Leveraging Green Dynamic Capabilities and Institutional Support for Green Technological Innovation and Performance: Evidence from Spanish Manufacturing Firms

Abstract

Purpose

Drawing on dynamic capabilities theory (DCT) and the resource-based view (RBV) perspective, this study proposes a moderated mediation model examining how green dynamic capabilities (GDCs) influence green performance (GP) through the mediation of green technological innovation (GTI), with the moderating effect of institutional support. Using a quantitative approach, partial least squares structural equation modeling (PLS-SEM) and moderated mediation analysis were employed to examine the study model, which was based on data collected from 343 managers in Spanish manufacturing firms. The results indicate that GDCs have a positive impact on GP dimensions, including green management and green product and process performance, and GTI serves as a significant mediator. Moreover, institutional support strengthens the relationship between GDC and GTI. The moderated mediation results also reveal that GTI's mediating role on GDCs and different aspects of green performance is stronger when institutional support is high. The results underscore the importance of firms spending on GDCs, promoting GTI, and exploiting institutional support to gain sustainable competitive advantages. By integrating DCT and RBV, this study extends the application of these theories to new contexts, providing insights that are both academically and practically relevant.

Keywords: Green dynamic capabilities, Green technological innovation, Institutional support, Green performance

1 Introduction

Environmental sustainability has become imperative for organizations striving to retain competitive advantage and remain economically feasible in the long term. Addressing major environmental challenges, including reducing carbon emissions, saving natural resources, and minimizing waste, requires green practices (Abbas, 2020). Specifically, manufacturing firms can avoid their negative environmental impact, follow strict regulatory standards, and increase their operational efficiency by adopting green performance practices (green management performance [GMP], green product performance [GPDP], and green process performance [GPRP]) (Shehzad et al., 2023a), which will result in huge savings in the cost of operation and increased profitability (Mwove et al., 2024). With green performance, organizations can capitalize on the growing demand among consumers for sustainability to create new market opportunities and enhance their brand reputation (Li et al., 2024). Especially, manufacturing firms are urgently confronted with the need to grow the economy while adhering to high environmental standards (Wang & Juo, 2021). The green performance is therefore a key strategy, as it enables firms to balance ecological stewardship and economic prosperity, meet social responsibilities, and develop a competitive advantage (Abbas & Khan, 2023). Consequently, promoting green practices in the business environment is not only advantageous but also crucial, as it aligns organizational activities with the needs of global sustainability and fosters sustainable, resilient development (Bresciani et al., 2022).

Environmental management has become a strategic necessity, particularly for manufacturing companies seeking to achieve ecological sustainability while maintaining competitiveness and ensuring long-term economic viability (Wan et al., 2025). In this sense, green dynamic capabilities (GDCs) are crucial, as they enable firms to sense, reconfigure, and capitalize on resources effectively in response to changing environmental challenges and opportunities (Bresciani et al., 2022; Taleb & Pheniqi, 2023). The functions of these abilities include organizational processes that enhance the anticipation of ecological changes, promote sustainability in administrative frameworks, create ecologically responsible products, and streamline production procedures to reduce waste and energy use (Amaranti et al., 2024). Additionally, GDCs not only ensure regulatory compliance in response to strengthened environmental standards but also innovate, enhance operating efficiency, and improve responsiveness to the market (Singh et al., 2022). Nevertheless, the concurrent attempts to expand economically in advanced manufacturing settings and still meet the high environmental requirements position the necessity to investigate GDCs to remain profitable and sustainable (Wang & Juo, 2021). Although the significance of GDCs is increasingly recognized, a significant gap remains in the literature on how GDCs affect different areas of green performance (GMP, GPDP, and GPRP), each of which presents distinct routes to economic-environmental alignment (Abbas, 2024; Singh et al., 2022). Consequently, the proposed study helps fill this gap by empirically evaluating the role of GDCs in improving green performance, thereby contributing to the debate on sustainable development and resilience in organizations operating in high-performance manufacturing settings.

It has become increasingly clear that environmental sustainability is an area of focus with which manufacturing firms grapple as they pursue long-term competitiveness and economic viability. Given its increasing significance, green performance acquisition constitutes a vital solution for firms to respond to environmental and economic challenges (Wang & Juo, 2021). Green dynamic capabilities are foundational for sustainable operation (Shehzad et al., 2024a). However, having these capabilities does not automatically guarantee better environmental outcomes. These dynamic capabilities are translated into tangible improvements by green technological innovation (GTI) in developing eco-friendly products, optimizing production processes, and applying proper environmental management systems (Ismail, 2023; Mao & Lu, 2023). This mechanism changes strategic capabilities into assessable ecological and monetary presentation key to facilitating key difficulties like waste decrease, vitality proficiency, and conformity with the enactment (Sun et al., 2022). In addition, GTI helps to improve operational efficiency, lower costs, and enhance brand reputation and market positioning, all of which are significant for companies to maintain a competitive advantage in their crowded markets (Abbas & Khan, 2023; Wang et al., 2023). Although GDCs have been regarded as crucial for firms' performance (Amaranti et al., 2024; Borah et al., 2025), empirical evidence regarding the mediating mechanism of GTI in the relationship between GDCs and green performance is scarce. Therefore, addressing this gap is essential for developing targeted strategies that leverage technological advancements to maximize sustainability outcomes and foster organizational success. Thus, this research seeks to explore the mediating role of GTI in the relationship between GDC and GP.

