ten selected countries, we employ the feasible generalized least squares (FGLS) model. Prior research has utilized the pooled ordinary least squares (OLS), fixed effect, or random effect panel regressions to evaluate how different variables affect firm performance. The stochastic disturbance regression term in these regression methods must conform to the assumptions of spherical disturbance perturbation. In the likely presence of group-wise heteroscedasticity, cross-sectional correlation, and autocorrelation within panels in the stochastic disturbance term, the FGLS model is the preferred choice for parameter estimation. By adjusting the stochastic disturbance term, the FGLS model allows for a more accurate estimation of the parameters (Greene, 2018). It is utilized to estimate the parameters by modifying the stochastic

disturbance term to enhance the efficiency of the estimators. It effectively mitigates multicollinearity problems and considers cross-sectional dependence. Compared to OLS regression, the FGLS model is considered unbiased and asymptotically normal (Aitken, 1936; Miller & Startz, 2018). For FGLS,

$$\widehat{\beta}_{GLS} = \left(X \widehat{\Sigma}^{-1} X \right)^{-1} X \widehat{\Sigma}^{-1} Y \quad (1)$$

The explained variable is denoted as Y , representing the firm performance. The vector X encompasses a set of explanatory variables, including different eco-innovations and control variables. The transpose of X indicates its rearranged form. Σ is the Kronecker product, which is expressed as

$$\Sigma = \Omega_{m \times m} \otimes I_{T_i \times T_j} \quad (2)$$

The quantity of observations is symbolized by m , and T_i indicates the duration of observation. The estimated variance matrix is obtained by replacing the estimator $\widehat{\Omega}_{i,j}$ with Ω in the corresponding position. Accordingly, the specific FGLS models for the present study are expressed as follows:

$$FPE_{it} = \alpha + \beta_1 PDEI_{it} + \gamma_1 sps_{it} + \gamma_2 gps_{it} + \gamma_3 fsize_{it} + \gamma_4 fage_{it} + \epsilon_{it} \quad (3)$$

$$FPE_{it} = \alpha + \beta_1 PCEI_{it} + \gamma_1 sps_{it} + \gamma_2 gps_{it} + \gamma_3 fsize_{it} + \gamma_4 fage_{it} + \epsilon_{it} \quad (4)$$

$$FPE_{it} = \alpha + \beta_1 OGEI_{it} + \gamma_1 sps_{it} + \gamma_2 gps_{it} + \gamma_3 fsize_{it} + \gamma_4 fage_{it} + \epsilon_{it} \quad (5)$$

$$FPE_{it} = \alpha + \beta_1 OVEI_{it} + \gamma_1 sps_{it} + \gamma_2 gps_{it} + \gamma_3 fsize_{it} + \gamma_4 fage_{it} + \epsilon_{it} \quad (6)$$

Where FPE_{it} represents performance for the i^{th} firm at time t . OVEI is the overall eco-innovation. The terms age and size represent firm age and firm size, respectively. All other terms are already defined earlier.

To ensure the consistency of our findings, we employ the Breusch-Pagan (BP) test and the White test to detect the possibility of heteroscedasticity. The BP test assesses the hypothesis that error variances are equal (homoscedastic) against the alternative hypothesis that they exhibit a multiplicative pattern (heteroskedastic). Though the White test serves a similar purpose, it is particularly effective when we deal with non-linear heteroscedasticity and have errors that do not follow a normal distribution. The results of the Breusch-Pagan and White tests are presented in Table 2. Subsequently, we investigate the possibility of serial correlation and cross-sectional dependency. The Wooldridge SE F-Test is employed to detect serial correlation, and the results are reported in Table 3. Similarly, Pesaran's test is employed to examine cross-sectional dependency, if any (Table 4).

The results presented in Table 2 reveal the presence of heteroscedasticity in the model. This is evident as the null hypothesis is rejected at a significance level of 1% for the measures of firm performance. Besides, the model also exhibits serial correlation, as indicated by the results of the Wooldridge F-test, rejecting the null hypothesis of no serial correlation at a 1% significance level (Table 3). Similarly, Pesaran's test supports the concerns regarding cross-sectional dependency, which also rejects the null hypothesis at a 1% significance level (Table 4). Consequently, the FGLS approach is chosen as the appropriate method based on the above diagnostic tests, which addresses these problems adequately. Needless to say, FGLS is widely employed in various studies investigating the relationship between

Table 2. Results of the heteroscedasticity test.

| Dependent variable firm performance | Model 1 (PDEI) | Model 2 (PCEI) | Model 3 (OGEI) | Model 4 (OVEI) |
|-------------------------------------|----------------|----------------|----------------|----------------|
| Breusch-Pagan test | | | | |
| Chi ² | 297738.21 | 536.12 | 584.38 | 164.36 |
| Prob > Chi ² | 0.000 | 0.000 | 0.000 | 0.000 |
| Chi ² | 19969.56 | 1325.52 | 1180.43 | 1396.74 |
| White test | | | | |
| Prob > Chi ² | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Source: Authors' estimates.

Table 3. Results of the serial correlation test (White test).

| Dependent variable firm performance | Model 1 (PDEI) | Model 2 (PCEI) | Model 3 (OGEI) | Model 4 (OVEI) |
|-------------------------------------|----------------|----------------|----------------|----------------|
| Chi ² | 2061.784 | 2158.755 | 2131.654 | 2000.017 |
| Prob > Chi ² | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Source: Authors' estimates.

