Received: 16 March 2023 | Revised: 13 July 2023 | Accepted: 28 July 2023

DOI: 10.1002/bse.3533

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Green is the new black: How research and development and green innovation provide businesses a competitive edge

Mohammad Jamal Bataineh[1] | Pedro Sánchez-Sellero[2] | Fayssal Ayad[3]

[1]Department of Business Administration, Faculty of Economics and Business, Universidad de Zaragoza, Campus Paraiso, Zaragoza, Spain

[2]Department of Business Administration, School of Engineering, Universidad de Zaragoza, Campus Río Ebro, Zaragoza, Spain

[3]National Higher School of Statistics and Applied Economics, Department of Econometrics, Pôle Universitaire de Koléa, Tipaza, Algeria

Correspondence
Pedro Sánchez-Sellero, Department of Business Administration, School of Engineering, Universidad de Zaragoza, Campus Río Ebro, Zaragoza 50018, Spain.
Email: pedross@unizar.es

Funding information
MCIN/AEI/10.13039/501100011033 and "ERDF A way of making Europe", Grant/Award Number: PID2021-123154NB-I00; Government of Aragón (Spain) and ERDF, Grant/Award Number: COMPETE (S52_23R) research group

Abstract

As part of the burgeoning research on green innovation (GI) and its influence on competitive advantage (CA), this paper examines the moderating effect of research and development (R&D) on this nexus. Our framework identifies five critical capabilities that contribute to CA, namely, firm image, labor costs, product differentiation, product quality, and market share. Using a novel bias-correction methodology, we examined the Spanish Technological Innovation Panel (PITEC in Spanish) database from 2003 to 2016 to determine whether GI practices foster CA. Treatment-effects analyses, including propensity score matching and fuzzy difference-in-differences (DiD), demonstrated that R&D expenditures have a positive moderating effect on CA when controlling for the covariates GI practices, firm age, and firm size. This research advances our understanding of the interplay between GI practices, R&D investments, and CA and, as such, has implications for decision makers aiming to create sustainable CA through GI. Our findings are also highly relevant for firms seeking to remain competitive in today's evolving business climate.

KEYWORDS
bias-correction estimation in panel data, competitive advantage, fuzzy difference-in-differences, green innovation, propensity score matching, R&D

1 | INTRODUCTION

The depletion of natural resources and the use of harmful compounds have raised environmental concerns (Borsatto & Amui, 2019). As a result, many companies now recognize the importance of implementing eco-friendly technology as it has multiple benefits, such as improving firms' green image and reputation, which leads to a wider adoption of sustainable innovations (Petruzzelli et al., 2011).

To remain competitive and address environmental concerns, companies must invest in research and development (R&D) to enhance their technological capabilities, which results in new and innovative solutions (Triguero et al., 2017). This increase in R&D investment is particularly relevant given the limited resources, increasing population levels, and rising industrial production (Melander, 2017; Porter & Van der Linde, 1995). Additionally, sustainable practices can help companies to accentuate their social responsibility and boost their image in the eyes of the public (Hadj, 2020).

Abbreviations: AGE, firm age; ATEs, average treatment effects; ATETs, average treatment effects on the treated; BRAND, brand or trademark in the market; CA, competitive advantage; COPYRIGHT, copyrights; COST, labor cost; DiD, difference-in-differences; DIFF, product differentiation; GI, green innovation; GMM, generalized method of moments; HSEGR, the improvement in health, safety, and environment; LATE, the local average treatment effect; MKSHARE, market share; PEGR, the reduction in energy or materials used per unit; PITEC, the Spanish Technological Innovation Panel; PSM, propensity score matching; QUALITY, product quality; R&D, research and development; RBV, resource-based view; RDE, research and development expenditures; REGR, compliance with environmental, health, or safety regulatory requirements; SIZE, firm size; TC, the time-corrected; UTILITY, utility models (petty patents).

One way that companies integrate sustainability criteria into their systems is green innovation (GI), which consists in considering environmental, social, and financial factors throughout the process of idea generation, R&D practices, and commercialization (Hermundsdottir & Aspelund, 2021). The concept of GI emerged from the growing awareness of environmental issues among consumers, the public, and governments worldwide (Sellitto et al., 2020). GI can help firms to create environmentally friendly products and processes that promote energy conservation, prevent pollution, and encourage waste recycling (Chen et al., 2006).

However, success in this regard calls for technological and innovative capabilities to help firms to navigate high market uncertainties and changes (del Río et al., 2015). According to resource-based view (RBV) theory, a firm's resources are crucial to its success, and strategic resources provide a great opportunity to develop CA (Barney, 1991). Therefore, actively engaging in internal organizational improvements or seeking external collaboration arrangements to foster innovation can enhance firm productivity significantly (Sánchez-Sellero et al., 2015).

In today's business environment, firms face the significant challenge of balancing environmental impact with financial performance (Li et al., 2019). Therefore, firms need to consider the environmental impact of their operations and to develop strategies that promote sustainability while also ensuring profitability. Failure to do so can harm their reputation and, ultimately, affect their CA (Eiadat et al., 2008).

Firms that aim to remain competitive and meet stakeholder demands must invest in green initiatives and adopt sustainable practices (El-Kassar & Singh, 2019; Zhang et al., 2020). Green projects and initiatives foster compliance with regulations and help to build a positive image and to increase the market share by appealing to environmentally conscious customers. Therefore, gathering stakeholder input from various sources—including customers, business owners, suppliers, and government regulations—is of great import in shaping a company's green capabilities and practices (Sellitto et al., 2020).

GI has been identified as essential in achieving sustainability goals while minimizing the environmental impact (Rennings, 2000). These innovations are becoming increasingly important as businesses strive to comply with regulatory standards and build a positive image in the eyes of stakeholders (Sellitto et al., 2020). By incorporating sustainability into their R&D practices, firms are able to develop new and innovative solutions that promote energy conservation, prevent pollution, and encourage waste recycling, among other benefits.

Integrating GI into business practices can yield significant benefits for organizations. Specifically, GI not only mitigates environmental impact but also supports businesses in achieving essential objectives such as regulatory compliance, an enhanced brand image, and a larger market share. Hence, it is imperative for organizations to recognize the advantages of incorporating GI into their operations.

However, adopting GI requires broad knowledge and skills that may not be readily available within a single company. To overcome this challenge, companies pursuing GI must collaborate with external partners and establish more intensive external R&D relationships (Ardito et al., 2019). By committing to R&D practices, businesses can generate novel ideas, leverage the latest technology, and incorporate data from external sources, which, in turn, can enhance their capabilities, facilitate knowledge-sharing, develop new skills, and optimize resource use (Bataineh et al., 2023).

Variations in demand may pose significant challenges for firms as they increase competition (Tseng et al., 2013), introduce uncertainty, and heighten risk (Lin et al., 2014). Addressing these challenges would involve enhancing their capabilities by exchanging knowledge and information with external partners, absorbing knowledge (Girod & Whittington, 2017; Sánchez-Sellero et al., 2014), and balancing stakeholder concerns with enterprise capabilities (El-Kassar & Singh, 2019).

In this regard, firms have to modify their practices and approaches toward the environment (Huse et al., 2005), which could mean applying efficient green practices that minimize costs and differentiate products. Thus, premium pricing (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013) and regard for environmental matters could help firms obtain CAs and sustainability (Veronica et al., 2020). Firms may also be compelled to invest in environmental R&D in order to reduce compliance costs, which can result in a twofold benefit: enhancing environmental performance while cutting costs, a win–win situation for both the economy and the environment (Porter & Van der Linde, 1995).

Several factors can influence firms' CA; in this study, however, we focus on GI and R&D as both play a crucial role in determining firm success in today's business environment. In fact, GI and R&D are fundamental to develop new environmentally friendly products and services that offer firms a unique selling point and increase their market share. R&D is the driving force of innovation and is essential to develop new technologies and products. Hence, variations in GI activities reflect the level of R&D input. Increased R&D expenditure can lead to higher levels of technology transfer, knowledge acquisition, and product quality, which, in turn, may help to increase CA in the long term. Moreover, with the growing concern for sustainable development and environmental protection, governments worldwide are implementing policies that promote and incentivize GI and R&D. Firms that invest in R&D to develop green technologies are better positioned to meet regulatory requirements, reduce their environmental footprint, and respond to the changing needs of consumers.

This paper aims to investigate the interplay between R&D, GI, and CA and, specifically, to address two research questions. Firstly, can GI significantly enhance the CA of businesses? And, secondly, to what extent do R&D expenditures moderate the relationship between GI and CA?

While extant literature has provided ample evidence that GI practices and R&D can significantly enhance firms' CA, there is a notable gap in empirical research on the precise mechanisms that underpin this phenomenon. Specifically, there is a paucity of research on the intricate links between GI practices and R&D and firms' overall capabilities such as market share, product quality, product differentiation, labor costs, and firm image. Despite the burgeoning interest in GI practices, empirical research on the moderating effect of R&D on the relationship between GI practices and CA is scarce. The present study therefore seeks to shed light on the impact of GI practices on CA, with a specific focus on the moderating role of R&D activities in this relationship. Research of this nature may advance our understanding of the complex dynamics that influence firms' ability to leverage GI practices and R&D to achieve and sustain CA.

More specifically, this study aims to investigate the effects of GI practices and R&D on the CA of firms in Spain. To this end, and using the Spanish Technological Innovation Panel (PITEC) database, we focus the analysis on two key aspects of GI practices: the reduction of energy and material use in production and the implementation of health, safety, and environmental regulations and procedures. Hence, we measure CA using a multidimensional framework that captures various aspects of this construct, including market share, product quality and differentiation, labor costs, and intellectual property components that contribute to firms' overall image. By exploring the complex interplay between GI practices, R&D, and CA within the unique context of Spanish firms, this study may make a significant contribution to the existing body of knowledge on this topic and inform future research and practice in this area.

Furthermore, the study advances knowledge within the field in several ways. Firstly, it makes a novel and valuable contribution to the GI literature by offering fresh empirical insights on the impact of GI practices on CA from a non-financial standpoint with regard to cost reduction, product differentiation, firm image, product quality, and market share. Secondly, unlike previous studies, which mostly rely on cross-sectional or short panel data, this research draws on the rich and extensive PITEC data survey, which tracked several indicators for over 12,800 Spanish companies over a 14-year period (2003–2016). The longitudinal perspective of this study facilitates a thorough examination of the changes unfolding within the field of GI. It especially foregrounds the role played by R&D investments in moderating these transformations and influencing firms' long-term competitiveness. This work also explores how the implementation and advancement of environmentally sustainable practices—coupled with R&D initiatives—contribute to firms' ability to differentiate their offer, reduce costs, enhance brand image, improve product quality, and expand the market share. Thirdly, this work makes important methodological contributions by incorporating recent advances in econometric techniques, namely, the bias-corrected method of moments estimators for dynamic panel data models (Breitung et al., 2022) and treatment-effects methodologies such as propensity score matching (PSM) and fuzzy difference-in-differences (DiD) to investigate the causal impact of R&D on CA while accounting for GI.

This study represents a sizable effort to investigate the impact of GI and R&D on CA, providing valuable guidance for businesses seeking to enhance their capabilities and achieve sustainable development. By offering new empirical insights into the nexus between GI practices, R&D, and CA, this study may inform strategic decision making at both the managerial and policy levels, enabling businesses and policymakers to design effective approaches that promote sustainable growth and enhance firms' competitiveness. As such, the findings of this study have significant implications for a wide range of stakeholders—including managers, policymakers, academics, and practitioners—and underscore the importance of continued research in this vital area.

To address our main agenda, this paper provides firstly the theoretical framework and formulation of the hypotheses. The subsequent section describes the used methodology, followed by presenting the results and their discussion. Finally, the paper concludes.

2 | THEORETICAL FRAMEWORK AND DEVELOPING THE HYPOTHESES

2.1 | Theory insights

It is widely acknowledged that the adoption of GI by businesses offers a plethora of benefits. GI practices can reduce operational costs, improve public image, and increase employee satisfaction. By implementing green practices, companies not only save money on energy and waste disposal, they also decrease uncertainty and avoid financial risks while complying with regulations. Therefore, GI practices are critical for sustainable development and can provide a competitive edge, as emphasized by institutional theory, as noted by Sharma and Vredenburg (1998) and Borsatto and Amui (2019). According to this theory, adopting green practices is crucial for firms' long-term success, as they help them to reduce their environmental impact and enhance their reputation among consumers.