The interplay between green dynamic capabilities and technological innovation is crucial for manufacturing firms to achieve a sustainable competitive advantage and environmental excellence (Abbas, 2024). The GDCs of the firm and the supportive environment afforded by institutional frameworks greatly influence the successful implementation of GTI (Du et al., 2024). These capabilities are highly dependent on the external institutional environment. The relationship between GDCs and GTI is complemented by institutional support, such as government policies, financial incentives, regulatory frameworks, cultural norms, and industry collaborations (Dong et al., 2024). Firms rely on institutional support to provide necessary resources, reduce uncertainties, and create a conducive environment for innovation (Zhang et al., 2017) and, therefore, can unleash their full potential for GDCs to accelerate the development and implementation of green technologies. The stringent environmental regulations surrounding the market, combined with high consumer expectations, require a robust support system for practical green innovation (Ishaq et al., 2024). Although existing literature acknowledges the importance of institutional support for GDCs to stimulate firms' performance (Borah et al., 2025; Li, 2022). Yet, little research has investigated the moderating role of institutional support on the relationship between GDCs and GTI. While these factors have been mostly studied in isolation, their interactive effects and the conditions under which institutional support can spur GTI have been overlooked. Consequently, the study probes to what degree institutional support moderates the effects of GDCs on GTI.

This study fills existing research gaps by employing the Resource-Based View (RBV) and dynamic capabilities theory to investigate the effects of GDCs and GTI on green performance. More specifically, we aimed to investigate the impact of GDCs on green performance and examine the mediating role of GTI, as well as the moderating role of institutional support. We first hypothesize that there is a positive relationship between different aspects of green performance (green management, green process, and green product performance) and GDCs. Second, we study GTI as a mediator between GDCs and green performance. Third, the moderating effect of institutional support in the relationship between GDCs and GTI was studied. The study further hypothesized that GTI more strongly mediates the impact of GDCs on different facets of green performance under greater institutional support than lesser institutional support.

Based on the above-identified research gap, this study seeks to address the following research questions:

RQ: How do GDCs influence firms' green performance?

RQ2: Does GTI mediate the relationship between GDDs and green performance?

RQ3: Does institutional support moderate the relationship between GDCs and GTI?

The paper is organized as follows: The second section elaborates on the research hypotheses; the third defines data collection and research design; the fourth presents the data analysis and its results; the fifth discusses the research implications and limitations; and the sixth concludes the study.

2 Literature review

2.1 Theoretical underpinnings

Based on the integration of dynamic capabilities theory (DCT) and the resource-based view (RBV), this study examines the relationships among GDCs, GTI, institutional support, and green performance. RBV offers a bottom-line view that firms attain sustainable competitive advantage through the development and utilization of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991; Pan et al., 2021). From this perspective, GDCs are strategic capabilities within an organization that enable firms to create and exploit their distinctive green resources, including eco-efficient technologies and green practices in the supply chain, leading to improved green performance (Abbas, 2024; Dangelico et al., 2017; Khaskhely et al., 2022). RBV pays attention to the internal structure of the resources and capabilities but is more likely to assume a relatively stable environment. Figure 1 illustrates the conceptual framework of this study.