Table 4. Results of the cross-sectional dependence.

| | FPE | PDEI | PCEI | OGEI | OVEI | SPS | GPS | AGE | size |
|----------------------|----------|---------|---------|---------|---------|----------|---------|----------|---------|
| Pesaran's test of CD | 1502.353 | 148.710 | 251.744 | 114.559 | 210.290 | 1152.182 | 420.416 | 3935.389 | 647.402 |
| Prob | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Source: Authors' estimates.

Table 5. FGLS with robust standard errors results regarding the relationship between green innovation and firm performance.

| | Model 1 FPE | Model 2 FPE | Model 3 FPE | Model 4 FPE |
|------|----------------|----------------|----------------|----------------|
| PDEI | 0.41*** | | | |
| PCEI | | 1.92*** | | |
| OGEI | | | 1.27*** | |
| OVEI | | | | 0.11*** |
| SPS | 0.59*** | 0.52*** | 0.57*** | 0.55*** |
| GPS | 0.33*** | 0.32*** | 0.33*** | 0.33*** |
| Age | 1.43*** | 1.04*** | 1.35*** | 1.01*** |
| Size | 0.52*** | 0.47*** | 0.53*** | 0.28*** |

Source: Authors' estimates.

*** $p < 0.01$.

sustainability and financial deepening (Akintande et al., 2020; De Pascale et al., 2020; Le & Nguyen, 2019; Obiora et al., 2020).

3.5. Robustness check

Additionally, to check the robustness of the results, the two-step system generalized method of moments (GMM) model is used to examine the influence of explanatory variables on firm performance. Some important variables in our model might be endogenous. The problems of heteroscedasticity and endogeneity associated with panel data can also be addressed by GMM. It is also considered a suitable model for a dataset having small time spans (T) and big cross-sections (N) (Bhattacharya et al., 2017). GMM comprises two subtypes: difference GMM and system GMM. The employment of instruments that are valid under the presumption that the disturbance terms are actually independent and serially uncorrelated is what makes both difference and system GMM approaches so attractive. The system GMM is more resistant to autocorrelation and heteroscedasticity. It turns out to be better than difference GMM if the dependent variable is significantly more persistent (Blundell & Bond, 1998). So we have used system GMM as a robustness check mechanism in our work.

4. Results and discussion

As mentioned earlier, we have employed FGLS with robust standard errors to study the effects of green innovation on firms' financial performance in G7 and BRICS countries. The findings (Table 5) reveal that OVEI and all its three individual dimensions exert positive impacts on firm performance, corroborating earlier studies (Bossle et al., 2016; Cai & Li, 2018; de Oliveira Brasil et al., 2016; Larbi-Siaw et al., 2022). A one percent increase in OVEI leads to an 11% increase in firms' financial performance in these countries. While all the individual dimensions do influence positively, the impacts of PCEI (1.92) (Marcon et al., 2017; Rodriguez & Wiengarten, 2017) followed by OGEI (1.27) (Hojnik & Ruzzier, 2016) turn out to be much greater than that of PDEI (0.41).

We have also carried out a separate sub-sample analysis for the BRICS and G7 countries (Table 6). Interestingly, the coefficients of the OVEI for both the sub-samples turn out to be more or less the same. However, the coefficient of PDEI (2.11) in the G7 countries is very high, and there seem to be significant differences in the impacts between the two groups of countries. There is also a visible difference in the impacts of OGEI between them. However, the impacts of PCEI tend to be, by and large, the same between the two groups. Interestingly, both overall and sub-sample analyses indicate that the coefficients of all the control variables are positive and significant.

To test the robustness of the results, we have also employed the System GMM for the overall sample as well as the two sub-samples (Tables 7 and 8). Interestingly, these results, by and large, indicate a similar association between green innovation and firm performance. The signs of coefficients remain the same, with a little variation in the values across dimensions. In all the models, the coefficients of the control variables are positive and significant, implying that with the increase in age and size and improvement in SPS and GPS, the firms tend to perform better financially.

The findings support the notion that environmental innovation, encompassing product, process, and organizational dimensions, exerts positive impacts on firms' financial performances. These dimensions play a critical role in influencing firm performance in both BRICS and G7 countries, though with varying proportions. The results closely align with the findings of Cheng et al. (2014), who focused on 121 electronics manufacturing companies in Thailand. The results also seem to partially agree with the models proposed by de Oliveira for textile manufacturing firms originating in Brazil (de Oliveira Brasil et al., 2016) and manufacturing firms in Ghana (Larbi-Siaw et al., 2022).

One interesting revelation is that in BRICS countries, the primary drivers of firm performance are process and organizational innovation, while product innovation carries lesser importance. In contrast, in G7 countries, product innovation takes precedence, followed by process and organizational innovations. These results seem to provide interesting implications. BRICS countries are in the process of developing organizational and process innovations (Amores-Salvadó et al., 2015; Cheng et al., 2014; de Oliveira Brasil et al., 2016; Larbi-Siaw et al., 2022). They need to capitalize on these dimensions further with a renewed focus while ensuring that product innovation gets due attention. On the contrary, G7

Table 6. Sub-sample analysis.