Furthermore, green practices may lead to cost savings by reducing energy consumption and waste. As proposed by Porter's hypothesis, environmental regulations can stimulate innovation and competitiveness in businesses. This is due to the need for cleaner technologies, resulting in benefits such as cost savings, improved efficiency, and new market prospects (Porter, 1991; Porter & Van der Linde, 1995).

RBV theory states that companies can achieve CA by identifying and developing resources and capabilities that are valuable, rare, and difficult-to-imitate such as physical assets, intellectual property, organizational processes, and human capital (Barney, 1991). Firms aim to develop in the market so they can generate and leverage value, which involves the ability to sense and shape external opportunities, reconfigure internal resources, and develop new competencies.

The dynamic capabilities approach confirms that firms' capacity is essential to attain CA by integrating, constructing, and reconfiguring internal and external resources and competencies to rapidly respond to and shape changing business environments (Teece et al., 1997). This approach highlights the importance of adapting to change and innovating in response to new challenges.

Accordingly, the adoption of GI can provide CA by reducing costs, complying with regulations, enhancing reputation, and stimulating innovation. This is consistent with institutional theory, Porter's hypothesis, RBV theory, and dynamic capabilities approach, which emphasize the importance of adopting green practices to achieve sustainable long-term success.

2.2 | What is GI?

The terms "green innovation," "environmental," "sustainable," and "eco-innovation" are often used interchangeably in the literature (Hermundsdottir & Aspelund, 2021; Horbach, 2016; Sánchez-Sellero & Bataineh, 2022). GI practices are driven by public regulations, market forces, and customer demand, and they encompass a range of capabilities that can improve economic, environmental, and social performance in the short and long term (García-Marco et al., 2020). These capabilities include practices such as introducing new eco-friendly products, minimizing energy and material consumption, preventing pollution, promoting recycling and reuse, and managing corporate environmental responsibilities (Chen et al., 2006; Rennings, 2000). Improvements such as these materialize in aspects like products, services, technologies, and organizational processes, and they can have positive effects on both society and the environment (Cillo et al., 2019). There are two sides to GI, as it can be regarded as both a capability and a strategy. By strategically investing in GI, enterprises can mitigate their environmental impact, cultivate a positive reputation as socially responsible actors, enhance their financial performance, and gain a competitive edge.

GI typically involves a higher degree of uncertainty and novelty and often requires firms to venture outside of their core competencies, which leads to a greater likelihood of relying on external sources for collaboration and seeking out new knowledge (Jové-Llopis & Segarra-Blasco, 2020). To successfully adopt GI, firms should assess their capabilities, the resources of their suppliers, and public policies. Moreover, they need to tackle internal, technological, and environmental challenges, as doing so they can leverage new environmental markets and increase their capabilities for GI (Chang, 2011). Considering these aspects would help firms to balance the advantages, costs, and efficiency gains (Chiou et al., 2011). In addition, Chen et al. (2006) note that the costs of GI must be weighed against the potential benefits to ensure that investments in GI are both financially and environmentally sustainable.

2.3 | GI and competitive advantage (CA)

CA is a multifaceted concept that encompasses social, cultural, economic, technological, and environmental aspects (Ritchie & Crouch, 2003). It is defined as an organization's capacity to outperform its rivals in terms of cost, technology, brand, organizational practices, and other factors (Barney, 1991), which can be seen as a non-financial indicator that reflects the financial position and environmental sustainability (Costantini & Mazzanti, 2012).

A company's CA is determined by its dynamic capabilities and knowledge-based skills to adapt to changing environments through innovative approaches (Del Vecchio et al., 2018; Teece et al., 1997). These capabilities are linked to environmental objectives that help the firm to gain a market advantage by transforming resources into valuable products and services, increasing productivity, and reducing environmental impact (García-Marco et al., 2020; Porter & Van der Linde, 1995).

According to institutional theory, globalization requires companies to comply with global social norms by aligning their activities to external environmental regulations and standards. Thus, firms must implement innovative solutions that prioritize the production of environmentally friendly goods and efficient processes; green production becomes therefore key in product differentiation and in achieving a competitive edge. Such green practices can have a favorable impact on companies' CA and economic status (Porter, 1991; Porter & Van der Linde, 1995; Shrivastava, 1995).

Despite the potential for increased costs to customers, environmental initiatives can help companies produce more eco-friendly products and services. These initiatives include reducing energy consumption, increasing recycling, and providing healthier, less toxic goods and services (Janssen & Jager, 2002; Shrivastava, 1995). As customers become more aware of the environmental impact of their purchases (Paparoidamis et al., 2019), there is an increased demand for green products and services (Yalabik & Fairchild, 2011). In response, companies such as Walmart and IBM have taken into account the environmental performance of their suppliers when making business decisions (Barla, 2007). Firms can also charge higher prices for eco-friendly products, further incentivizing green product innovation (Porter & Van der Linde, 1995).

GIs present appropriate solutions to achieve CAs (Shrivastava, 1995). GI can result in drivers of CA, namely, cost reduction and product differentiation, which can lead to increased market share, higher profits, and improved customer satisfaction (Porter & van der Linde, 1995; Sellitto et al., 2020).

Competitive measures can be classified into financial metrics—such as return on investment, return on sales, return on equity, and profitability—and operational or non-financial measures—such as market share, quality, and customer satisfaction (Zehir et al., 2015). While financial indicators are clearly important in assessing competitiveness, our research highlights the value of non-financial indicators. By incorporating these measures into their assessments, businesses can gain a more complete picture of their competitive position and make informed decisions about their strategies and operations.

In this context, Rusinko's (2007) research on the US commercial carpet industry indicates that implementing green practices can lead to enhance measures on competitive outcomes, such as product quality and reduced manufacturing costs. Likewise, the review paper by Hermundsdottir and Aspelund (2021) revealed that most studies support the idea that GI is positively correlated with CA. This advantage spans multiple indicators, including market share, cost reduction, productivity, differentiation, quality, and firms' image and reputation. El-Kassar and Singh (2019) found that organizations could gain a CA by investing in GI, leveraging big data, and implementing effective management commitment and HR policies. CA was evaluated using items that measured its innovative abilities, product quality, customer satisfaction, and production costs.

Globally, the growth of GI offers several benefits, including cost reduction, environmentally friendly products, and product differentiation; it can also improve firms' image, grant access to new markets, and enhance product value. Decision makers can leverage these advantages to achieve cost savings, penetrate new markets, and promote transaction efficiency, which can have a positive impact on companies' CA and financial well-being.

2.3.1 | GI and market share

Firm capacity and market share are closely related and mutually reinforcing in green product innovation (Li et al., 2019). This connection denotes that firms can increase their customer base by focusing on eco-friendly practices and proactive planning. Additionally, firms may expand into new markets and segments that prioritize environmental sustainability.

Competitive pressures drive firms to boost their market share and maintain an eco-friendly image by implementing efficient production processes and utilizing sustainable materials and energy sources (Hojnik & Ruzzier, 2016). In order to improve market share, profitability, and survival, firms compete to attract specific market segments (Hu & Wall, 2005). According to Sarkar (2013), adopting greener processes and practices not only provides access to new markets but also yields CAs in the short and long term through efficient resource use.

Enterprises that prioritize eco-performance can gain a competitive edge in the market by offering low-cost or unique strategies, building strong green reputations, attracting more customers, and expanding their market share (Lin et al., 2014). By incorporating green technology into their products, companies can differentiate themselves and satisfy consumers' green preferences, ultimately securing their place in the market (Reinhardt, 1998). The global growth of environmental awareness has prompted companies to focus on corporate environmental management in order to meet the demands of customers who are more likely to buy eco-friendly products and pay higher prices for them (Chen, 2008). Failure to follow green guidelines can lead to long-term difficulties for products to succeed (Pujari et al., 2003).

2.3.2 | GI and product quality

In light of seeking Societies remarkably to improve life quality including economic, health, and environmental quality (Song & Wang, 2018), and as a basis of meet new market demands and adhering to environmental criteria, firms consider new innovative ways concerning the methods of production, durability, and product disposal (Peattie, 1999).

Former studies have revealed that companies can gain a competitive edge and enhance their reputation by optimizing their efficiency and product quality by improving the design, durability, and reliability of their products (Chang, 2011; Chen, 2008; Chen et al., 2006; Chiou et al., 2011). This can be achieved by reducing material consumption, using less hazardous materials and packaging, and increasing the use of recyclable materials (Hermundsdottir & Aspelund, 2021). For instance, scientists at Raytheon improved product quality by redesigning the process to eliminate chlorofluorocarbons (CFCs) when cleaning printed circuit boards (Rusinko, 2007). In this context, executives and decision makers have responsibilities regarding product quality, health and safety, process improvement, and compliance with environmental regulations, in addition to leading R&D and training for green practices (Pujari et al., 2003).

Furthermore, competitiveness is associated with delivering high-quality products and services to customers (Newall, 1992). For example, a prior study (Corrigan, 1996) found remarkable growth in Irish export industries and CA when promoted as green European centers for high-quality products and services. In this regard, firms can make extra profits by differentiating their green products (Chang, 2011; Chen, 2008) and delivering high-quality products and services, which enhance firms' competitive positions (Borsatto & Amui, 2019; Hermundsdottir & Aspelund, 2021).

2.3.3 | GI and product differentiation

GIs become a worthy opportunity for firms to obtain CAs through product differentiation, and this is increasingly important in highly competitive markets (Hojnik & Ruzzier, 2016; Lin et al., 2014). Differentiation can be achieved through innovative and premium features and higher quality levels than those offered by competitors (Sellitto et al., 2020); it reflects a good reputation and meets customer needs, in addition to increasing profits by selling new products at a premium price (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Menguc et al., 2010). Li et al. (2019) argue that the features of green products are essential factors in product differentiation, which affects customer decisions and mediates how green capabilities affect CA.

Many studies consider differentiation of products is crucial in distinguish firms in the market and reaching CA that reduces price sensitivity, promotes firm capabilities, and avoids threats of substitute products (Chang, 2011; Chen et al., 2006; Hart, 1995; Porter & Van der Linde, 1995; Zehir et al., 2015). For example, Apple's differentiation lies in their proficiency in developing user-friendly software, the iTunes platform, and the simplicity of design and product line (Zook & Allen, 2011). This can also prevent new competitors from entering the market (Li et al., 2019), as they cannot easily replicate the unique products and services (Grant, 1991). However, Pujari et al. (2003) argue that even the most advanced environmental technologies are not sufficient to achieve sustainable development unless firms replace conventional products and alter their product development and marketing processes. Therefore, GIs become an important opportunity for firms to obtain CAs by providing new features and higher quality products than those offered by competitors. This can be achieved through the implementation of environmental practices in the development of new products and services, which can increase customer loyalty and attract new customers. Additionally, GIs can prevent new competitors from entering the market due to their unique products and services, which are difficult to replicate.

2.3.4 | GI and labor cost

CAs commonly accrue from materials, labor, and energy conservation (Shrivastava, 1995). Firms are responding to the fast-paced advancements in technology, as well as the evolving needs of their customers and suppliers by developing green, innovative products to increase cost-effectiveness and enhance their profitability (Chan et al., 2016). This motivates companies to adopt proactive environmental measures that can reduce costs, enhance resource productivity, and improve competitiveness (Porter & Van der Linde, 1995),

GI can support environmental management and protection while increasing resource productivity for businesses (Chen et al., 2006) through improved energy and material efficiency; this, in turn, leads to cost reductions by minimizing defects and process losses. For example, Tetra Pak has developed sophisticated methods for evaluating packaging costs, which can reduce operating costs for dairy or juice companies by up to 12% (Zook & Allen, 2011). Cost advantage may also encourage smaller manufacturers to participate in environmental manufacturing practices (Hart, 1995; Liao, 2016; Rusinko, 2007; Sellitto et al., 2020).

Firms used to view GI as a costly burden to reduce environmental harm. However, this mindset has shifted as firms now recognize the business opportunities and potential of GI. Short-term losses can lead to long-term advantages, prompting firms to invest more upfront for greater payoffs in the future (Hojnik & Ruzzier, 2016). Firms with first-mover advantages and innovation subsidies can better meet the demand for green products from consumers, resulting in high returns that compensate for the additional costs of green R&D (Li et al., 2019).

GI thereby is a valuable tool for businesses to create new opportunities, minimize threats, increase profits, and reduce manufacturing costs (Zameer et al., 2020) and concentrate in activities that have positive environmental effects, such as redesigning production processes that reduce labor costs and save energy (Horbach, 2016).