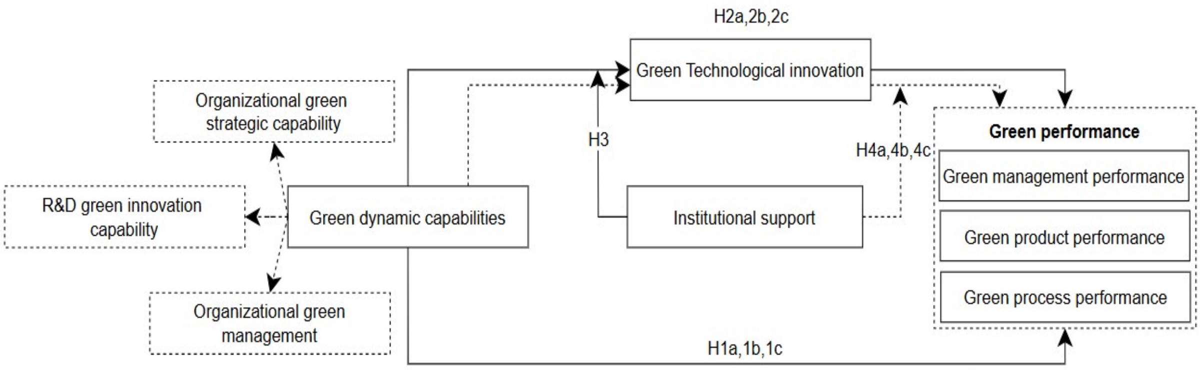

Figure 1. Research model

On the contrary, DCT, in addition to the RBV, focuses on the firm's capacity to adapt, incorporate, and recombine both internal and external capabilities in response to rapidly shifting environments (Wan et al., 2025). This is especially relevant to environmental sustainability, where regulation, consumer preferences, and technological advancements require constant change (Wang & Juo, 2021). DCT identifies three critical aspects: detecting the environmental changes, utilizing the opportunities offered by GTI due to the focus on sustainability, and modifying resource bases to adapt to emerging environmental requirements (Borah et al., 2025; Li, 2022). In this sense, RBV determines what is essential as resources, whereas DCT describes how companies can renew and rearrange their resources to remain competitive in dynamic green environments.

The perspectives are both complementary and complicated. RBV may not be sufficient to describe how value can be created through the use of static resources in unstable situations. Still, DCT can address this issue by emphasizing the importance of flexibility and continuous learning. However, DCT operates on the premise of the existence of resources and capabilities, which it takes no pains to define and classify as a significant strength of RBV. Hence, through the combination of the RBV and DCT, the research will have a broader perspective that encompasses the value of green resources, as well as the dynamic activities by which firms adjust and innovate to achieve high green performance. The proposed dual-theoretical approach can be used to develop a nuanced understanding of the interaction between internal capabilities (GDCs) and external institutional support in enhancing green technological innovation and performance.

2.2 Green dynamic capabilities and green performance

GDCs are capabilities at the firm level that enable organisations to sense the challenges and opportunities in their environment and exploit these opportunities by reconfiguring and integrating resources, thereby transforming their asset base to achieve sustainable performance (Shang et al., 2019). GDCs as a part of the broader dynamic-capability framework, with its three components of sensing, seizing, and transforming (Teece, 2018), represents the ability of an enterprise to consciously develop, expand, or modify its resources in the light of the changing ecological and market environments (Abbas, 2024; Helfat et al., 2009). Since these capabilities develop due to the idiosyncratic managerial practices, culture, and learning processes of a firm, it is challenging for competitors to replicate them (Singh et al., 2022). Organisations that possess a great sense-making ability react more promptly to the green efforts of competitors, realise the changing needs of customers, and translate ecological knowledge into both product and process innovations, thus attaining a competitive edge (Li, 2022)

GP is a multifaceted construct comprising various environmental impacts of a firm beyond regulatory compliance (Shehzad et al., 2023a). GP stands for the firm's environmental activity efficiency and effectiveness and offers important information on ecological effects, regulatory compliance, and organizational processes (Neely et al., 1995). Following the extensive literature review, researchers examined GP via GMP, GPRP, and GPDP (Abbas, 2020; Xie et al., 2019). GMP is adopted by modifying current management systems and policies to mitigate negative organizational impacts and establish sustainable systems (Li et al., 2018). GPRP is an effort to reduce resource consumption in manufacturing by transitioning away from fossil fuels towards bioenergy or renewable energy (Ma et al., 2017). In GPDP, products are introduced that are non-toxic, biodegradable or consume minimal non-renewable energy, and waste reduction improves energy efficiency (Abbas, 2020).

GDCs are gradually being regarded as crucial stimulants of GMP, which enables companies to feel environmental pressure, capture green opportunities, and allocate organizational resources to accommodate them (Abbas, 2024; Bresciani et al., 2022). Through strategic alignment, resource reconfiguration, and investment in environmental technologies, firms can enhance regulatory compliance, stakeholder engagement, and overall ecological governance (Khaskhely et al., 2022). However, this capability depends on resource allocation, strategic foresight, and operational agility, bringing much convenience in environmental outcomes and competitiveness (Appiah, 2024; Wan et al., 2025). Firms with strong GDC use reconfiguration of human capital, technology, supply chain relationships, and financial resources to improve environmental performance (Khaskhely et al., 2022). Typically, this involves investing in green technologies, employee training in ecological expertise, and forming strategic partnerships to get sleeves rolled up regarding knowledge and resources about silviculture (Pan et al., 2021). Navigating these challenges and opportunities of the green economy requires adapting GDC.