| | Model 1 FPE | | Model 2 FPE | | Model 3 FPE | | Model 4 FPE | |
|------|----------------|---------|----------------|---------|----------------|---------|----------------|---------|
| | BRICS | G7 | BRICS | G7 | BRICS | G7 | BRICS | G7 |
| PDEI | 0.08*** | 2.10*** | | | | | | |
| PCEI | | | 1.83*** | 1.80*** | | | | |
| OGEI | | | | | 1.35*** | 1.04*** | | |
| OVEI | | | | | | | 0.10*** | 0.11*** |
| SPS | 0.59*** | 0.55*** | 0.52*** | 0.52*** | 0.57*** | 0.56*** | 0.55*** | 0.54*** |
| GPS | 0.33*** | 0.33*** | 0.32*** | 0.32*** | 0.32*** | 0.33*** | 0.32*** | 0.33*** |
| Age | 6.30*** | 1.50*** | 4.57*** | 1.27*** | 5.47*** | 1.82*** | 4.65*** | 1.43*** |
| Size | 1.52*** | 1.09* | 1.44*** | 1.19*** | 1.72*** | 1.49** | 2.13*** | 0.83* |

Source: Authors' estimates.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. System GMM (two-step).

| | Model 1 FPE | Model 2 FPE | Model 3 FPE | Model 4 FPE |
|-------------|----------------|----------------|----------------|----------------|
| L.FPE | 0.24*** | 0.10*** | 0.15*** | 0.06* |
| PDEI | 0.07** | | | |
| PCEI | | 1.44*** | | |
| OGEI | | | 1.23*** | |
| OVEI | | | | 0.10*** |
| SPS | 0.51*** | 0.57*** | 0.51*** | 0.56*** |
| GPS | 0.22*** | 0.28*** | 0.26*** | 0.30*** |
| Age | 0.81*** | 0.79*** | 0.86*** | 0.61*** |
| Size | 0.10*** | 0.06*** | 0.53*** | 0.13* |
| AR(1) | 0.001 | 0.031 | 0.001 | 0.000 |
| AR(2) | 0.322 | 0.114 | 0.335 | 0.224 |
| Hansen test | 0.124 | 0.159 | 0.115 | 0.105 |

Source: Authors' estimates.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8. System GMM country wise (two-step).

| | Model 1 FPE | | Model 2 FPE | | Model 3 FPE | | Model 4 FPE | |
|-------------|----------------|---------|----------------|---------|----------------|---------|----------------|---------|
| | BRICS | G7 | BRICS | G7 | BRICS | G7 | BRICS | G7 |
| L.FPE | 0.31*** | 0.08** | 0.10*** | 0.24*** | 0.15*** | 0.25*** | 0.24*** | 0.10** |
| PDEI | 1.01** | 1.93*** | | | | | | |
| PCEI | | | 1.39*** | 0.91*** | | | | |
| OGEI | | | | | 1.62*** | 1.04*** | | |
| OVEI | | | | | | | 0.10*** | 0.11*** |
| SPS | 0.45*** | 0.55*** | 0.55*** | 0.50*** | 0.44*** | 0.52*** | 0.55*** | 0.54*** |
| GPS | 0.24*** | 0.30*** | 0.29*** | 0.25*** | 0.27*** | 0.32*** | 0.32*** | 0.33*** |
| Age | 0.43* | 0.77*** | 0.90*** | 0.06* | 0.06* | 1.27*** | 4.65*** | 1.43*** |
| Size | 0.01* | 0.01* | 0.04* | 0.04* | 0.02* | 1.19*** | 2.13*** | 0.83* |
| AR(1) | 0.001 | 0.000 | 0.067 | 0.021 | 0.041 | 0.000 | 0.012 | 0.000 |
| AR(2) | 0.221 | 0.369 | 0.445 | 0.778 | 0.665 | 0.692 | 0.517 | 0.492 |
| Hansen test | 0.214 | 0.125 | 0.183 | 0.121 | 0.441 | 0.831 | 0.227 | 0.371 |

Source: Authors' estimates.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

countries seem to benefit more from their product innovations. While encouraging further innovations in that dimension, they must pay attention to process and organizational innovations. Nevertheless, product innovation puts thrust on eco-design, eco-product, and clean energy products, contributing to firms' sustainability (Mazzoni, 2020). According to Tseng and Bui (2017), green-design or environmental friendly product design is an improved process of manufacturing that takes into account the environmental, social, and economic factors associated with a product's life cycle. Its aim is to minimize the ecological footprint and prioritize the efficient use of resources (Ivascu, 2020). Another crucial aspect that requires attention is the continuous evolution or revolution of eco-products, including a reduction in raw material intensity, and increasing renewable energy concentration, product recyclability, and strength (Mazzoni, 2020; Stankevičienė & Nikanorova, 2020). It will foster a firm's participation in a sustainable economy.

5. Conclusion and policy implications

The objective of this study was to examine how environmental innovation affects firm performance in countries experiencing different levels of development. For the said purpose, BRICS and G7 countries were considered. Employing FGLS and system GMM models, the analysis revealed that environmental innovation has a positive impact on firm performance. Additionally, firms in BRICS countries seem to gain more from PCEI and OGEI compared to firms in G7 countries. Contrarily, in G7 countries, PDEI carries greater significance compared to other dimensions, indicating possibly a more advanced stage of eco-innovation in these countries. These findings partially support the notion of divergent eco-innovation outcomes between G7 and BRICS countries. Further, G7 countries perhaps are already endowed with the necessary resources for green innovation, whereas BRICS countries are still evolving in this area.

One major takeaway of this study is that eco-innovation, regardless of dimensions, can help firms perform better financially. As the latter's performance has ramifications for the overall growth of an economy, it may be pertinent to promote green innovation in all spheres of economic activities. Efforts to encourage green innovation in products, processes, and organizations can go a long way toward enhancing the growth prospects of both G7 and BRICS countries.