2.3.5 | GI and firm image

Firm image reflects a firm's reputation among stakeholders and the community, as well as customer loyalty to the brand (Hermundsdottir & Aspelund, 2021). A firm culture of innovation and creativity also strengthens a firm's image (Jensen & Beckmann, 2009). However, firm image and reputation are intangible assets and have remarkable influence on overall performance (Miles & Covin, 2000). GI practices that improve brand image and access to new markets thus also help achieve competitiveness (Porter & Van der Linde, 1995; Shrivastava, 1995). Cronin et al. (2011) assert that a firm's image and loyalty strengthen if it implements green practices, which, in turn, can boost its competitiveness. For example, green practices contribute to Tesla's firm image by demonstrating their commitment to sustainability and environmental responsibility. Tesla is an example of a company that has benefited from implementing green initiatives, such as using renewable energy sources, reducing emissions, and recycling. These practices have been instrumental in creating a positive perception of the company and its products by the public, resulting in an increase in sales and brand loyalty (Lobo, 2020).

Several studies have demonstrated that the implementation of GI improves the image of companies and serves as an indicator of CA (Hu & Wall, 2005; Rusinko, 2007; Zameer et al., 2020). This underscores the importance of prioritizing sustainability and green orientation in business operations to stay ahead in the market. Thus, firms have to increase their investments in order to increase their green organizational identity and environmental commitment in order to promote the performance of GIs.

The performance of GIs supports a firm's green image (Chen, 2008) and reflects social responsibility (Cronin et al., 2011) consistent with stakeholder pressures and government regulations. Intellectual property rights are, in turn, key instruments in the field of GI because they encourage inventors to develop green technologies; they also boost confidence in and guidance about the products they purchase (Vimalnath et al., 2020). Then, intellectual property rights are important for the image of companies. Securing patents, trademarks, and copyrights not only safeguard products and services from copy or replication, it also builds trust and reliability. In this way, companies become industry leaders and emphasize their commitment to innovation and creativity, which grants them a CA over rivals.

Accordingly, investing in various GI activities is not only beneficial for the environment but also for companies looking to stay ahead of the competition. By introducing differentiated quality products, expanding market access, enhancing public image, and reducing costs, companies can position themselves as industry leaders.

Based on the foregoing, we formulated the following hypotheses for the present study:

> **Hypothesis 1.** Reduction in energy or material use impacts a firm's competitive advantage.

> **Hypothesis 2.** Improvements in health, safety, and the environment impact a firm's competitive advantage.

> **Hypothesis 3.** Compliance with regulatory requirements concerning environmental, health, or safety issues impacts a firm's competitive advantage.

2.4 | GI, R&D, and CA

Developing technological capabilities through R&D is crucial for firms to innovate and learn from external sources of information (Demirel & Kesidou, 2019). This external knowledge is essential for improving productivity and the efficiency of internal R&D activities, which is necessary to remain competitive in the fast-paced innovation landscape (Natalicchio et al., 2018; Teece et al., 1997). Firms that enhance their technological capabilities by investing in R&D are more

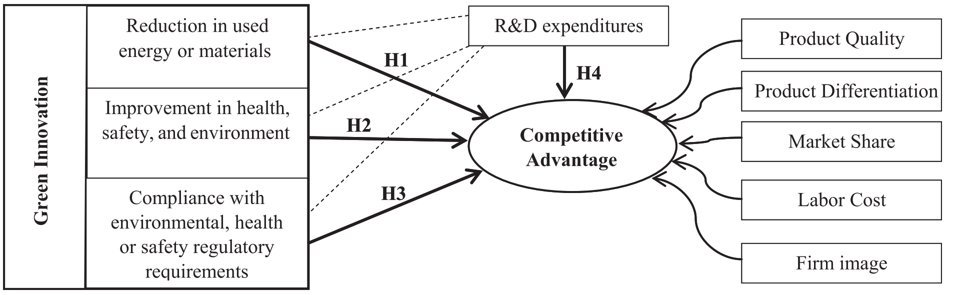

FIGURE 1 Framework of the study.

likely to be aware of new environmental opportunities (Jové-Llopis & Segarra-Blasco, 2018).

Growing R&D expenditures thereby demonstrates that firms have sufficient market information to reinforce technology opportunities and performance (Duque-Grisales et al., 2020) and is more likely a response to strict environmental regulations (Rennings, 2000). Also, it can contribute to the adoption of a GI strategy by supplying unique products that can encourage a firm's green development and bolster its environmental protection initiatives (Li et al., 2019). del Río et al. (2015) demonstrated that technological capabilities by R&D advance GI. Likewise, Demirel and Kesidou (2019) argued that a firm's performance effectively is improved by allocating resources via R&D and innovation. In this way, variances in applying GI activities reflect the level extent of R&D input (Horbach, 2016). Thus, R&D expenditures serve as a supportive motivator for firms to engage in GI (del Río et al., 2015), introduce clean technology, and thereby improve productivity (Duque-Grisales et al., 2020).

Accordingly, raising R&D expenditures contributes to introducing higher degrees of technology transfer, acquiring new knowledge, and creating higher quality products. Thus, it can pave the way for new business and reduce the risk and uncertainty by enabling the commercialization of new technologies and innovative products (Samad & Manzoor, 2015). All-around, when firms follow applying proactive GI through spending on R&D practices, they will achieve a long-term CA (Hao et al., 2019).

Overall, the implementation of GI activities is determined by the level of R&D input. Firms that invest in R&D expenditures are motivated to engage in GI, introduce clean technology, and improve productivity. By proactively investing in R&D practices, firms can achieve a long-term CA.

Based on the reasoning above, we formulated the following hypothesis:

> **Hypothesis 4.** R&D expenditures moderate the impact of green innovation on a firm's competitive advantage.

2.5 | Framework of the study

Based on the reviewed literature, we can formulate our framework in which we could test for four main hypotheses, as shown in Figure 1. It is important to note that due to the unavailability of the total cost reduction variable in PITEC, we consider the reduction in labor cost as a proxy, which denotes a salient indicator of CA (Shrivastava, 1995). According to the dynamic capabilities approach, organizations should effectively manage internal resources, such as people and Human Resources practices, in order to maintain core competences throughout time. Thus, productivity and CA can be pointed out by various labor costs (Zatzick & Iverson, 2006).

3 | METHODOLOGY

3.1 | Data

This study exploits the rich data provided by the PITEC following the methodology of the Community Innovation Survey (CIS) of the European Union. PITEC utilizes the widely used CIS framework, making it a valuable tool for comparative research with similar datasets. This methodology is broadly used for research on innovation, particularly GI studies in other European countries, which favors cross-country comparisons due to the use of similar datasets (Martínez-Ros & Kunapatarawong, 2019). Many studies are driven on PITEC, especially in the field of GI (Bataineh et al., 2023; del Río et al., 2015; García-Marco et al., 2020); it provides valuable observations for innovation studies at the firm level with more than 460 variables for 12,849 firms over a span period of 14 years, from 2003 to 2016.

Spain has experienced a significant push toward innovative and sustainable practices, particularly concerning environmental conservation. Thus, the increasing focus on GI and the strengthening of environmental regulations make the country an ideal setting for exploration (Sánchez-Sellero & Bataineh, 2022). Spain is also a member of the Paris Agreement (2015), a global framework to protect the environment and reduce pollution by 2030 (García-Marco et al., 2020). In terms of GI, Spain is a moderate innovator and is more advanced than the EU average (Martínez-Ros & Kunapatarawong, 2019; Sánchez-Sellero & Bataineh, 2022). However, based on the data from the Eco-Innovation Scoreboard, Spain has weaker environmental regulations, environmental awareness, and willingness to pay for environmentally friendly products compared to Central European and Nordic countries (Jové-Llopis & Segarra-Blasco, 2018). The analysis of the current state of GI in Spain provides insight into how to enhance and support green initiatives in the country. This will help us to understand the potential for GI in Spain and how it can be bolstered.

3.2 | Measures and variables of the study

3.2.1 | GI

In line with previous works (Bataineh et al., 2023; García-Marco et al., 2020; Sánchez-Sellero & Bataineh, 2022), this study operationalizes the GI construct under three independent variables extracted from the PITEC database, which measure activities regarding GI. Despite the fact that this survey is not specifically designed to detect GI, its items are very useful. Thus, we take from PITEC, the self-reported data of the items related to "all activities lead to less energy and/or materials per unit produced"; "the activities drive improvement of health, safety, and the environment"; and "practices comply with environmental, health, or safety regulatory requirements." It is important to note that there are no GI variables in 2003, and the measurement of the three variables is based on three sub items from 2003 to 2007, whereas it was based on five sub items from 2008 to 2016. Therefore, starting from 2008, we combine similar sub items measurements for each independent variable over the period 2008–2016 in order to be consistent with the previous period 2003–2007. Finally, each independent variable takes a value of high, medium, or low if close to the values (2.5, 3), (1.5, 2), and (0.5, 1), respectively (see Table 1).

3.2.2 | CA

CA is typically measured by comparing a firm's position to that of its competitors in terms of specific performance criteria such as profitability, sales, or customer satisfaction. However, as suggested by the RBV approach and Porter and Van der Linde's (1995) framework, capabilities related to market share, product quality, product differentiation, labor costs, and firm image are closely related to a CA, as they reflect the firm's ability to set itself apart from and outperform its competitors.

The RBV approach emphasizes the importance of identifying and developing resources and capabilities that are valuable, rare, and

TABLE 1 Variables of the study.

Variable	Abbreviation	Variable description	Key references
Market Share	*MKSHARE*	Equals 3, 2, 1, or 0 if market share is high, medium, low, or not relevant, respectively.	Shrivastava (1995); Chen et al. (2006); Hermundsdottir and Aspelund (2021)
Product Quality	*QUALITY*	Equals 3, 2, 1, or 0 if product quality is high, medium, low, or not relevant, respectively.	Chen et al. (2006); Chang (2011); Hermundsdottir and Aspelund (2021)
Product Differentiation	*DIFF*	Equals 3, 2, 1, or 0 if product differentiation is high, medium, low, or not relevant, respectively.	Shrivastava (1995); Hermundsdottir and Aspelund (2021); Sellitto et al. (2020).
Labor Cost	*COST*	Equals 3, 2, 1, or 0 if labor cost reduction is high, medium, low, or not relevant, respectively.	Chen et al. (2006); Hermundsdottir and Aspelund (2021); Shrivastava (1995); Sellitto et al. (2020).
Firm image	*UTILITY*	Utility models (petty patents); equals 1 if yes, 0 otherwise.	Chen et al. (2006); Chang (2011); Hermundsdottir and Aspelund (2021); Shrivastava (1995)
	COPYRIGHT	Copyrights; equals 1 if yes, 0 otherwise.	
	BRAND	Brand (trademark) in the market; equals 1 if yes, 0 otherwise.	
Competitive Advantage	*CA*	$CA = \log(MKTSHARE + QUALITY + DIFFEREN + COST + UTILITY + COPYRIGHT + BRAND + 0.1)$	
Green Innovation	*PEGR*	Equals (2.5, 3), (1.5, 2), and (0.5, 1) if the reduction in energy or materials used per unit is high, medium, or low, respectively.	Sánchez-Sellero and Bataineh (2022); Martínez-Ros and Kunapatarawong (2019); García-Marco et al. (2020)
	HSEGR	Equals (2.5, 3), (1.5, 2), and (0.5, 1) if the improvement in health, safety, and environment (HSE) is high, medium, or low, respectively.	
	REGR	Equals (2.5, 3), (1.5, 2), and (0.5, 1) if compliance with environmental, health, or safety regulatory requirements is high, medium, or low, respectively.	
Firm Size	*SIZE*	Natural logarithm of the total number of employees.	Bataineh et al. (2023); del Río et al. (2015); Martínez-Ros and Kunapatarawong (2019)
Firm Age	*AGE*	Natural logarithm of firm age.	
R&D expenditures	*RDE*	Equals 1 if the firm has internal and/or external R&D expenditure, 0 otherwise.	Sánchez-Sellero and Bataineh (2022); Horbach (2016); Jové-Llopis and Segarra-Blasco (2018)

difficult to imitate so as to create a unique value proposition that competitors find difficult to replicate (Barney, 1991). A company's capabilities—including market share, product quality, product differentiation, labor costs, and firm image—can thus be seen as internal resources that contribute to corporate CA. Moreover, environmental technologies offer various benefits that can result in CA for businesses. These benefits include cost reductions, revenue improvements, enhanced quality, and enhanced quality. As noted by Shrivastava (1995), these advantages can be attributed to the adoption of sustainable practices and technologies, which not only reduce the environmental impact of business operations but also enhance corporate image and reputation. Therefore, incorporating environmental technologies alongside these capabilities into business operations can result in both financial and non-financial benefits, which can, in turn, lead to a sustainable CA in the market.