Concerning GPDP, GDCs enable eco-design, environmental sensitivity, and product development in terms of the reduction of ecological footprints reduction (Ahmad et al., 2024; Singh et al., 2022). Companies that have more developed GDCs are more likely to come up with products that do not use as many resources, that do not produce much emissions and waste, and that can be more recyclable or biodegradable (Dangelico et al., 2017). GDCs also enhance GPDP about environmental impact with a focus on suppliers, green logistics, and other ways of minimizing the ecological effects of a product during its supply (Chin et al., 2015; Lee, 2023). Empirical results are, however, inconsistent. On the one hand, some studies confirm the existence of a strong positive relationship between GDCs and GPDP; on the other hand, some studies report that high costs of development, uncertainty in the market, and technological issues may restrict the successful implementation of GDCs into sustainable product innovations (Zhu et al., 2023). Such deviation cannot be overlooked without doing additional research on the influence of GDC and GPDP.

In the same regard, GDCs play a significant role in enhancing GPRP in terms of cleaner production processes, resource efficiency, and environmental management systems (Shehzad et al., 2023b; Singh et al., 2022). With constant improvements in processes, companies have the opportunity to become less harmful to the environment and enhance the productivity and affordability of operations (Li et al., 2024). However, other studies suggest that the maximum exploration of GDCs to improve processes is hindered by organizational resistance, a lack of technical capacities, and a mismatch between environmental strategies (Wan et al., 2025). These discrepancies highlight the need for research on GDCs to investigate their effects on GPRP in various industrial and institutional settings. Based on these intuitions, the study proposes the following hypotheses.

Hypothesis 1a**.** GDCs positively impact on GMP
Hypothesis 1b. GDCs positively impact on GPDP
Hypothesis 1c**.** GDCs positively impact on GPRP

2.3 Mediating role of green technological innovation

GTI describes the conscious use of environmental science and technology by a firm to lessen the environmental impact of the business activities by enhancing or developing new, environmentally friendly processes or products (Abbas & Sağsan, 2019). GTI is a response to the increasing realization that the current business status quo would result in the depletion of resources, pollution, and climate change, calling for a shift to more sustainable models (Abbas & Khan, 2023; Zhou et al., 2018). It combines environmental science and technological principles that can be applied to reduce the ecological impact of a firm's operations. Companies that successfully perform GTI enjoy the promotion of their brand reputation, better trust from stakeholders, and environmental legitimacy (Gebre Borojo et al., 2023). Moreover, GTI enables cost reduction through the efficient use of resources and reduction of waste, thereby increasing operational benefits (Abbas, 2024). Notably, it empowers companies to act in advance with environmental regulations and avoid legal risks in the long run, thus generating long-term sustainability and competitive strategy (Ismail, 2023).

Most researchers have studied the role of GTI in attaining environmental sustainability (Al-Khatib, 2022; Tariq et al., 2020). GTI is shown to be critical for developing new green products and processes, increasing resource efficiency, and decreasing environmental impacts in these studies. However, the types of GTI considered change from study to study, as some explore product innovation (Shehzad et al., 2023a), some consider process innovation (Al-Khatib, 2022), and some study more generic forms of green innovation (Borah et al., 2025). The consensus is that GTI is an important leverage point for enhanced green performance. For instance, Tariq et al. (2020) indicated that GPRP is higher in the case of mature firms than growth stage ones and that technological capabilities are important for firms to attain sustainable outcomes. Along similar lines, Jing et al. (2023) showed that digital capabilities play an important role in green innovation performance in manufacturing firms. These findings emphasize the role of both existing and new technologies in pushing green performance.

Studies show that the firms with stronger GDCs are more likely to engage in GTI, and further lead to better environmental and economic outcomes (Borah et al., 2025; Du et al., 2024; Li, 2022), also support the mediating role of GTI in the relationship between GDCs and GP. Green product and process innovation has been positively influenced by GDC (Borah et al., 2025). GTI mediates between GDC and different outcomes, including brand sustainability (Ismail, 2023), environmental performance, and green competitive advantage (Jing et al., 2023). The study also demonstrated that GDC has found green transformational leadership to promote GTI (Ahmad et al., 2024). GDC also mediates green innovation, which is partially associated with corporate social responsibility practices (Singh et al., 2022). For agricultural technology startups, green process innovation fully mediates the relationship between green entrepreneurial orientation, proactive sustainability strategy, and environmental performance (Frare & Beuren, 2022). This literature research shows the relevance of GDC and GTI to the green performance of various industries and the need for further development. Therefore, this study proposes the following hypotheses:

Hypothesis 2a**.** GTI mediates the relationship between GDCs and GMP.

Hypothesis 2b**.** GTI mediates the relationship between GDCs and GPDP.

Hypothesis 2c**.** GTI mediates the relationship between GDCs and GPRP.

2.4 Moderating the role of institutional support

The broad term for the technical and financial assistance the government and its entities give in providing vital resources for innovation and development to companies is institutional support (Shu et al., 2015). Various government agencies and other administrative regulators provide funding, licenses, operational autonomy, information, and technology, which provides (Li & Atuahene-Gima, 2001). Governments provide institutional support through institutional design, policy formulation, and the reduction of environmental uncertainty (Zhang et al., 2017). Sustainability in business performance is brought about by the institutions that support GI activities in their organizations (Abbas & Sağsan, 2019).