From the perspective of policy implications, one may advocate for robust regulations, monitoring, and support for firms across both developed and emerging economies as steps toward incorporating eco-innovations into their processes. Adoption of eco-innovation technologies and processes could enhance resource efficiency, reduce waste generation, and minimize environmental impact. By investing in energy-efficient equipment, optimizing production processes, and implementing sustainable supply chain practices, firms can achieve cost savings over time (Chiarvesio et al., 2015; Chiou et al., 2011). Managers can play a crucial role in identifying opportunities for cost-saving innovations, allocating resources effectively, and overseeing the implementation of green practices across different processes. Embracing green innovation would also allow firms to differentiate themselves in the marketplace by

offering environmental-friendly products and services. Consumers are increasingly seeking eco-friendly alternatives, and firms prioritizing sustainability can take advantage of this (Bossle et al., 2016; de Oliveira Brasil et al., 2016).

The firms are required to engage themselves in effective marketing and communication strategies to highlight their organizational commitment to environmental responsibility, thereby enhancing brand reputation and loyalty (Bossle et al., 2016). By adopting sustainable practices, they can reduce their environmental footprint and, consequently, minimize possible regulatory penalties (Cheng et al., 2014). Additionally, integrating eco-innovation into management frameworks would allow firms to identify and mitigate supply chain disruptions and resource scarcity. It would also help them gain access to government incentives, grants, or subsidies wherever available. Moreover, sustainable business practices can attract socially responsible investors who prioritize environmental, social, and governance (ESG) criteria in their investment decisions. Embracing green innovation can also enhance productivity, and retention by aligning organizational values with employees' personal beliefs and aspirations (Grund & Westergaard-Nielsen, 2008).

The varying impacts of various dimensions of eco-innovation between two groups of countries reflect varying stages of their development and priorities toward eco-innovation. From a policy perspective, these findings have important ramifications for policymakers and practitioners alike. First, in BRICS countries may consider implementing targeted initiatives to promote environmental innovation and enhance firms' capacity to leverage eco-friendly practices for improved performance (Gyedu et al., 2021; Hojnik & Ruzzier, 2016). This could involve investing in research and development, providing financial incentives, and fostering collaboration between government, academia, and industry. Additionally, G7 countries should continue to support and incentivize firms to engage in environmental innovation, particularly in areas where there may be untapped potential for growth and competitiveness. This may involve strengthening regulatory frameworks, promoting knowledge sharing and best practices, and encouraging investments in sustainable technologies and practices. There is also a need for greater collaboration between G7 and BRICS countries so that all can synergistically grow toward addressing a common goal (Murshed, 2020; Testa et al., 2011).

However, the study is still not free from limitations. As it is based on firm-level analysis, the generalization of the findings for the entire economy may be made with caution. Moreover, the model estimation is based only on ten years of data. The data for a longer period would help understand the short-run and long-run dynamics separately. This study can also be broadened by incorporating both listed and un-listed firms. Notwithstanding these limitations, it may be concluded that green innovation can be a way forward to attain and maintain a sustainable future as it ensures better firm performance for both developed and emerging economies alike.

Authors contributions

Nirupam Mukhopadhyay: conceptualization, methodology, data and analysis, writing original draft. Narayan Chandra Nayak: conceptualization, writing review and editing, supervision.

Disclosure statement

No potential conflict of interest was reported by the author(s).

About the authors

Nirupam Mukhopadhyay is a research scholar at the Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, India. His research interests include Green growth, Green innovation and diffusion of innovation at firm as well as Macroeconomic level.

Narayan Chandra Nayak is senior professor of Economics at the Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, India. His research interests include Applied Macroeconomics, Public policy, Food security and Financial Inclusion and growth dynamics.

Funding

No funding received.

Data availability statement

Data can be made available on request.