Therefore, it is clear that a company's capabilities can indeed be used as a measure of its CA, provided they are developed and used strategically to create a value proposition that is unique and difficult-to-replicate. While it is true that these capabilities do not directly measure a firm's position relative to its competitors, they do provide important information about the internal resources and capabilities that enable it to compete effectively in the marketplace. We therefore argue that these capabilities can serve as indicators of a firm's potential for CA.

In particular, market share is a commonly used measure of CA, as it reflects the firm's position relative to its competitors. Similarly, product quality and differentiation are often cited as key drivers of CA, as they enable a firm to create products that stand out from those of its competitors. Labor costs and firm image, while less commonly used as measures of CA, can also play a significant role in helping a firm to gain an edge over its rivals.

Hence, we measured CA in accordance with five variables, namely, firm image, labor costs, product differentiation, product quality, and market share. An item is provided for each variable in the PITEC database, except firm image, which was approached via three types of intellectual property, mainly, (i) "petty patents" (short life spans from 6 to 10 years), which give market exclusivity to patent holders, are easier to obtain, and have less stringent requirements; (ii) "copyrights," or long-term legal rights that prevent the use of innovative work without authorization from the owner; and (iii) "trademark," an exclusive right to use personal names, logos, letters, colors, and so on (European Commission, 2019). Measurements of all the items that comprise CA are detailed in Table 1. With regard to the items labor costs, product differentiation, product quality, and market share, all zero values were dropped from the raw database before proceeding, because values of "0" had no quantitative meaning in the original reporting and stand for "not relevant."

To operationalize measurements of the dependent variable, that is, "CA," we aggregated the values of the seven items that make up this variable to generate a score as indicated in Table 1. This score was first rescaled by adding 0.1 in order to avoid null scores before submitting the rescaled values to the logarithmic function. This rescaling should not pose a problem as the estimated statistics change in ways that preserve all measured effects and testing outcomes (Wooldridge, 2012).

In addition to our independent and dependent variables, and as shown in Table 1, we included two main control variables, namely, firm size, measured by the number of employees, and firm age. These two variables were included in the study using their natural logarithm values. In accordance with the parsimony principle, we deliberately kept the number of control variables to a minimum.

Logarithmic measures are commonly used in econometric models for dependent and/or independent variables (Wooldridge, 2012). Wooldridge (2012) notes that models that use a log-dependent variable are better equipped to address problems of heteroscedasticity and skewness and confer advantages linked to narrowing the range of the variables, which leads to statistical estimates that are likely less sensitive to extreme values and outliers.

3.3 | Data analysis

3.3.1 | Dynamic panel data model estimation with bias correction

Since the seminal paper of Anderson and Hsiao (1981) was published, the generalized method of moments (GMM) with the instrumental variables approach has become the standard estimation of linear dynamic panel data models. The GMM estimator successively refined by Holtz-Eakin et al. (1988) and Arellano and Bond (1991) is, however, hampered by the problem of weak instruments and overidentification when data persistence is strong (Blundell & Bond, 1998). As a result, system GMM estimator, which combines moment conditions for models in first differences and in levels, has been proposed to deal with these issues (Breitung et al., 2022).

Hence, despite its wide use in practice, the GMM system continues to exhibit the same problem when the variance of individual-specific effects is larger than that of idiosyncratic errors (Bun & Windmeijer, 2010). Thus, several alternatives to the GMM approach have been proposed, basically focusing on maximum likelihood and bias correction of within-groups estimators (Hayakawa & Pesaran, 2015; Hsiao et al., 2002; Kiviet, 1995).

Similarly, after demonstrating that a bias-corrected estimator can be obtained as a method of moments estimator, Breitung et al. (2022) propose the bias-corrected method of moments estimators for linear dynamic panel data models with unobserved group-specific effects. This estimator can deal with higher-order autoregressive dynamics with support for unbalanced panel datasets and individual-specific heteroscedasticity in the large panel with fixed time frameworks (Breitung et al., 2022). This novel approach is particularly appealing as it proposes cluster-robust/panel corrected standard errors that account for cross-sectional dependence and higher-order autoregressive models, while this method performs very well in terms of efficiency and correctly sized tests when benchmarked against GMM and maximum likelihood approaches (Breitung et al., 2022).

Given these advantages, in this paper, we adopted the method of Breitung et al. (2022), which implements the bias-corrected estimation of linear dynamic panel data models. In line with previous studies (Li et al., 2019), we chose a fixed-effects model (FEM) because we aim to estimate long-term dynamic changes and, also, because it helps to minimize omitted-variable bias due to unobserved heterogeneity (Cameron & Trivedi, 2005; Dranove, 2012).

To conduct our analyses on Stata 17, we considered CA as the dependent variable and REGR, HSEGR, and PEGR as independent variables, while controlling for SIZE and AGE. We investigated the moderating effect of R&D separately in subsequent analyses, as outlined below, to avoid including a potential time-invariant variable (R&D) in our bias-correction regressions. In this regard, Kripfganz and Schwarz (2019) found that when such variables are omitted after inclusion, a substantial bias is introduced in the estimated model due to collinearity. The dynamic equation included time effects to account for the effect of time over the long term and to be consistent with the assumption of FEM. After estimating the basic model, we first tested for serial autocorrelation using the Arellano and Bond test for lags 1–3. If AR(1) was significant at the level and AR tests were not significant for higher lags, then we moved forward with our basic model; otherwise, we re-estimated the basic model by adding the lagged 2 CA as a regressor, then we repeated the Arellano and Bond test following the same rules to test for higher serial autocorrelation before continuing the analyses. The objective at this point was to first deal with the problem of serial autocorrelation before testing for endogeneity using the generalized Hausman specification test.

3.3.2 | Treatment-effects analysis with PSM

We included time effects in the dynamic model to test whether certain years had significant effects on CA. When an effect was significant for a given year, there was probably a confounding variable not included in the dynamic model, which had a significant interaction effect with the given dummy year on CA. Such situations could arise when we did not control sufficiently for other factors in our dynamic model or if there was a significant change in an unknown variable for a given year, which theoretically affects CA.

We conducted treatment-effect analysis of the R&D expenditures of the firms on CA to test whether the RDE in GI variables had a moderating effect on CA, whenever the effect in a given year was significant in the dynamic analysis. R&D has been investigated extensively in the GI literature, and it has been shown to be a very important factor (Sánchez-Sellero & Bataineh, 2022).

Typically, if we aim to draw inferences with no selection bias, a treatment should be investigated under the randomization assumption (Burns et al., 2011). However, the PITEC data are observational, and firms are exposed based on one condition, namely, having R&D expenditures or not. Thus, in the absence of randomized controlled trials, we propose a matching-based method, which has become the gold standard for data preprocessing in observational causal inferences (King & Nielsen, 2019). Matching reduces imbalance and bias between treatment and control groups (Angrist & Pischke, 2015; Iacus et al., 2011; Rosenbaum, 2002).

King and Nielsen (2019) report that one of the most widely used matching techniques in the literature is the PSM method, which, under certain assumptions, exploits the traits of the subjects to predict the likelihood of receiving the treatment (Rosenbaum & Rubin, 1983; Wood et al., 2015). On the basis of propensity scores (treatment probabilities), PSM chooses subgroups of the treatment and control groups with similar covariate distributions to control for their confounding effects for bias in the estimated treatment effects (Howarter, 2015; Morgan, 2018).

In this study, we included all GI variables as covariates for PSM (i.e., PEGR, HSEGR, and REGR) because we aimed to test the moderating effect of RDE. We deliberately restricted our PSM to these variables, because using too many covariates may lead to a lack of common support, while using too few may violate the unconfoundedness assumption (Heinrich et al., 2010). The RDE variable is available in the PITEC database and indicates whether a firm had internal and/or external expenses related to R&D during a given year. If a firm did incur R&D expenditures, the value 1 was assigned for the treatment variable; otherwise, the value was set to 0 (the firm belongs to the control group).

We mainly estimated the average treatment effects (ATEs) and average treatment effects on the treated (ATETs) after applying logit-PSM by keeping the number of matches per observation to 1. Robust standard errors were reported using the Abadie and Imbens (2016) method. In the post-estimation step, we provide diagnostics for overlap and balance assumptions.

The overlap assumption requires that each individual has a positive probability of receiving each treatment level (1 vs. 0). We estimated overlap density plots by means of the Epanechnikov kernel function, and we consider there is evidence of violation of the overlap assumption when an estimated density has too much mass around 0 or 1 (Busso et al., 2014).

Covariates of PSM are assumed to be balanced by matching because treatment assignment (R&D) is related to the GI covariates that also affect the CA. The estimation makes CA conditionally independent of the treatment by conditioning on covariates. Thus, our estimated PSM model is correctly specified when it balances the covariates. Following Austin (2011) and Guo and Fraser (2014), we provided diagnostics for the balance assumption, while also considering that Rubin (2008) suggests checking whether the model balances the covariates before accepting the estimated treatment-effect results. We checked the matched standardized differences (MSDs) for each covariate and their matched variance ratio (MVR). Typically, MSD values should all be close to 0 while MVR estimates should be close to 1 in order to provide evidence of covariate balance. Moreover, we

TABLE 2 Descriptive statistics.

Variables		Statistic N	Mean	SD
Dependent variable	*Competitive Advantage (CA)*	59,004	2.23	0.25
Green innovation	*Less energy/material per production (PEGR)*	96,576	1.11	1.01
	Improvement of HSE (HSEGR)	96,576	1.25	1.13
	Compliance with environmental regulations (REGR)	96,576	1.35	1.21
Control variables	*Firm Size (SIZE)*	133,704	4.19	1.72
	Firm Age (AGE)	155,170	1.29	0.33
Other variables	*Market Share (MKSHARE)*	76,373	2.23	0.75
	Product Quality (QUALITY)	82,223	2.45	0.67
	Product Differentiation (DIFF)	80,855	2.35	0.75
	Labor Cost (COST)	69,548	1.93	0.78
		N	Freq.	%
	UTILITY	138,665	9369	6.76
	COPYRIGHT	138,665	2134	1.54
	BRAND	138,665	22,371	16.13
	R&D expenditures (RDE)	135,799	70,798	52.13

Note: Frequency analysis for value 1 is reported for variables *UTILITY*, *COPYRIGHT*, *BRAND*, and *RDE*.

checked the balance plots (kernel density plot with Epanechnikov function and the box plot) to investigate whether the balance assumption had been violated.

3.3.3 | Fuzzy DiD

After checking the moderating effect of RDE, restricted to significant years through PSM, in this section, we propose extending, as a post-hoc analysis, the investigation of this effect for the entire sample and years by adopting a fuzzy DiD design. The DiD framework enabled us to assess the effect of the treatment (RDE) in our observational data.

Treatment-effects estimation is typically conducted via linear regressions, including time and group fixed effects. However, de Chaisemartin and D'Haultfœuille (2020) posited that this type of regression, which is an extension of the Wald-DiD, does not satisfy the no-sign reversal property assumption, that is, a negative effect of the treatment variable even if the treatment effect is positive for every subject in the sample.

To this end, de Chaisemartin et al. (2019) suggested that in many situations of the DiD design, the treatment rate increases in some groups compared to others, while no group remains stable (fully untreated vs. fully treated). Furthermore, de Chaisemartin and D'Haultfœuille (2018) showed that for such fuzzy structures, under certain assumptions, treatment-effects estimation could be carried out by several estimands, mainly the Wald-DiD estimator and the time-corrected (TC) Wald ratio, which identify the local average treatment effect (LATE) and can be used to draw inferences using the bootstrap method.

In this paper, we estimated LATE of RDE on the outcome variable CA by fuzzy DiD using the Wald and TC-DiD estimators with 1,000 bootstrap replications, while controlling for GI (PEGR, HSEGR, and REGR), firm size, and firm age as covariates in the model. Standard errors and confidence intervals were computed by clustering at the firm level. We also performed equality tests between Wald and TC-DiD estimands because they identify LATE under different assumptions, as indicated by de Chaisemartin et al. (2019).