The effectiveness of GDCs in promoting GTI is dependent on a supportive institutional environment, and a weak or unsupportive environment will prevent this relationship (Ishaq et al., 2024). Many studies have looked at what institutional supports moderate the effects of. Positive moderation of the GDCs – GTI relationship has been shown by government policies such as financial incentives, tax breaks, and R&D subsidies (Abid et al., 2024; Du et al., 2024). These policies reduce the financial barriers to green innovation so that firms can invest in GDCs and undertake GTI more easily (Du et al., 2024). At the same time, this role of environmental regulation is moderating as it will create a more favorable environment for the GTI by increasing the costs of ecological damage and incentives firms to supply cleaner technologies (Du et al., 2024; Nie et al., 2024). Nie et al. (2024) focused on the moderating effect of environmental regulation on the relationship between green research intensity and diversified firm performance in China. Also, relationship can be moderated by social norms and societal expectations associated with environmental sustainability (Abid et al., 2024), (Shahzad et al., 2022). The stronger the social norms, the greater the pressure on firms to adopt green practices, and therefore, the more powerful the GDCs are in driving the GTI (Abid et al., 2024). On the other hand, weak or conflicting social norms may leave uncertainty about green innovations and make it difficult for such green innovations to be adopted (Shahzad et al., 2022). These arguments led us to propose the following hypothesis

Hypothesis 3: Institutional support positively moderates the relationship between GDCs and GTI.

2.5 Moderated mediating effects

The effect of GDCs on green performance through GTI is considerably dependent on institutional supporting mechanisms. Institutional support is the regulatory system, which includes environmental regulations and emission standards, government policy incentives like subsidies and tax exemptions to adopt green technologies, norms within society about consumer preferences towards sustainability, and stakeholder pressure, such as the need for sound environmental, social, and governance reporting (Abid et al., 2024; Zhang et al., 2024; Zhao & Tang, 2024). With strong institutional support, firms perceive less risk in green investments, thus encouraging the use and implementation of novel environmental technologies. Vigorous regulations and policies alleviate financial constraints and increase companies' confidence in investing in innovations that promote environmental sustainability (Abbas, 2024). At the same time, the societal norms and the expectations of the stakeholders, which may be called the drivers of the market demand, support the idea of eco-friendly products, which makes the firms even more committed to green technology projects (Sun et al., 2022). In contrast, when institutional support is weak, uncertainties and the absence of clear incentives are the primary impediments to investment in GTI. The reduced regulatory directives and policy incentives deter the firms from being proactive in investing in environmentally sustainable projects, undermining the mediating effect of GTI in translating GDCs into better green performance results (Gebre Borojo et al., 2023). Therefore, institutional support becomes a key factor in the efficacy of GDCs in enhancing green performance through GTI. Based on this rationale, the following hypotheses are put forward:

Hypothesis 4a**:** The effect of GDCs on GMP is more strongly mediated through GTI under higher institutional support than lower institutional support.

Hypothesis 4b**:** The effect of GDCs on GPDP is more strongly mediated through GTI under higher institutional support than lower institutional support.

Hypothesis 4c**:** The effect of GDCs on GPRP is more strongly mediated through GTI under higher institutional support than lower institutional support.

3 Methodology

3.1 Research Design and Rationale

This study considers medium-sized Spanish manufacturing enterprises to test the proposed hypotheses. While previous research combines small and medium-sized enterprises (SMEs) into a single category (Cegarra-Navarro et al., 2024; Piwowar-Sulej et al., 2024), this research differentiates medium-sized enterprises from smaller firms. However, the differentiation is based on the assumption that they are more resourceful and proactive in implementing environmental management systems because they possess better access to the economy of scales as a resource of funding and investment capabilities (Díaz-Chao et al., 2016). On the other hand, smaller enterprises are often limited in terms of financial resources, skills, and abilities (Wong et al., 2020). Since MEs and small enterprises offer different innovation dynamics and environmental management practices, analyzing them separately is more useful for correctly reading their innovation.

3.2 Sample Selection

As one of the top 5 European countries influencing the manufacturing economy, Spain justifies the selection of Spanish manufacturing companies. Moreover, previous studies have shown that Spanish manufacturing firms need to shift towards more sustainable industrial models (Cegarra-Navarro et al., 2024). Companies with at least five years of operational experience are in the sample. This criterion's rationale is that organizations with more experience may attain structural inertia through established routines, thus hindering their adoption of green innovations (Sirén et al., 2017). In addition, experienced organizations are more likely to have the background and resources to develop and implement environmental innovation (Tang et al., 2018).