References

- Aitken, A. C. (1936). A further note on multivariate selection. *Proceedings of the Edinburgh Mathematical Society*, 5, 1–17.
- Akintande, O. J., Olubusoye, O. E., Adenikinju, A. F., & Olanrewaju, B. T. (2020). Modeling the determinants of renewable energy consumption: Evidence from the five most populous nations in Africa. *Energy*, 206, 117992. <https://doi.org/10.1016/j.energy.2020.117992>
- Aldieri, L., Makkonen, T., & Vinci, C. (2020). Environmental knowledge spillovers and productivity: A patent analysis for large international firms in the energy, water and land resources fields. *Resources Policy*, 69(c), 101877. <https://doi.org/10.1016/j.resourpol.2020.101877>
- Amores-Salvadó, J., Martín-de Castro, G., & Navas-López, J. E. (2015). The importance of the complementarity between environmental management systems and environmental innovation capabilities: A firm level approach to environmental and business performance benefits. *Technological Forecasting and Social Change*, 96, 288–297.
- Atalay, M., Anafarta, N., & Sarvan, F. (2013). The relationship between innovation and firm performance: An empirical evidence from Turkish automotive supplier industry. *Procedia-Social and Behavioral Sciences*, 75, 226–235.
- Atan, R., Alam, M. M., Said, J., & Zamri, M. (2018). The impacts of environmental, social, and governance factors on firm performance: Panel study of Malaysian companies. *Management of Environmental Quality: An International Journal*, 29(2), 182–194. <https://doi.org/10.1108/MEQ-03-2017-0033>
- Barnett, M. L., & Salomon, R. M. (2012). Does it pay to be really good? Addressing the shape of the relationship between social and financial performance. *Strategic Management Journal*, 33(11), 1304–1320. <https://doi.org/10.1002/smj.1980>
- Berchicci, L., & King, A. (2007). 11 Postcards from the edge: a review of the business and environment literature. *Academy of Management Annals*, 1, 513–547.
- Bhattacharya, M., Awaworyi Churchill, S., & Paramati, S. R. (2017). The dynamic impact of renewable energy and institutions on economic output and CO₂ emissions across regions. *Renewable Energy*, 111, 157–167. <https://doi.org/10.1016/j.renene.2017.03.102>
- Biswas, A., & Roy, M. (2015). Leveraging factors for sustained green consumption behavior based on consumption value perceptions: Testing the structural model. *Journal of Cleaner Production*, 95, 332–340. <https://doi.org/10.1016/j.jclepro.2015.02.042>
- Bitencourt, C. C., de Oliveira Santini, F., Zanandrea, G., Froehlich, C., & Ladeira, W. J. (2020). Empirical generalizations in eco-innovation: A meta-analytic approach. *Journal of Cleaner Production*, 245, 118721. <https://doi.org/10.1016/j.jclepro.2019.118721>
- Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143.
- Bocken, N. M. P., Farracho, M., Bosworth, R., & Kemp, R. (2014). The front-end of eco-innovation for eco-innovative small and medium sized companies. *Journal of Engineering and Technology Management*, 31, 43–57. <https://doi.org/10.1016/j.jengtecman.2013.10.004>
- Bossle, M. B., Dutra de Barcellos, M., Vieira, L. M., & Sauvée, L. (2016). The drivers for adoption of eco-innovation. *Journal of Cleaner Production*, 113, 861–872. <https://doi.org/10.1016/j.jclepro.2015.11.033>
- Brundtland, G. H. (1987). *Our common future: Report of the World Commission on Environment and Development*. UN-Dokument A/42/427. <http://www.un-documents.net/ocf-ov.htm>
- Cai, W. G., & Zhou, X. L. (2014). On the drivers of eco-innovation: Empirical evidence from China. *Journal of Cleaner Production*, 79, 239–248. <https://doi.org/10.1016/j.jclepro.2014.05.035>
- Cai, W., & Li, G. (2018). The drivers of eco-innovation and its impact on performance: Evidence from China. *Journal of Cleaner Production*, 176, 110–118. <https://doi.org/10.1016/j.jclepro.2017.12.109>
- Cheng, C. C., Yang, C., & Sheu, C. (2014). The link between eco-innovation and business performance: A Taiwanese industry context. *Journal of Cleaner Production*, 64, 81–90. <https://doi.org/10.1016/j.jclepro.2013.09.050>
- Chiarvesio, M., Marchi, V. D., & Maria, E. D. (2015). Environmental innovations and internationalization: Theory and practices. *Business Strategy and the Environment*, 24(8), 790–801. <https://doi.org/10.1002/bse.1846>
- Chiesa, V., & Frattini, F. (2011). Commercializing technological innovation: Learning from failures in high-tech markets. *Journal of Product Innovation Management*, 28(4), 437–454. <https://doi.org/10.1111/j.1540-5885.2011.00818.x>
- Chiou, T.-Y., Chan, H. K., Lettice, F., & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transportation Research Part E: Logistics and Transportation Review*, 47(6), 822–836. <https://doi.org/10.1016/j.tre.2011.05.016>