4 | RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics for the dependent, independent, and control variables. The average score for CA among Spanish firms was 2.23, with a low standard deviation (0.25). The average score for GI variables was lower than the mean value of scale measurement (1.5) with a high standard deviation ranging between 1.01 and 1.21. In terms of mean comparisons, firms that showed adherence to environmental and regulatory requirements were ranked first, followed by those with improvements in health, safety, and the environment; then, we ranked companies focusing on decreasing use of resources per unit generated. This shows that firms in our sample prioritized REGR over HSEGR and PEGR. Moreover, our data indicate an average firm size of 4.19 and an average firm age of 1.29, expressed in natural logarithm measurements.

CA measures indicated that the mean values for the variables MKSHARE, QUALITY, DIFF, and COST were relatively high. The standard deviations were also relatively low, indicating low dispersion across these variables. In addition, intellectual property rights indicated that brand was the most prevalent type of intellectual property,

TABLE 3 Dynamic panel-data bias-corrected estimations.

Independent variables		Dependent variable: *Competitive Advantage (CA)* Coeff.	Robust Std. err.	*Z* statistic	P > |*z*|
Lagged one of the dep. var. (L1.CA)		0.516	0.018	27.51	.000
Lagged one of the dep. var. (L2.CA)		−0.091	0.010	−8.61	.000
Control variables	*Firm size (SIZE)*	0.008	0.003	2.26	.024
	Firm age (AGE)	−0.059	0.021	−2.76	.006
	Constant	1.191	0.042	27.73	.000
Green innovation	*Less energy/material per unit production (PEGR)*	0.054	0.003	18.19	.000
	Improvement of HSE (HSEGR)	0.020	0.003	6.80	.000
	Compliance with environmental regulations (REGR)	0.016	0.002	6.42	.000
Post estimates	*Arellano and Bond test for AR(1)*	*H0: no autocorrelation of order 1* $z = -24.8830$; *Prob* > |*z*| = *.0000*			
	Arellano and Bond test for AR(2)	*H0: no autocorrelation of order 2* $z = 9.2975$; *Prob* > |*z*| = *.0000*			
	Arellano and Bond test for AR(3)	*H0: no autocorrelation of order 3* $z = -1.5067$; *Prob* > |*z*| = *.1319*			

Note: 3,848 groups are dropped due to gaps or insufficient number of observations. Retained number of groups is 2,898 with 21,140 observations; Dynamic panel-data estimations with fixed-effects model and robust estimation where standard errors are adjusted for clustering on the individual level; yearly time effects are not reported because they are all not significant, except for year 2007 (coeff. = −0.010; Std. err. = 0.005; $p = .04 < .05$); algorithm of bias-correction estimation converged after 3 iterations.

followed by utility and copyright. Table 2 also indicates that more than half of the Spanish companies surveyed invest in R&D, which highlights the importance of innovation in the business environment of the country. Investing in R&D is crucial for companies to remain competitive and relevant in their industries; it may also lead to long-term benefits such as improved productivity, profitability, and, ultimately, a greater market share. Therefore, it is not surprise that many Spanish firms prioritize R&D in their business strategies.

4.1 | Main results

Table 3 presents the results of our bias estimation of GMM under dynamic panel model specification. Overall, the main results displayed rejection of serial correlation for higher-order 3 ($z = -1.50$, $p > .05$) and no problem of endogeneity, as indicated by the generalized Hausman test ($p > .05$). The time effects of no year were statistically significant ($p > .05$), except for 2007, which could be attributed to an unobserved change in another variable not included in our estimated model. Thus, further analyses were conducted to investigate this issue.

The remaining results support the relationship between GI practices and CA in Spanish firms, as follows:

Hypothesis 1 states that *Reduction in energy or material use impacts a firm's CA*. Our results confirm that cutting back on energy and material can give firms a CA. RBV theory supports this notion, as it emphasizes the importance of leveraging firms' resources and capabilities to gain an edge over their rivals. By decreasing production costs through energy and material conservation, businesses can offer lower prices to customers, which grants them an advantage in the market. Additionally, reducing energy and material use can help firms to become more environmentally friendly, which can improve their public image and reputation. Therefore, Hypothesis 1 is confirmed.

Hypothesis 2 states that *Improvements in health, safety, and the environment impact a firm's CA*. Institutional theory suggests that firms should devise practices and develop novel approaches that focus on creating eco-friendly products and efficient processes, which means that green products are essential in product differentiation and attaining a CA. Companies with strong health, safety, and environmental standards tend to have higher levels of customer satisfaction, employee engagement, and overall profitability. Additionally, customers and other stakeholders often see these firms as more responsible and trustworthy, which usually leads to increased customer loyalty and brand recognition and, ultimately, a competitive edge. Thus, the results of this study support Hypothesis 2.

Hypothesis 3 specifies that *Compliance with regulatory requirements concerning environmental, health, or safety issues impacts a firm's CA*. As environmental regulations are becoming more stringent, firms should take steps to ensure compliance in order to maximize their CA. Environmental regulations can stimulate the adoption of innovative practices that overcome trade barriers. By constraining the ability of unsustainable producers to take advantage of market competition, these regulations encourage the implementation of sustainable practices and promote fair competition. In line with the Porter hypothesis, adhering to environmental regulations can help firms to offset the costs and burdens of regulatory compliance—leading to reduced costs and increased competitiveness—through the creation of new markets for environmentally desirable products and processes. This can also

TABLE 4 Treatment effect estimates with propensity score matching.

	Outcome variable: *Competitive Advantage (CA)*			
Estimate effect of treatment	**Coeff.**	**Robust Std. err.**	***Z* statistic**	**P > |*z*|**
ATE: R&D expenditures (1 vs. 0)	0.041	0.009	4.47	.000
ATET: R&D expenditures (1 vs. 0)	0.040	0.009	4.47	.000

TABLE 5 Covariate balance summary.

			Covariates		
Model estimates			***PEGR***	***HSEGR***	***REGR***
ATE model	Standardized differences	Raw	0.080	0.080	0.022
		Matched	−0.011	0.004	−0.004
	Variance ratio	Raw	1.059	1.037	0.977
		Matched	0.980	0.993	0.992
ATET model	Standardized differences	Raw	0.080	0.080	0.022
		Matched	0.000	0.000	0.000
	Variance ratio	Raw	1.059	1.037	0.977
		Matched	1	1	1

TABLE 6 Fuzzy-DiD estimations.

Estimator	LATE	Std. err.	*t* statistic	P > |*t*|	[95% confidence interval]	
Wald-DiD	0.020	0.004	4.433	.000	0.011	0.029
TC-DiD	0.017	0.004	3.814	.000	0.008	0.026
Equality test	Delta = 0.002 [Std. err. = 0.001] (*t* statistic = 2.447; P > |t| = .014)					

carry first-mover advantages, allowing firms to pursue distinct differentiation products, improve their green image, and gain a CA (Porter & Van der Linde, 1995; Rennings, 2000). Also, businesses can build a positive image with customers and other stakeholders and reduce their risk of legal requirements. Customers increasingly look for companies committed to sustainability and protecting the environment. Additionally, committed firms can avoid costly fines and other penalties arising from non-compliance. Thus, we cannot reject Hypothesis 3.

Table 3 shows that the study hypotheses are supported ($\beta = .054$, .020, and .016; $p < .001$). The results demonstrate that implementing GI can give firms a CA, such as gaining a leadership role in the market, developing a strong green reputation, and expanding the market share. Additionally, customers may be more likely to purchase green products due to the advantages they offer, such as added safety, healthiness, efficiency, and cost-effectiveness, which is supported by several studies (Chen et al., 2006; Chiou et al., 2011; Li et al., 2019; Rusinko, 2007; Zameer et al., 2020). The environmental transformations undertaken by companies can have substantial implications for achieving success and attaining a CA. When embracing GI, businesses carefully consider a wide variety of factors, including governmental restrictions, owner preferences, supplier capabilities, customer demands and interests, and the driving forces of technology and organizational dynamics (Chen et al., 2006).

In this study, we controlled for firm size (*SIZE*) and firm age (*AGE*). *SIZE* had a significant and positive effect ($\beta = .008$, $p < .05$) on CA. This suggests that larger firms adopt GI better, enhancing their productivity and competitiveness, because they have more capabilities than small firms. In contrast, statistical analyses demonstrated that firm age has a detrimental effect ($\beta = -.059$, $p < .005$) on CA. As the world shifts toward more sustainable and environmentally friendly practices, many businesses have been quick to adopt green initiatives in order to stay competitive. However, shifting to greener practices may pose a challenge for older companies that have already invested in traditional technologies. The transition requires a high degree of risk and collaboration, which can be daunting for more established businesses. Additionally, as the firm ages, keeping up with the latest trends and technologies may become increasingly difficult, further reducing its CA. These findings are in line with previous research (Bataineh et al., 2023; Chen et al., 2006).

4.2 | Additional analyses

This paper used PSM in combination with fuzzy DiD to analyze treatment effects. Combining these two techniques enabled us to accurately assess the effects of a treatment on an outcome of interest and determine whether the treatment was effective. We conducted a treatment-effect analysis with PSM on CA for the year 2007, taking

R&D expenditures as the treatment and GI variables as the covariates, finding a significant effect. Table 4 shows the main results obtained after implementing the procedures outlined in the preceding section.

The ATE of R&D expenditures was 0.041, which reached statistical significance ($p < .001$), indicating that for the year 2007, having R&D expenditures likely increased CA (CA) by 0.041 on average. Furthermore, the ATET for R&D expenditures was 0.040 and reached statistical significance ($p < .001$). These results indicate that investing in R&D can help companies to gain a CA. Companies with higher levels of R&D spending are more likely to see a greater impact on their competitive edge than those with lower levels of investment.

As shown in Table 5, MSD values were near 0, and MVR statistics were near 1 for all covariates and both models ATE and ATET. These results are supported by balance kernel density plots and box plots for the two models, ATE and ATET, as shown in Figures A1–A4 of the Appendix A, indicating evidence for balance in our estimated models by the PSM.

Overlap density plots for both the ATE and ATET models, as shown in Figures A5 and A6 (Appendix A), indicate no considerable mass density around 0 or 1. These results provide evidence that the overlap assumption cannot be rejected.

The main results of fuzzy DiD are presented in Table 6. The Wald-DiD was equal to 0.020 and statistically significant ($p < .001$). According to this estimator, having R&D expenditures (RDE $=$ 1) increased CA by 0.020 on average while controlling for GI, size, and age of the firm as covariates. The TC-DiD estimator was lower (0.017) and significant ($p < .001$), suggesting that if the treatment holds (RDE $=$ 1), then we should expect an average 0.017 rise in CA while controlling for the same covariates.

The equality test provided evidence of a significant difference between Wald-DiD and TC-DiD estimators ($p < .05$). This difference could be attributed to the underlying assumptions of each estimator. In fact, Wald-DiD identifies LATE under two main assumptions, mainly (i) the effect of the treatment should be invariant for time; and (ii) equality of treatment effects exists between the treatment and the control groups when the treatment increases in both of them; whereas, the TC-DiD relies on common trend assumptions within subgroups of units sharing the same treatment as of the first date (De Chaisemartin & D'Haultfoeuille, 2018).

Hypothesis 4 specifies that *R&D expenditures are moderating GI impacts on the firm's CA*. The main results of treatment-effect analyses by PSM and fuzzy DiD confirmed a significant positive effect of the RDE variable on CA while controlling for GI variables as covariates.

Post hoc analyses of the entire sample and years with fuzzy DiD confirmed a moderating effect of R&D expenditures on CA when controlling for GI practices, age, and size of the firm as covariates. Organizational capabilities such as R&D are vital for businesses to benefit from their green initiatives (Demirel & Kesidou, 2019). The findings suggest that RDE is a significant element in the connection between GI and a company's competitive edge. Investing in R&D is crucial to a firm's prosperity and is a major driver of economic growth and business value, which are based on creating innovative products, improving existing ones, and increasing production efficiency, all of which can raise sales. Additionally, higher levels of R&D investment can facilitate the adoption of green initiatives and make clean technologies more accessible, ultimately improving productivity (Demirel & Kesidou, 2019). This can reduce the costs associated with GI, which can also contribute to the firm's CA. As such, it is reasonable to state that R&D expenditures are a moderating factor in the relationship between GI and a firm's CA. Consistent with resources-based theory, firms can gain a CA by leveraging their resources and capabilities.