This study population was drawn from managers of manufacturing MEs listed in the SABI database "https://sabi.bvdinfo.com" with more than 5 years of experience in this manufacturing sector, totaling 3,465 companies. A random sample of 227 companies of this population was taken. From September to December 2024, 679 questionnaires were distributed online, and procedures were self-administered with official permission from company management. Out of the distributed questionnaires, 371 were returned, and the response rate was 54.6%. A total of 343 questionnaires were considered usable after eliminating 28 incomplete or insufficient responses for a final response rate of 50.5%. The response rate far exceeds the 15% threshold Menon et al. (1996) recommended for surveys aimed at senior management (with a margin of error of 5.76% at a 95.5% confidence level).

3.3 Measurement scale

The development of the questionnaire for this research was systematic, beginning with a review of relevant literature to construct scales for all variables. Then, feedback from the experts was used to refine the measurement items for clarity and comprehensibility. Validated scales were used to measure constructs. Organizational green strategic capability (OGSC), R&D green innovation capability (RGIC), and organizational green management capability (OGMC) were used to measure GDC. Four items were used to evaluate OGSC, three to measure RGIC, and four to measure OGMC. The GDCs dimensions were adapted from Singh et al. (2022). The five items from Huang and Li (2017) and Sahoo et al. (2022) were used to examine GTI, which involves process optimization, product redesign, recycling, eco-labeling, and technological advancement. Items from Shehzad et al. (2023a) and Abbas (2020) were used to assess GMP (six items), GPRP (five items), and GPDP (five items). Institutional support consisted of four items based on Ishaq et al. (2024), which included policy, technological, financial, and facilitation of licensing. These items capture the multidimensionality of institutional support by covering regulatory support, provision of resources as well as infrastructural enablers, which sum up to generating a favorable environment of green innovation. Previous research has shown that the performance of a firm's GI practices depends on its contextual factors, including firm type, ownership form, size, and age (Abbas, 2020). Thus, firm type, ownership structure, size, and age are included as control variables (see Table 1). Firm type is defined as manufacturing firms, ownership form is defined as state or non-state-owned firms, firm size is measured as an employee number, and firm age is in years when data was collected.

3.4 Non-response bias, endogeneity, and common method bias

To achieve methodological rigor, this study employed several non-response bias tests, endogeneity tests, and common method bias (CMB) tests. First, we evaluated the non-response bias using a paired t-test, comparing the first and last 50 respondents (Anderson & Gerbing, 1988). The analysis revealed no significant differences, indicating that the issue of non-response bias is not a concern. Second, since models based on regression can exhibit endogeneity (Hult et al., 2018). To address the concern of endogeneity, we employed the Gaussian copula methodology with SmartPLS 4. The findings confirmed that the model was not endogenous. Finally, as cross-sectional survey designs are vulnerable to CMB (Podsakoff et al., 2003). To address this, both procedural and statistical measures were employed. Respondents were assured confidentiality procedurally and were given a clear, error-free survey (Kraus et al., 2020). Consistent with the approach of earlier PLS-SEM studies (Baquero, 2024; Shehzad et al., 2023a), statistical tests were performed using Harman's single-factor and variance inflation factor (VIF) analyses. Harman's single-factor test resulted in a single factor that accounted for only 29.179% of the variance, which falls below the 50% threshold (Podsakoff et al., 2003). Additionally, a full collinearity test using SmartPLS was used to confirm that all VIF values were below 3.3 and that CMB was not a concern (Kock, 2015).

Table 1. Demographic profile of respondents

Characteristics		Frequency	Percent
Firm_type			
	Chemical and Petroleum	50	14.577%
	Fertilizer	40	11.662%
	Cement	49	14.286%
	Textile	56	16.327%
	Auto part manufacturing	47	13.703%
	Sports goods	49	14.286%
	Leather	41	11.953%
	Others	11	3.207%
Ownership			
	State-owned enterprise	113	32.945%
	Collectively-owned	110	32.070%
	Private-owned enterprise	108	31.487%
	Other	12	3.499%
Firm_size			
	<100	78	22.741%
	100-200	61	17.784%
	201-500	69	20.117%
	501-1000	55	16.035%
	>1000	80	23.324%
Firm_age			
	< 5 Years	67	19.534%
	6-10 Years	64	18.659%
	11-20Years	81	23.615%
	21-40years	66	19.242%
	>40Years	65	18.950%

4 Data Analysis Procedure

In SmartPLS 4, the PLS-SEM was used in a two-stage procedure. PLS-SEM was selected for several reasons: it is well suited to dependent variables and precision in variance assessment. According to Roldán and Sánchez-Franco (2012), it is a prediction-oriented method that simultaneously handles the measurement and structural models. Furthermore, it works better than regression in estimating mediation effects, measurement error adjustment, and computing accurate mediating effect estimates (Preacher & Hayes, 2008). Secondly, using SmartPLS is easy, and it accommodates simple and complex theoretical models without data normalization (Hair et al., 2016). Moreover, its robustness with small sample sizes makes it popular in strategic management research (Shehzad et al., 2024b; Sherani et al., 2024). Additionally, we ran moderated mediation effects with the PROCESS macro with a regression-based bootstrapping approach (Hayes, 2017). This method does not require strict normality assumption to yield robust confidence intervals. This study integrates advanced techniques and best practices to guarantee its reliability and significantly contribute to the strategic management domain.