- Dalhammar, C. (2015). Industry attitudes towards ecodesign standards for improved resource efficiency. *Journal of Cleaner Production*, 123, 155–166. <https://doi.org/10.1016/j.jclepro.2015.12.035>
- Dangelico, R. M., Pujari, D., & Pontrandolfo, P. (2017). Green product innovation in manufacturing firms: A sustainability-oriented dynamic capability perspective. *Business Strategy and the Environment*, 26, 490–506.
- Davidescu, A. A., Paul, A. M. V., Gogonea, R.-M., & Zaharia, M. (2015). Evaluating Romanian eco-innovation performances in European context. *Sustainability*, 7(9), 12723–12757. <https://doi.org/10.3390/su70912723>
- De Jesús Pacheco, D. A., ten Caten, C. S., Jung, C. F., Ribeiro, J. L. D., Navas, H. V. G., & CruzMachado, V. A. (2016). Eco-innovation determinants in manufacturing SMEs: Systematic review and research directions. *Journal of Cleaner Production*, 142(4), 2277–2287. <https://doi.org/10.1016/j.jclepro.2016.11.049>
- de Oliveira Brasil, M. V., Sá de Abreu, M. C., da Silva Filho, J. C. L., & Leocádio, A. L. (2016). Relationship between eco-innovations and the impact on business performance: An empirical survey research on the Brazilian textile industry. *Revista de Administração*, 51(3), 276–287. <https://doi.org/10.1016/j.rausp.2016.06.003>
- De Pascale, G., Sardaro, R., Facciolongo, N., & Contò, F. (2020). What is the influence of FDI and international people flows on environment and growth in OECD countries? A panel study. *Environmental Impact Assessment Review*, 84, 106434. <https://doi.org/10.1016/j.eiar.2020.106434>
- Díaz-García, C., González-Moreno, Á., & Sáez-Martínez, F. J. (2015). Eco-innovation: Insights from a literature review. *Innovation*, 17(1), 6–23. <https://doi.org/10.1080/14479338.2015.1011060>
- Ergun, K., Aydoğmuş, M., & Gülay, G. (2022). Impact of ESG performance on firm value and profitability. *Borsa Istanbul Review*, 22, S119–S127. <https://doi.org/10.1016/j.bir.2022.11.006>
- Farooq, U., Al-Gamrh, B., & Dai, J. (2024). Green drives greenbacks: The impact of sustainable innovation on corporate cash holdings in BRICS nations. *Journal of Cleaner Production*, 436, 140533. <https://doi.org/10.1016/j.jclepro.2023.140533>
- Franceschini, S., & Panseira, M. (2015). Beyond unsustainable eco-innovation: The role of narratives in the evolution of the lighting sector. *Technological Forecasting and Social Change*, 92, 69–83. <https://doi.org/10.1016/j.techfore.2014.11.007>
- Frosch, R. A. (1994). Industrial ecology: Minimizing the impact of industrial waste. *Physics Today*, 47(11), 63–68. <https://doi.org/10.1063/1.881405>
- García-Granero, E. M., Piedra-Muñoz, L., & Galdeano-Gómez, E. (2018). Eco-innovation measurement: A review of firm performance indicators. *Journal of Cleaner Production*, 191, 1304–317. <https://doi.org/10.1016/j.jclepro.2018.04.215>
- García-Granero, E. M., Piedra-Muñoz, L., & Galdeano-Gómez, E. (2020). Measuring eco-innovation dimensions: The role of environmental corporate culture and commercial orientation. *Research Policy*, 49(8), 104028. <https://doi.org/10.1016/j.respol.2020.104028>
- Gonenc, H., & Scholtens, B. (2017). Environmental and financial performance of fossil fuel firms: A closer inspection of their interaction. *Ecological Economics*, 132, 307–328. <https://doi.org/10.1016/j.ecolecon.2016.10.004>
- Greene, W. (2018). *Econometric analysis* (8th ed.). Pearson Education Limited.
- Grund, C., & Westergaard-Nielsen, N. (2008). Age structure of the workforce and firm performance. *International Journal of Manpower*, 29(5), 410–422. <https://doi.org/10.1108/01437720810888553>
- Gyedu, S., Heng, T., Ntarmah, A. H., He, Y., & Frimpong, E. (2021). The impact of innovation on economic growth among G7 and BRICS countries: A GMM style panel vector autoregressive approach. *Technological Forecasting and Social Change*, 173(2021), 121169. <https://doi.org/10.1016/j.techfore.2021.121169>
- Hart, S. L., & Dowell, G. (2011). Invited editorial: A natural-resource-based view of the firm: Fifteen years after. *Journal of Management*, 37(5), 1464–1479. <https://doi.org/10.1177/0149206310390219>
- Hellström, T. (2007). Dimensions of environmentally sustainable innovation: The structure of eco-innovation concepts. *Sustainable Development*, 15(3), 148–159. <https://doi.org/10.1002/sd.309>
- Herman, K. S., & Xiang, J. (2022). Channeled through trade: How foreign environmental regulations induce domestic renewable energy innovation. *Energy Research & Social Science*, 89, 102629. <https://doi.org/10.1016/j.erss.2022.102629>
- Hojnik, J., & Ruzzier, M. (2016). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, 19, 31–41. <https://doi.org/10.1016/j.eist.2015.09.006>
- Horbach, J. (2008). Determinants of environmental innovation—New evidence from German panel data sources. *Research Policy*, 37(1), 163–173. <https://doi.org/10.1016/j.respol.2007.08.006>
- Inglese-Lotz, R., & Pouris, A. (2013). The influence of scientific research output of academics on economic growth in South Africa: An autoregressive distributed lag (ARDL) application. *Scientometrics*, 95(1), 129–139. <https://doi.org/10.1007/s11192-012-0817-3>
- Ivascu, L. (2020). Measuring the implications of sustainable manufacturing in the context of Industry 4.0. *Processes*, 8(5), 585. <https://doi.org/10.3390/pr8050585>
- Jabbour, C. J. C., Saturnino Neto, A., Gobbo, J. A.Jr., Ribeiro, M. S., & Jabbour, A. B. L. S. (2015). Eco-innovations in more sustainable supply chains for a low-carbon economy: A multiple case study of human critical success factors in Brazilian leading companies. *International Journal of Production Economics*, 164, 245–257. <https://doi.org/10.1016/j.ijpe.2014.11.015>
- Johl, S. K., & Toha, M. A. (2021). The nexus between proactive eco-innovation and firm financial performance: A circular economy perspective. *Sustainability*, 13(11), 6253. <http://dx.doi.org/10.3390/su13116253>

- Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics*, 45(1), 133–155. <https://doi.org/10.1007/s10640-009-9309-1>
- Katsikeas, C. S., Leonidou, C. N., & Zeriti, A. (2016). Eco-friendly product development strategy: Antecedents, outcomes, and contingent effects. *Journal of the Academy of Marketing Science*, 44(6), 660–684. <https://doi.org/10.1007/s11747-015-0470-5>
- Kemp, R., & Oltra, V. (2011). Research insights and challenges on eco-innovation dynamics. *Industry & Innovation*, 18(3), 249–253. <https://doi.org/10.1080/13662716.2011.562399>
- Kemp, R., & Pearson, P. (2007). *Final report MEI project about measuring eco-innovation* (Vol. 10). UM Merit.
- Kijek, T. (2015). Modelling of eco-innovation diffusion: The EU eco-label. *Comparative Economic Research*, 18(1), 65–79. <https://doi.org/10.1515/cer-2015-0004>
- Klewitz, J., Zeyen, A., & Hansen, E. G. (2012). Intermediaries driving eco-innovation in SMEs: A qualitative investigation. *European Journal of Innovation Management*, 15(4), 442–467. <https://doi.org/10.1108/14601061211272376>
- Kuo, T.-C., & Smith, S. (2018). A systematic review of technologies involving eco-innovation for enterprises moving towards sustainability. *Journal of Cleaner Production*, 192, 207–220. <https://doi.org/10.1016/j.jclepro.2018.04.212>
- Larbi-Siaw, O., Xuhua, H., Owusu, E., Owusu-Agyeman, A., Fulgence, B. E., & Frimpong, S. A. (2022). Eco-innovation, sustainable business performance and market turbulence moderation in emerging economies. *Technology in Society*, 68, 101899.
- Le, T.-H., & Nguyen, C. P. (2019). Is energy security a driver for economic growth? Evidence from a global sample. *Energy Policy*, 129, 436–451. <https://doi.org/10.1016/j.enpol.2019.02.038>
- Lee, K. H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production*, 108, 534–542. <https://doi.org/10.1016/j.jclepro.2015.05.114>
- Levidow, L., Lindgaard-Jørgensen, P., Nilsson, A., Skenhall, S. A., & Assimacopoulos, D. (2016). Process eco-innovation: Assessing meso-level eco-efficiency in industrial water-service systems. *Journal of Cleaner Production*, 110, 54–65. <https://doi.org/10.1016/j.jclepro.2014.12.086>
- Lin, H., Zeng, S. X., Ma, H. Y., Qi, G. Y., & Tam, V. W. Y. (2014). Can political capital drive corporate green innovation? Lessons from China. *Journal of Cleaner Production*, 64, 63–72. <https://doi.org/10.1016/j.jclepro.2013.07.046>
- López, F. J. D., & Montalvo, C. (2015). A comprehensive review of the evolving and cumulative nature of eco-innovation in the chemical industry. *Journal of Cleaner Production*, 102, 30–43. <https://doi.org/10.1016/j.jclepro.2015.04.007>
- Marcon, A., de Medeiros, J. F., & Ribeiro, J. L. D. (2017). Innovation and environmentally sustainable economy: Identifying the best practices developed by multinationals in Brazil. *Journal of Cleaner Production*, 160, 83–97. <https://doi.org/10.1016/j.jclepro.2017.02.101>
- Mazzoni, F. (2020). Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster. *Insights into Regional Development*, 2, 661–676.
- McNamara, G., & Bromiley, P. (1999). Risk and return in organizational decision making. *Academy of Management Journal*, 42(3), 330–339. <https://doi.org/10.2307/256923>
- Miller, S., & Startz, R. (2018). Feasible generalized least squares using machine learning. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2966194>
- Misani, N., & Pogutz, S. (2015). Unraveling the effects of environmental outcomes and processes on financial performance: A non-linear approach. *Ecological Economics*, 109, 150–160. <https://doi.org/10.1016/j.ecolecon.2014.11.010>
- Mondejar-Jimenez, J., Segarra-Oña, M., Peiró-Signes, A., Pay A-Martínez, A. M., S., & Aez-Martínez, F. J. (2015). Segmentation of the Spanish automotive industry with respect to the environmental orientation of firms: Towards an ad-hoc vertical policy to promote eco-innovation. *Journal of Cleaner Production*, 86, 238–244. <https://doi.org/10.1016/j.jclepro.2014.08.034>
- Moratis, L., & Melissen, F. (2019). How do the sustainable development goals question rather than inform corporate sustainability? *Resources, Conservation and Recycling*, 141, 253–254. <https://doi.org/10.1016/j.resconrec.2018.10.043>
- Munodawafa, R. T., & Johl, S. K. (2019). A systematic review of eco-innovation and performance from the resource-based and stakeholder perspectives. *Sustainability*, 11(21), 6067. <https://doi.org/10.3390/su11216067>
- Murshed, M. (2020). An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. *Environmental Science and Pollution Research*, 27(29), 36254–36281. <https://doi.org/10.1007/s11356-020-09497-3>
- Nelson, V. (2009). *Wind energy: renewable energy and the environment*. CRC Press.
- Nishitani, K., Jannah, N., Kaneko, & S. Hardinsyah. (2017). Does corporate environmental performance enhance financial performance? An empirical study of Indonesian firms. *Environmental Development*, 23, 10–21. <https://doi.org/10.1016/j.envdev.2017.06.003>
- Obiora, S. C., Bamisile, O., Opoku-Mensah, E., & Kofi Frimpong, A. N. (2020). Impact of banking and financial systems on environmental sustainability: An overarching study of developing, emerging, and developed economies. *Sustainability*, 12(19), 8074. <https://doi.org/10.3390/su12198074>
- OECD (2005a). *Oslo manual: Guidelines for collecting and interpreting innovation data* (Vol. 46). Author.
- OECD (2005b). *Oslo manual: Guidelines for collecting and interpreting technological innovation data*. Organisation for Economic Co-operation and Development; Statistical Office of the European Communities.