The upward trend seen in R&D practices addresses environmental impacts and enriches novel knowledge and advanced technology. We have sufficient evidence to theorize that R&D moderates the relationship between GI and CA. R&D expenditures thus have a positive impact on the environment and lead to advancements in technology. R&D spending plays a significant role in introducing eco-friendly technologies and contributing to green growth; it also helps to reduce the risk of technology obsolescence and broadens technological knowledge. Innovation and R&D practices improve productivity, human resource management, and work organization. Investing in R&D can contribute to maximizing the benefits of green initiatives and gaining a competitive edge (Duque-Grisales et al., 2020; Samad & Manzoor, 2015; Veronica et al., 2020). Therefore, companies should invest in R&D and build organizational capabilities to ensure the success of their green efforts.

5 | CONCLUSION AND STUDY IMPLICATIONS

Due to the apparent growing concern for environmental issues worldwide, government institutions, businesses, customers, and decision makers are more inclined to implement GI and create eco-friendly products. Introducing green practices helps firms to innovate efficiently in the form of reduced costs, product differentiation, better quality, and, thereby, access to strictly regulated markets, thus gaining CA over their competitors. In order to reach an ecologically sustainable global economy, businesses and industries must organize around ecologically sound principles, and this necessarily involves greening their products, production systems, and management practices (Shrivastava, 1995). National and regional policies support GI and sustainable development in Spain, increasing environmental innovations, resource efficiency, and clean technologies (European Commission, 2017). The primary objective of this paper was to explore the relationship between GI, R&D expenditures, and CA. Specifically, we aimed to determine whether GI can significantly enhance the CA of businesses and the moderating effect of R&D expenditures in this relationship.

Hence, we first deployed an unorthodox econometric methodology based on bias-corrected method of moments estimators for linear dynamic panel data models at the firm level to the rich, longitudinal PITEC database, spanning 2003–2016 and including 12,849 firms. The main results indicate that GI practices, such as reducing energy or material use; improvements in health, safety, and the environment; and compliance with environmental, health, or safety regulatory requirements boost CA. A second phase of analysis, using PSM and fuzzy DiD, showed that R&D expenditures positively moderate the relationship between GI and CA. Finally, the study highlights the importance of R&D investment for firms seeking to gain a CA, particularly regarding GI. Decision makers should therefore conscientiously consider the moderating effect of R&D expenditures and prioritize resources and capabilities when developing strategies for success.

The results of this study have several implications for practitioners. First, firms should strive to reduce their energy and material use in order to gain a CA. This can be achieved by implementing energy-efficient technologies, adopting green practices, and employing renewable resources. Additionally, firms should focus on improving their health, safety, and environmental standards to gain a competitive edge. This can be achieved through the implementation of safety protocols, adoption of green practices, and utilization of sustainable resources. Fostering a culture of sustainability is also vital for long-term success, which involves implementing sustainable initiatives, integrating eco-friendly practices, and promoting resource efficiency.

This nexus could inspire researchers, decision makers, and stakeholders to adopt proactive environmental strategies that contribute to CA when investing in green projects and R&D. Hence, we identify a variety of managerial implications for decision makers. Considering the changing requirements of consumers in a scenario dominated by heightened environmental concerns, rapid technological developments, and increasing competition, firms should develop new products that are both innovative and environmentally innocuous. Decision makers also should be much more active in facilitating businesses with the amenities required to promote the adoption of green projects and the development of R&D practices by providing more R&D subsidies. Launching GI projects, in addition to updating environmental regulations, enables firms to penetrate new markets and achieve a CA. According to institutional theory, globalization pushes firms to defer to global social pressures by aligning their green practices with external environmental regulations and policies. In line with this theory, our results reveal that decision makers would be well-served to recognize how to refine internal practices and strategies in order to introduce new environmentally friendly products, efficient processes, and higher quality that can contribute to product differentiation and achieve CA.

This research is not free from certain limitations. Firstly, this study does not differentiate between sector typologies (clean vs. dirty). Mean differences in CA could be persistently heterogeneous between these two main sectors with regard to environmental issues, a firm's unobserved characteristics, and our studied covariates, that is, GI. Secondly, while we did not distinguish between capabilities and CA, we considered labor costs to be a proxy indicator for CA in the absence of a better proxy like production costs. Future research should include sensitivity analyses on such choices to test the robustness of our results. Future studies could explore and add new practices related to GI, including, among others, supply chain management, procurement strategies, and worker training. Research of the impact of these practices on CA and their subsequent effects on financial performance can lead to a better understanding of the broader implications of GI. This would contribute to the advancement of knowledge in the field and provide valuable insights for businesses seeking to align sustainability efforts with long-term profitability. On an econometric level, exploring the possibility of nonlinear conditions and/or nonlinear DiD with staggered setups and heterogeneous effects could provide new insights on the complexity of modeling the nexus between GI, R&D, and CA.

ACKNOWLEDGMENTS

This paper was supported by the grant PID2021-123154NB-I00 funded by MCIN/AEI/10.13039/501100011033 and "ERDF A way of making Europe" and by the COMPETE (S52_23R) research group funded by Government of Aragón (Spain) and ERDF.

ORCID

Mohammad Jamal Bataineh https://orcid.org/0000-0003-4299-9636
Pedro Sánchez-Sellero https://orcid.org/0000-0002-6475-0578
Fayssal Ayad https://orcid.org/0000-0003-0446-0453

REFERENCES

Abadie, A., & Imbens, G. W. (2016). Matching on the estimated propensity score. *Econometrica*, *84*(2), 781–807. https://doi.org/10.3982/ecta11293

Aguilera-Caracuel, J., & Ortiz-de-Mandojana, N. (2013). Green innovation and financial performance: An institutional approach. *Organization & Environment*, *26*(4), 365–385. https://doi.org/10.1177/1086026613507931

Anderson, T. W., & Hsiao, C. (1981). Estimation of dynamic models with error components. *Journal of the American Statistical Association*, *76*(375), 598–606. https://doi.org/10.2307/2287517

Angrist, J. D., & Pischke, J.-S. (2015). *The Path From Cause to Effect: Mastering 'Metrics*. Princeton University Press.

Ardito, L., Messeni Petruzzelli, A., Pascucci, F., & Peruffo, E. (2019). Inter-firm R&D collaborations and green innovation value: The role of family firms' involvement and the moderating effects of proximity dimensions. *Business Strategy and the Environment*, *28*(1), 185-197.40690. https://doi.org/10.1002/bse.2248

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behavioral Research*, *46*(3), 399–424. https://doi.org/10.1080/00273171.2011.568786

Barla, P. (2007). ISO 14001 certification and environmental performance in Quebec's pulp and paper industry. *Journal of Environmental Economics and Management*, *53*(3), 291–306. https://doi.org/10.1016/j.jeem.2006.10.004

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700

Bataineh, M. J., Sánchez-Sellero, P., & Ayad, F. (2023). The role of organizational innovation in the development of green innovations in Spanish firms. *European Management Journal*. https://doi.org/10.1016/j.emj.2023.01.006

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/10.1016/s0304-4076(98)00009-8

Borsatto, J. M. L. S., & Amui, L. B. L. (2019). Green innovation: Unfolding the relation with environmental regulations and competitiveness. *Resources, Conservation and Recycling*, *149*, 445–454. https://doi.org/10.1016/j.resconrec.2019.06.005

Breitung, J., Kripfganz, S., & Hayakawa, K. (2022). Bias-corrected method of moments estimators for dynamic panel data models. *Econometrics and Statistics*, *24*, 116–132. https://doi.org/10.1016/j.ecosta.2021.07.001

Bun, M. J., & Windmeijer, F. (2010). The weak instrument problem of the system GMM estimator in dynamic panel data models. *The Econometrics Journal*, *13*(1), 95–126. https://doi.org/10.1111/j.1368-423X.2009.00299.x

Burns, P. B., Rohrich, R. J., & Chung, K. C. (2011). The levels of evidence and their role in evidence-based medicine. *Plastic and Reconstructive Surgery*, *128*(1), 305–310. https://doi.org/10.1097/PRS.0b013e318219c171

Busso, M., DiNardo, J., & McCrary, J. (2014). New evidence on the finite sample properties of propensity score reweighting and matching estimators. *Review of Economics and Statistics*, *96*(5), 885–897. https://doi.org/10.1162/REST_a_00431

Cameron, A. C., & Trivedi, P. K. (2005). *Microeconometrics: Methods and Applications*. Cambridge university press. https://doi.org/10.1017/CBO9780511811241

Chan, H. K., Yee, R. W., Dai, J., & Lim, M. K. (2016). The moderating effect of environmental dynamism on green product innovation and performance. *International Journal of Production Economics*, *181*, 384–391. https://doi.org/10.1016/j.ijpe.2015.12.006

Chang, C. H. (2011). The influence of corporate environmental ethics on competitive advantage: The mediation role of green innovation. *Journal of Business Ethics*, *104*(3), 361–370. https://doi.org/10.1007/s10551-011-0914-x

Chen, Y. S. (2008). The driver of green innovation and green image–green core competence. *Journal of Business Ethics*, *81*(3), 531–543. https://doi.org/10.1007/s10551-007-9522-1s

Chen, Y. S., Lai, S. B., & Wen, C. T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67*(4), 331–339. https://doi.org/10.1007/s10551-006-9025-5

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

Cillo, V., Petruzzelli, A. M., Ardito, L., & del Giudice, M. (2019). Understanding sustainable innovation: A systematic literature review. *Corporate Social Responsibility and Environmental Management*, *26*(5), 1012–1025. https://doi.org/10.1002/csr.1783

Corrigan, J. (1996). How a green image can drive Irish export growth. *Greener Management International*, *16*, 87–96.

Costantini, V., & Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. *Research Policy*, *41*(1), 132–153. https://doi.org/10.1016/j.respol.2011.08.004

Cronin, J. J., Smith, J. S., Gleim, M. R., Ramirez, E., & Martinez, J. D. (2011). Green marketing strategies: An examination of stakeholders and the opportunities they present. *Journal of the Academy of Marketing Science*, *39*(1), 158–174. https://doi.org/10.1007/s11747-010-0227-0

de Chaisemartin, C., & D'Haultfoeuille, X. (2018). Fuzzy differences-in-differences. *The Review of Economic Studies*, *85*(2), 999–1028. https://doi.org/10.1093/restud/rdx049

de Chaisemartin, C., & d'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review*, *110*(9), 2964–2996. https://doi.org/10.1257/aer.20181169

de Chaisemartin, C., D'Haultfœuille, X., & Guyonvarch, Y. (2019). Fuzzy differences-in-differences with stata. *The Stata Journal*, *19*(2), 435–458. https://doi.org/10.1177/1536867X19854019

del Río, P., Peñasco, C., & Romero-Jordán, D. (2015). Distinctive features of environmental innovators: An econometric analysis. *Business Strategy and the Environment*, *24*(6), 361–385. https://doi.org/10.1002/bse.1822

del Vecchio, P., di Minin, A., Petruzzelli, A. M., Panniello, U., & Pirri, S. (2018). Big data for open innovation in SMEs and large corporations: Trends, opportunities, and challenges. *Creativity and Innovation Management*, *27*(1), 6–22. https://doi.org/10.1111/caim.12224

Demirel, P., & Kesidou, E. (2019). Sustainability-oriented capabilities for eco-innovation: Meeting the regulatory, technology, and market demands. *Business Strategy and the Environment*, *28*(5), 847–857. https://doi.org/10.1002/bse.2286

Dranove, D. (2012). *Practical Regression: Fixed Effects Models*. Technical notes. Kellogg School of Management, Northwestern University (pp. 1–10).

Duque-Grisales, E., Aguilera-Caracuel, J., Guerrero-Villegas, J., & García-Sánchez, E. (2020). Does green innovation affect the financial performance of Multilatinas? The moderating role of ISO 14001 and R&D investment. *Business Strategy and the Environment*, *29*(8), 3286–3302. https://doi.org/10.1002/bse.2572

Eiadat, Y., Kelly, A., Roche, F., & Eyadat, H. (2008). Green and competitive? An empirical test of the mediating role of environmental innovation strategy. *Journal of World Business*, *43*(2), 131–145. https://doi.org/10.1016/j.jwb.2007.11.012

El-Kassar, A. N., & Singh, S. K. (2019). Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices. *Technological Forecasting and Social Change*, *144*, 483–498. https://doi.org/10.1016/j.techfore.2017.12.016

European Commission. (2017). *Eco-Innovation in Spain: Eco-Innovation Observatory*. Annual Report, European Commission, available at https://bit.ly/2wjUoKL

European Commission. Executive Agency for Small and Medium-sized Enterprises(2019). In available at https://data.europa.eu/doi/10.2826/94924. (Ed.), *Your Guide to IP in Europe*. Publications Office of the European Union.