4.1 Assessment of the Measurement Model

The two-stage approach proposed by Cataldo et al. (2017) was used to create the second order of the GDC construct in this research. During this initial stage, the eight dimensions (Model A) were estimated regarding the latent variables comprising them (Cataldo et al., 2017). Individual item reliability, construct reliability, convergent validity, and discriminant validity for each of the eight first-order constructs were assessed following the guidelines by Hair et al. (2017).

The outer loadings of each item were examined to assess individual indicator reliability with a threshold of ≥0.6 (Hair et al., 2016). If the removal of items would increase the Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha (α), items with outer loadings below 0.6 were considered candidates for removal (Hair et al., 2019). All retained items on the eight dimensions, as shown in Table 2, have outer loadings from 0.630 to 0.895, which are all above the 0.6 threshold. Additionally, T values obtained via bootstrapping confirmed the significance of these outer loadings by following Kline's (2013) criterion for statistical significance, which was $t \geq 1.96$ ($p = 0.05$, two-tailed test). Acceptable outer loadings over all eight factors verify satisfactory individual item reliability.

The construct reliability was established by assessing the Cronbach's alpha (Cα), Composite Reliability (CR), and Dijkstra-Henseler's rho (ρ_A), with values above 0.700 acceptable (Raykov & Marcoulides, 2011). Table 2 shows that Cα values are between 0.726 and 0.860, ρ_A values between 0.737 and 0.867, and CR values between 0.833 and 0.901 across the eight dimensions, all well above the acceptable thresholds. These results suggest that all eight first-order constructs have adequate levels of reliability. In addition, the AVE was used to examine Convergent validity, and the values were ≥0.500, which was acceptable (Hair et al., 2016). Table 2 shows that the AVE values meet the convergent validity criterion and exceed the 0.500 threshold.

In the second stage, the GDC construct was reestablished as a second-order construct (Model B) using the latent variable scores obtained from the first stage using the procedure of Cataldo et al. (2017). Table 2 demonstrates that Model B meets the measurement model criteria: Factor loadings for all the constructs are found to be greater than 0.60 (e.g., OGMC = 0.896, OGSC = 0.799, RGIC = 0.833), and the AVE for GDC is found to be 0.712 that is above the threshold of 0.50 (Hair et al., 2014). In addition, the Ca and CR values of the second-order latent variable construct are 0.796 and 0.881, respectively, much greater than the benchmark of 0.70, proving consistency and reliability.

Table 2. Measurement model results

First-order Model A	items	Loadings	VIF	α	ρA	CR	AVE
Step I: Results of the assessment of the measurement model for first-order constructs (first-order measurement model)							
GMP	GMP1	0.685	1.362	0.752	0.755	0.834	0.502
	GMP2	0.698	1.553				
	GMP3	0.662	1.459				
	GMP5	0.756	2.131				
	GMP6	0.739	2.064				
GPDP	GPDP1	0.811	1.533	0.793	0.806	0.864	0.615
	GPDP2	0.817	1.974				
	GPDP3	0.778	1.887				
	GPDP4	0.728	1.393				
GPRP	GPRP1	0.853	2.251	0.860	0.867	0.901	0.647
	GPRP2	0.810	1.992				
	GPRP3	0.867	2.983				
	GPRP4	0.824	2.571				
	GPRP5	0.650	1.319				
GTI	GTI1	0.895	2.487	0.810	0.823	0.876	0.641
	GTI2	0.788	1.859				
	GTI3	0.818	1.998				
	GTI5	0.688	1.309				
IS	IS1	0.783	1.534	0.760	0.758	0.833	0.556
	IS2	0.630	1.591				
	IS3	0.773	1.621				
	IS4	0.786	1.327				
OGMC	OGMC1	0.786	1.779	0.840	0.843	0.893	0.677
	OGMC2	0.884	2.537				
	OGMC3	0.804	1.943				
	OGMC4	0.812	1.762				
OGSC	OGSC1	0.793	1.864	0.835	0.836	0.890	0.669
	OGSC2	0.851	2.303				
	OGSC3	0.830	2.028				
	OGSC4	0.796	1.669				
RGIC	RGIC1	0.776	1.401	0.726	0.737	0.845	0.645
	RGIC2	0.802	1.496				
	RGIC3	0.830	1.408				
Firm_age	____	1.000	1.000	1.000	1.000	1.000	1.000
Firm_size	____	1.000	1.000	1.000	1.000	1.000	1.000
Ownership	____	1.000	1.000	1.000	1.000	1.000	1.000
Firm_type	____	1.000	1.000	1.000	1.000	1.000	1.000
Second-order Model B							
Step II: Results of the measurement model assessment after generating second-order constructs (final measurement model)							
GDC	LV scores - OGMC	0.896	2.160	0.796	0.802	0.881	0.712