- Palmer, K., Oates, W. E., & Portney, P. R. (1995). Tightening environmental standards: The benefit-cost or the no-cost paradigm? *Journal of Economic Perspectives*, 9(4), 119–132. <https://doi.org/10.1257/jep.9.4.119>
- Pattern, D. M. (1992). Intra-industry environmental disclosure in response to the Alaskan oil spill: A note to legitimacy theory. *Accounting, Organization and Society*, 17(5), 471–475.
- Pattern, D. M. (2002). The relationship between environmental performance and environmental disclosure. A research note. *Accounting, Organization and Society*, 28(8), 763–773.
- Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, 9(4), 97–118. <https://doi.org/10.1257/jep.9.4.97>
- Przychodzen, J., & Przychodzen, W. (2013). Corporate sustainability and shareholder wealth. *Journal of Environmental Planning and Management*, 56(4), 474–493. <https://doi.org/10.1080/09640568.2012.685927>
- Przychodzen, J., & Przychodzen, W. (2015). Relationships between eco-innovation and financial performance—Evidence from publicly traded companies in Poland and Hungary. *Journal of Cleaner Production*, 90, 253–263. <https://doi.org/10.1016/j.jclepro.2014.11.034>
- Pure Strategies Report (2017). *Reaching the new corporate frontier*. Pure Insight.
- Rahman, H. U., Zahid, M., & Khan, M. (2022). Corporate sustainability practices: A new perspective of linking board with firm performance. *Total Quality Management & Business Excellence*, 33(7-8), 929–946. <https://doi.org/10.1080/14783363.2021.1908826>
- Rassier, D. G., & Earnhart, D. (2010). The effect of clean water regulation on profitability: Testing the Porter hypothesis. *Land Economics*, 86, 329–344.
- Rennings, K. (2000). Redefining innovation-eco-innovation research and the contribution from ecological economics. *Ecological Economics*, 32(2), 319–332. [https://doi.org/10.1016/S0921-8009\(99\)00112-3](https://doi.org/10.1016/S0921-8009(99)00112-3)
- Rodriguez, J. A., & Wiengarten, F. (2017). The role of process innovativeness in the development of environmental innovativeness capability. *Journal of Cleaner Production*, 142, 2423–2434. <https://doi.org/10.1016/j.jclepro.2016.11.033>
- Santos, D. F. L., Lima, M. M., Basso, L. F. C., Kimura, H., & Sobreiro, V. A. (2017). Eco-innovation and financial performance at companies established in Brazil. *International Journal of Business and Emerging Markets*, 9(1), 68–89. <https://doi.org/10.1504/IJBEM.2017.080783>
- Saygili, E., Arslan, S., & Birkan, A. O. (2022). ESG practices and corporate financial performance: Evidence from Borsa Istanbul. *Borsa Istanbul Review*, 22(3), 525–533. <https://doi.org/10.1016/j.bir.2021.07.001>
- Segarra-Oña, M.-d.-V., Peiró-Signes, A., & Cervelló-Royo, R. (2015). A framework to move forward on the path to eco-innovation in the construction industry: Implications to improve firms' sustainable orientation. *Science and Engineering Ethics*, 21(6), 1469–1484. <https://doi.org/10.1007/s11948-014-9620-2>
- Senadheera, S. S., Withana, P. A., Dissanayake, P. D., Sarkar, B., Chopra, S. S., Rhee, J. H., & Ok, Y. S. (2021). Scoring environment pillar in environmental, social, and governance (ESG) assessment. *Sustainable Environment*, 7(1), 1960097. <https://doi.org/10.1080/27658511.2021.1960097>
- Sesay, B., Yulin, Z., & Wang, F. (2018). Does the national innovation system spur economic growth in Brazil, Russia, India, China and South Africa economies? Evidence from panel data. *South African Journal of Economic and Management Sciences*, 21(1), 1–12. <https://doi.org/10.4102/sajems.v21i1.1647>
- Song, H., Zhao, C., & Zeng, J. (2017). Can environmental management improve financial performance: An empirical study of A-shares listed companies in China? *Journal of Cleaner Production*, 141, 1051–1056.
- Stankevičienė, J., & Nikanorova, M. (2020). Eco-innovation as a pillar for sustainable development of circular economy. *Business: Theory and Practice*, 21(2), 531–544. <https://doi.org/10.3846/btp.2020.12963>
- Stiglingh, A. (2015). *Financial development and economic growth in BRICS and G-7 countries: A comparative analysis* (Doctoral dissertation).
- Testa, F., Iraldo, F., & Frey, M. (2011). The effect of environmental regulation on firms' competitive performance: The case of the building & construction sector in some EU regions. *Journal of Environmental Management*, 92, 2136–2144.
- Tseng, M.-L., & Bui, T.-D. (2017). Identifying eco-innovation in industrial symbiosis under linguistic preferences: A novel hierarchical approach. *Journal of Cleaner Production*, 140, 1376–1389.
- Tsireme, A., Nikolaou, E. I., Georgantzis, N., & Tsagarakis, K. (2012). The influence of environmental policy on the decisions of managers to adopt G-SCM practices. *Clean Technologies and Environmental Policy*, 14, 953–964.
- Vivanco, D. F., Kemp, R., & Voet, E. V. D. (2015). The relativity of eco-innovation: environmental rebound effects from past transport innovations in Europe. *Journal of Cleaner Production*, 101, 71–85. <https://doi.org/10.1016/j.jclepro.2015.04.019>
- Wagner, M. (2010). The role of corporate sustainability performance for economic performance: A firm-level analysis of moderation effects. *Ecological Economics*, 69(7), 1553–1560. <https://doi.org/10.1016/j.ecolecon.2010.02.017>
- Walley, N., & Whitehead, B. (1994). It's not easy being green. *Reader in Business and the Environment* 36.81, 4.
- Walz, R., Pfaff, M., Marscheider-Weidemann, F., & Glöser-Chahoud, S. (2017). Innovations for reaching the green sustainable development goals—Where will they come from? *International Economics and Economic Policy*, 14(3), 449–480. <https://doi.org/10.1007/s10368-017-0386-2>
- White, H. (1982). Maximum likelihood estimation of misspecified models. *Econometrica*, 50(1), 1–25.
- Zhao, G., Zhou, P., & Wen, W. (2021). Feed-in tariffs, knowledge stocks and renewable energy technology innovation: The role of local government intervention. *Energy Policy*, 156, 112453. <https://doi.org/10.1016/j.enpol.2021.112453>