García-Marco, T., Zouaghi, F., & Sánchez, M. (2020). Do firms with different levels of environmental regulatory pressure behave differently regarding complementarity among innovation practices? *Business Strategy and the Environment*, *29*(4), 1684–1694. https://doi.org/10.1002/bse.2461

Girod, S. J., & Whittington, R. (2017). Reconfiguration, restructuring and firm performance: Dynamic capabilities and environmental dynamism. *Strategic Management Journal*, *38*(5), 1121–1133. https://doi.org/10.1002/smj.2543

Grant, R. M. (1991). The resource-based theory of competitive advantage: Implications for strategy formulation. *California Management Review*, *33*(3), 114–135. https://doi.org/10.2307/41166664

Guo, S., & Fraser, M. W. (2014). *Propensity Score Analysis: Statistical Methods and Applications* (Vol. 11). SAGE publications.

Hadj, T. B. (2020). Effects of corporate social responsibility towards stakeholders and environmental management on responsible innovation and competitiveness. *Journal of Cleaner Production*, *250*, 119490. https://doi.org/10.1016/j.jclepro.2019.119490

Hao, Y., Fan, C., Long, Y., & Pan, J. (2019). The role of returnee executives in improving green innovation performance of Chinese manufacturing enterprises: Implications for sustainable development strategy. *Business Strategy and the Environment*, *28*(5), 804–818. https://doi.org/10.1002/bse.2282

Hart, S. L. (1995). A natural-resource-based view of the firm. *Academy of Management Review*, *20*(4), 986–1014. https://doi.org/10.5465/amr.1995.9512280033

Hayakawa, K., & Pesaran, M. H. (2015). Robust standard errors in transformed likelihood estimation of dynamic panel data models with cross-sectional heteroskedasticity. *Journal of Econometrics*, *188*(1), 111–134. https://doi.org/10.1016/j.jeconom.2015.03.042

Heinrich, C. M., Maffioli, A., & Vazquez, G. (2010). A primer for applying propensity-score matching. In *Inter-American Development Bank: Impact-Evaluation Guidelines Technical Notes*. Inter-American Development Bank. No. IDB-TN-161

Hermundsdottir, F., & Aspelund, A. (2021). Sustainability innovations and firm competitiveness: A review. *Journal of Cleaner Production*, *280*, 124715. https://doi.org/10.1016/j.jclepro.2020.124715

Hojnik, J., & Ruzzier, M. (2016). The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia. *Journal of Cleaner Production*, *133*, 812–825. https://doi.org/10.1016/j.jclepro.2016.06.002

Holtz-Eakin, D., Newey, W., & Rosen, H. S. (1988). Estimating vector autoregressions with panel data. *Econometrica: Journal of the Econometric Society*, *56*, 1371–1395. https://doi.org/10.2307/1913103

Horbach, J. (2016). Empirical determinants of eco-innovation in European countries using the community innovation survey. *Environmental Innovation and Societal Transitions*, *19*, 1–14. https://doi.org/10.1016/j.eist.2015.09.005

Howarter, S. (2015). *The Efficacy of Propensity Score Matching in Bias Reduction with Limited Sample Sizes* (Doctoral dissertation,. University of Kansas.

Hsiao, C., Pesaran, M. H., & Tahmiscioglu, A. K. (2002). Maximum likelihood estimation of fixed effects dynamic panel data models covering short time periods. *Journal of Econometrics*, *109*(1), 107–150. https://doi.org/10.1016/S0304-4076(01)00143-9

Hu, W., & Wall, G. (2005). Environmental management, environmental image and the competitive tourist attraction. *Journal of Sustainable Tourism*, *13*(6), 617–635. https://doi.org/10.1080/09669580508668584

Huse, M., Neubaum, D. O., & Gabrielsson, J. (2005). Corporate innovation and competitive environment. *The International Entrepreneurship and Management Journal*, *1*(3), 313–333. https://doi.org/10.1007/s11365-005-2596-2

Iacus, S. M., King, G., & Porro, G. (2011). Multivariate matching methods that are monotonic imbalance bounding. *Journal of the American Statistical Association*, *106*(493), 345–361. https://doi.org/10.1198/jasa.2011.tm09599

Janssen, M. A., & Jager, W. (2002). Stimulating diffusion of green products. *Journal of Evolutionary Economics*, *12*(3), 283–306. https://doi.org/10.1007/s00191-002-0120-1

Jensen, M. B., & Beckmann, S. C. (2009). Determinants of innovation and creativity in corporate branding: Findings from Denmark. *Journal of Brand Management*, *16*(7), 468–479. https://doi.org/10.1057/palgrave.bm.2550138

Jové-Llopis, E., & Segarra-Blasco, A. (2018). Eco-innovation strategies: A panel data analysis of Spanish manufacturing firms. *Business Strategy and the Environment*, *27*(8), 1209–1220. https://doi.org/10.1002/bse.2063

Jové-Llopis, E., & Segarra-Blasco, A. (2020). Why does eco-innovation differ in service firms? Some insights from Spain. *Business Strategy and the Environment*, *29*(3), 918–938. https://doi.org/10.1002/bse.2407

King, G., & Nielsen, R. (2019). Why propensity scores should not be used for matching. *Political Analysis*, *27*(4), 435–454. https://doi.org/10.1017/pan.2019.11

Kiviet, J. F. (1995). On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. *Journal of Econometrics*, *68*(1), 53–78. https://doi.org/10.1016/0304-4076(94)01643-E

Kripfganz, S., & Schwarz, C. (2019). Estimation of linear dynamic panel data models with time-invariant regressors. *Journal of Applied Econometrics*, *34*(4), 526–546. https://doi.org/10.1002/jae.2681

Li, G., Wang, X., Su, S., & Su, Y. (2019). How green technological innovation ability influences enterprise competitiveness. *Technology in Society*, *59*, 101136. https://doi.org/10.1016/j.techsoc.2019.04.012

Liao, Z. (2016). Temporal cognition, environmental innovation, and the competitive advantage of enterprises. *Journal of Cleaner Production*, *135*, 1045–1053. https://doi.org/10.1016/j.jclepro.2016.07.021

Lin, R. J., Chen, R. H., & Huang, F. H. (2014). Green innovation in the automobile industry. *Industrial Management & Data Systems*, *114*(6), 886–903. https://doi.org/10.1108/IMDS-11-2013-0482

Lobo, A. (2020). *A Case Study on Tesla: The World's Most Exciting Automobile Company*. Medium. Retrieved April 5, 2023, from https://medium.com/@ashleylobo98/a-case-study-on-tesla-the-worlds-most-exciting-automobile-company-535fe9dafd30

Martínez-Ros, E., & Kunapatarawong, R. (2019). Green innovation and knowledge: The role of size. *Business Strategy and the Environment*, *28*(6), 1045–1059. https://doi.org/10.1002/bse.2300

Melander, L. (2017). Achieving sustainable development by collaborating in green product innovation. *Business Strategy and the Environment*, *26*(8), 1095–1109. https://doi.org/10.1002/bse.1970

Menguc, B., Auh, S., & Ozanne, L. (2010). The interactive effect of internal and external factors on a proactive environmental strategy and its influence on a firm's performance. *Journal of Business Ethics*, *94*(2), 279–298. https://doi.org/10.1007/s10551-009-0264-0

Miles, M. P., & Covin, J. G. (2000). Environmental marketing: A source of reputational, competitive, and financial advantage. *Journal of Business Ethics*, *23*(3), 299–311. https://doi.org/10.1023/A:1006214509281

Morgan, C. J. (2018). Reducing bias using propensity score matching. *Journal of Nuclear Cardiology*, *25*(2), 404–406. https://doi.org/10.1007/s12350-017-1012-y

Natalicchio, A., Messeni Petruzzelli, A., Cardinali, S., & Savino, T. (2018). Open innovation and the human resource dimension: An investigation into the Italian manufacturing sector. *Management Decision*, *56*(6), 1271–1284. https://doi.org/10.1108/MD-03-2017-0268

Newall, J. E. (1992). The challenge of competitiveness. *Business Quarterly*, *56*(4), 94–100.

Paparoidamis, N. G., Tran, T. T. H., Leonidou, L. C., & Zeriti, A. (2019). Being innovative while being green: An experimental inquiry into how consumers respond to eco-innovative product designs. *Journal of Product Innovation Management*, *36*(6), 824–847. https://doi.org/10.1111/jpim.12509

Peattie, K. (1999). Trappings versus substance in the greening of marketing planning. *Journal of Strategic Marketing*, *7*(2), 131–148. https://doi.org/10.1080/096525499346486

Petruzzelli, A. M., Dangelico, R. M., Rotolo, D., & Albino, V. (2011). Organizational factors and technological features in the development of green innovations: Evidence from patent analysis. *Innovation: Management, Policy and Practice*, *13*, 291–310. https://doi.org/10.5172/impp.2011.13.3.291

Porter, M. E. (1991). Towards a dynamic theory of strategy. *Strategic Management Journal*, *12*(S2), 95–117. https://doi.org/10.1002/smj.4250121008

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

Pujari, D., Wright, G., & Peattie, K. (2003). Green and competitive: Influences on environmental new product development performance.

Journal of Business Research, *56*(8), 657–671. https://doi.org/10.1016/S0148-2963(01)00310-1

Reinhardt, F. L. (1998). Environmental product differentiation: Implications for corporate strategy. *California Management Review*, *40*(4), 43–73. https://doi.org/10.2307/41165964

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

Ritchie, J. B., & Crouch, G. I. (2003). *The Competitive Destination: A Sustainable Tourism Perspective*. Cabi.

Rosenbaum, P. R. (2002). Overt bias in observational studies. In *Observational Studies. Springer Series in Statistics* (pp. 71–104). Springer. https://doi.org/10.1007/978-1-4757-3692-2_3

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. https://doi.org/10.1093/biomet/70.1.41

Rubin, D. B. (2008). For objective causal inference, design trumps analysis. *The Annals of Applied Statistics*, *2*(3), 808–840. https://doi.org/10.1214/08-AOAS187

Rusinko, C. (2007). Green manufacturing: An evaluation of environmentally sustainable manufacturing practices and their impact on competitive outcomes. *IEEE Transactions on Engineering Management*, *54*(3), 445–454. https://doi.org/10.1109/TEM.2007.900806

Samad, G., & Manzoor, R. (2015). Green growth: Important determinants. *The Singapore Economic Review*, *60*(02), 1550014. https://doi.org/10.1142/S0217590815500149

Sánchez-Sellero, P., & Bataineh, M. J. (2022). How R&D cooperation, R&D expenditures, public funds and R&D intensity affect green innovation? *Technology Analysis & Strategic Management*, *34*(9), 1095–1108. https://doi.org/10.1080/09537325.2021.1947490

Sánchez-Sellero, P., Rosell-Martínez, J., & García-Vázquez, J. M. (2014). Spillovers from foreign direct investment in Spanish manufacturing firms. *Review of International Economics*, *22*(2), 342–351. https://doi.org/10.1111/roie.12115

Sánchez-Sellero, P., Sánchez-Sellero, M. C., Sánchez-Sellero, F. J., & Cruz-González, M. M. (2015). Effects of innovation on technical progress in Spanish manufacturing firms. *Science, Technology and Society*, *20*(1), 44–59. https://doi.org/10.1177/0971721814561396

Sarkar, A. N. (2013). Promoting eco-innovations to leverage sustainable development of eco-industry and green growth. *European Journal of Sustainable Development*, *2*(1), 171–171. https://doi.org/10.14207/ejsd.2013.v2n1p171

Sellitto, M. A., Camfield, C. G., & Buzuku, S. (2020). Green innovation and competitive advantages in a furniture industrial cluster: A survey and structural model. *Sustainable Production and Consumption*, *23*, 94–104. https://doi.org/10.1016/j.spc.2020.04.007

Sharma, S., & Vredenburg, H. (1998). Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities. *Strategic Management Journal*, *19*(8), 729–753. https://doi.org/10.1002/(SICI)1097-0266(199808)19:8<729::AID-SMJ967>3.0.CO;2-4

Shrivastava, P. (1995). Environmental technologies and competitive advantage. *Strategic Management Journal*, *16*(S1), 183–200. https://doi.org/10.1002/smj.4250160923

Song, M., & Wang, S. (2018). Market competition, green technology progress and comparative advantages in China. *Management Decision*, *56*(1), 188–203. https://doi.org/10.1108/MD-04-2017-0375

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Triguero, Á., Cuerva, M. C., & Álvarez-Aledo, C. (2017). Environmental innovation and employment: Drivers and synergies. *Sustainability*, *9*(11), 2057. https://doi.org/10.3390/su9112057

Tseng, M. L., Wang, R., Chiu, A. S., Geng, Y., & Lin, Y. H. (2013). Improving performance of green innovation practices under uncertainty. *Journal of Cleaner Production*, *40*, 71–82. https://doi.org/10.1016/j.jclepro.2011.10.009

Veronica, S., Alexeis, G. P., Valentina, C., & Elisa, G. (2020). Do stakeholder capabilities promote sustainable business innovation in small and medium-sized enterprises? Evidence from Italy. *Journal of Business Research*, *119*, 131–141. https://doi.org/10.1016/j.jbusres.2019.06.025

Vimalnath, P., Tietze, F., Jain, A., & Prifti, V. (2020). IP Strategies for Green Innovations - An Analysis of European Inventor Awards. Centre for Technology Management working paper series, University of Cambridge, No. 2020/01. https://doi.org/10.17863/CAM.48823

Wood, J. S., Gooch, J. P., & Donnell, E. T. (2015). Estimating the safety effects of lane widths on urban streets in Nebraska using the propensity scores-potential outcomes framework. *Accident Analysis & Prevention*, *82*, 180–191. https://doi.org/10.1016/j.aap.2015.06.002

Wooldridge, J. M. (2012). *Introductory Econometrics: A Modern Approach*. Cengage.

Yalabik, B., & Fairchild, R. J. (2011). Customer, regulatory, and competitive pressure as drivers of environmental innovation. *International Journal of Production Economics*, *131*(2), 519–527. https://doi.org/10.1016/j.ijpe.2011.01.020

Zameer, H., Wang, Y., & Yasmeen, H. (2020). Reinforcing green competitive advantage through green production, creativity and green brand image: Implications for cleaner production in China. *Journal of Cleaner Production*, *247*, 119119. https://doi.org/10.1016/j.jclepro.2019.119119

Zatzick, C. D., & Iverson, R. D. (2006). High-involvement management and workforce reduction: Competitive advantage or disadvantage? *Academy of Management Journal*, *49*(5), 999–1015. https://doi.org/10.5465/amj.2006.22798180

Zehir, C., Can, E., & Karaboga, T. (2015). Linking entrepreneurial orientation to firm performance: The role of differentiation strategy and innovation performance. *Procedia-Social and Behavioral Sciences*, *210*, 358–367. https://doi.org/10.1016/j.sbspro.2015.11.381

Zhang, Y., Sun, J., Yang, Z., & Wang, Y. (2020). Critical success factors of green innovation: Technology, organization and environment readiness. *Journal of Cleaner Production*, *264*, 121701. https://doi.org/10.1016/j.jclepro.2020.121701

Zook, C., & Allen, J. (2011). The great repeatable business model. *Harvard Business Review*, *89*(11), 107–114.

How to cite this article: Bataineh, M. J., Sánchez-Sellero, P., & Ayad, F. (2023). Green is the new black: How research and development and green innovation provide businesses a competitive edge. *Business Strategy and the Environment*, 1–20. https://doi.org/10.1002/bse.3533

APPENDIX A: GRAPHICAL DIAGNOSTICS OF PSM

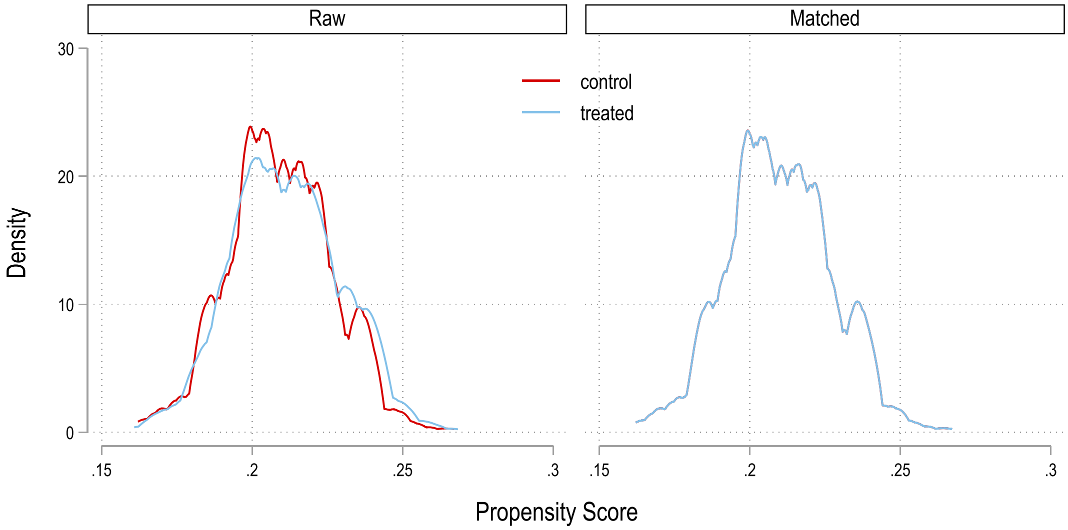

FIGURE A1 Balance kernel density plot for ATE model.

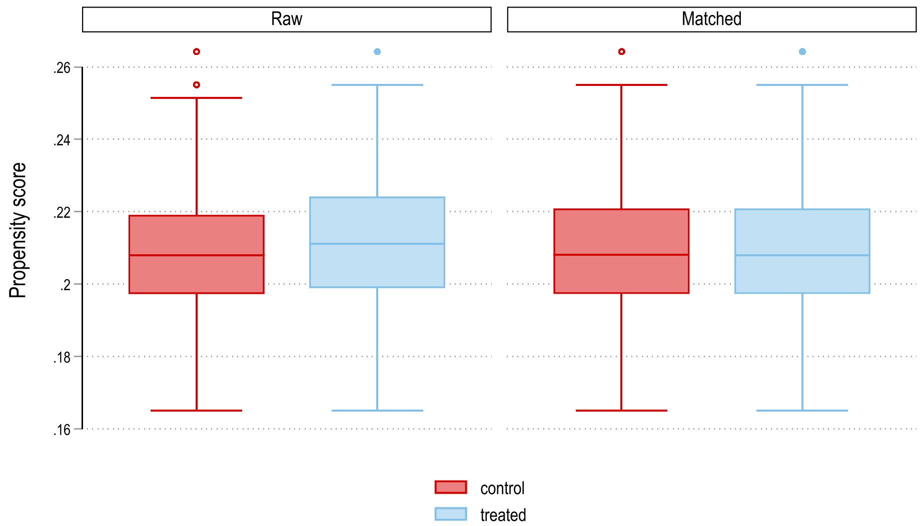

FIGURE A2 Balance box plot for ATE model.

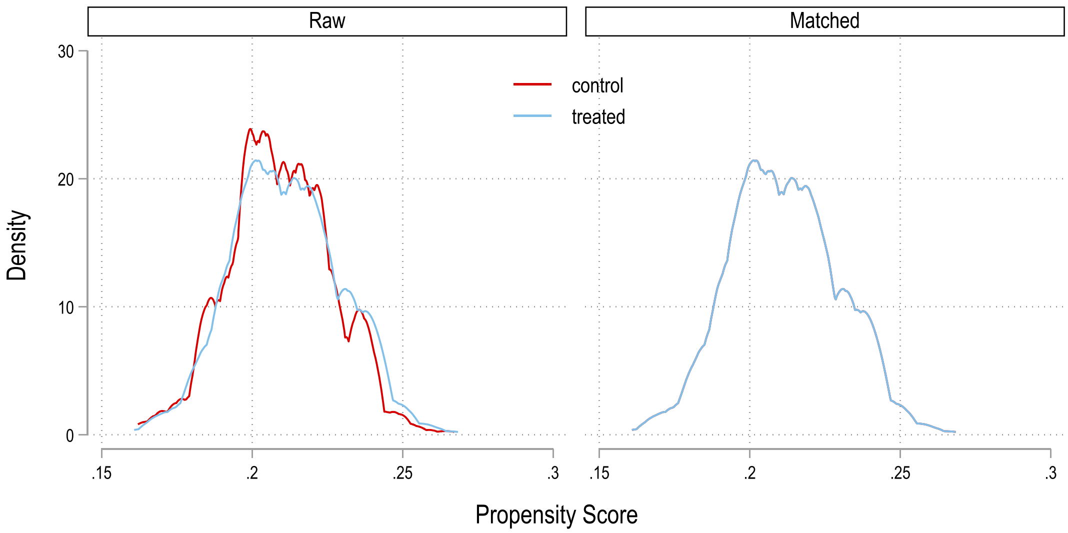

FIGURE A3 Balance kernel density plot for ATET model.

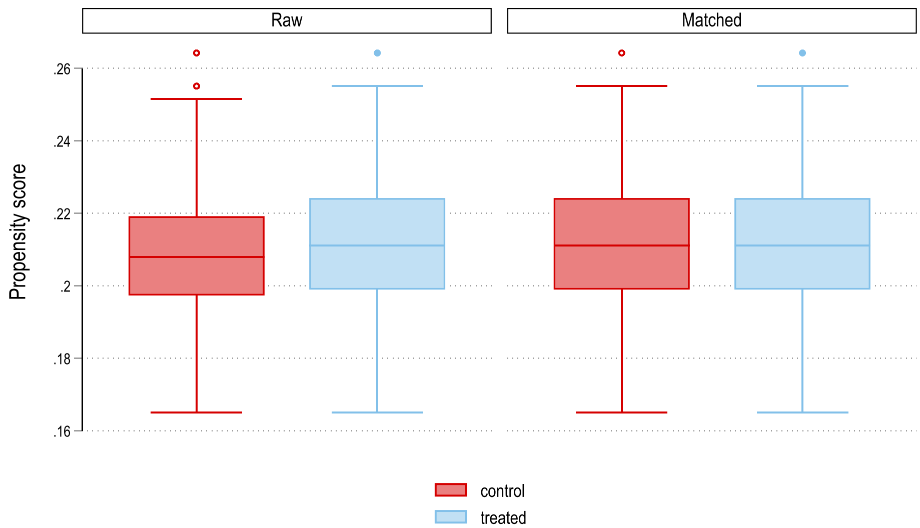

FIGURE A4 Balance box plot for ATET model.

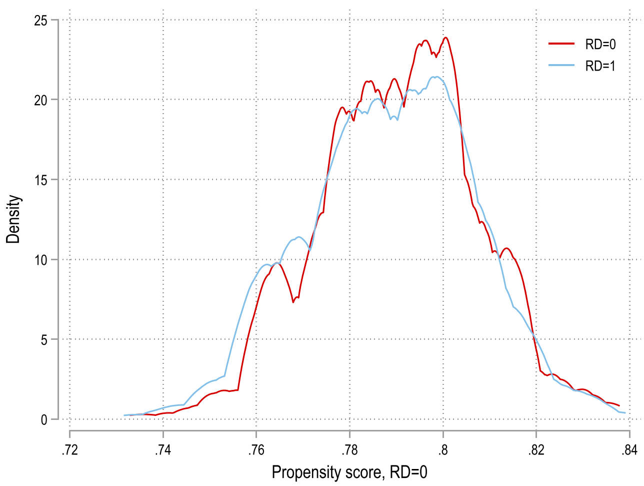

FIGURE A5 Overlap density plot for ATE model.

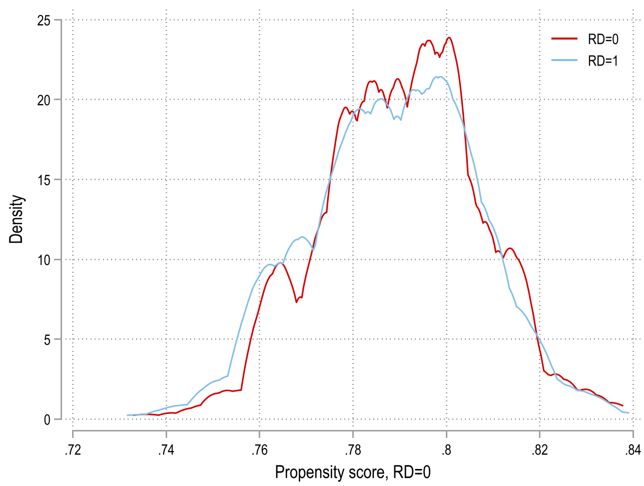

FIGURE A6 Overlap density plot for ATET model.