LV scores - OGSC	0.799	1.506
LV scores – RGIC	0.833	1.838

Table 3. Heterotrait-monotrait ratio for First-order Model

	Firm type	Ownership	Firm size	Firm age	GMP	GPDP	GPRP	GTI	IS	OGMC	OGSC	RGIC
Firm type												
Ownership	0.045											
Firm size	0.002	0.012										
Firm age	0.066	0.011	0.086									
GMP	0.070	0.067	0.046	0.065								
GPDP	0.129	0.061	0.053	0.053	0.784							
GPRP	0.104	0.024	0.031	0.021	0.823	0.769						
GTI	0.032	0.028	0.026	0.063	0.760	0.678	0.581					
IS	0.099	0.076	0.063	0.040	0.066	0.153	0.094	0.127				
OGMC	0.170	0.071	0.097	0.036	0.571	0.599	0.590	0.677	0.082			
OGSC	0.037	0.097	0.033	0.031	0.585	0.538	0.527	0.558	0.139	0.678		
RGIC	0.113	0.060	0.062	0.098	0.527	0.502	0.602	0.621	0.118	0.844	0.573	

Table 4. Heterotrait-monotrait ratio for Second-order Model

	Firm age	Ownership	Firm size	Firm type	GDC	GMP	GPDP	GPRP	GTI	IS
Firm age										
Ownership	0.011									
Firm size	0.086	0.012								
Firm type	0.066	0.045	0.002							
GDC	0.054	0.041	0.072	0.117						
GMP	0.065	0.067	0.046	0.070	0.671					
GPDP	0.053	0.061	0.053	0.129	0.653	0.784				
GPRP	0.021	0.024	0.031	0.104	0.685	0.823	0.769			
GTI	0.063	0.028	0.026	0.032	0.738	0.760	0.678	0.581		
IS	0.040	0.076	0.063	0.099	0.133	0.066	0.153	0.094	0.127	

A heterotrait-monotrait (HTMT) ratio of correlations was used to evaluate discriminant validity. Tables 3 and 4 illustrate the HTMT ratios for the first and second-order models. All HTMT ratios meet the HTMT criterion, as they are less than 0.85 (Henseler et al., 2015). For example, the highest HTMT value (0.844) in Table 3 and the highest HTMT ratio (0.738) in Table 4 are between RGIC and OGMC and GTI and GDC, respectively. These values confirm the discriminant validity of both first and second-order constructs.

4.2 Structural model assessment

Before testing the hypotheses, the study examines the explanatory power of the study model using effect size (f^2), coefficient of determination (R^2), and predictive relevance (Q^2). GDC produced small to large effects on GMP ($f^2 = 0.071$), GPDP ($f^2 = 0.105$), GPRP ($f^2 = 0.183$), and a large effect on GTI ($f^2 = 0.571$), all in line with Cohen (1988) small ($f^2 \geq 0.02$), medium ($f^2 \geq 0.15$) and large ($f^2 \geq 0.35$) effect sizes. Moreover, GTI was affected by GMP ($f^2 = 0.206$) with a medium effect, by GPDP ($f^2 = 0.131$) with a small effect size, and by GPRP ($f^2 = 0.052$) with a negligible effect. In contrast, the interaction term IS × GDC was insignificant for GTI ($f^2 = 0.017$). GMP, GPDP, GPRP, and GTI had R^2 values of 0.405, 0.386, 0.360, and 0.373, respectively, all above (Hair et al., 2010) the threshold for the acceptable explanatory power of 0.25. The predictive relevance, quantified by the Q^2 metric, was positive for all endogenous constructs (GMP = 0.191; GPDP = 0.222; GPRP = 0.220; GTI = 0.230) and above the threshold of $Q^2 > 0$, as recommended by Stone (1974). Collectively, these results confirm that the structural model is robust and predictive, thereby strengthening the study's contributions to the field of strategic management.

4.3 Hypothesis testing

Path coefficients are examined for signs and size to test the significance and relevance of hypothesized relationships. This study uses the bootstrapping approach (5000 bootstrap resamples) to produce t-values, p-values, and standard errors along with 95% bias-corrected confidence intervals for path coefficients (Hair et al., 2019).

The direct effects analysis involved the control variables and the primary relationship between the GDC and the performance measures. The effects of the control variables—firm age, firm size, ownership, and firm type on GMP, GPDP, or GPRP were not significant. On the contrary, GDC significantly positively affected GMP ($\beta = 0.261$, $t = 4.790$, $p < 0.001$), GPDP ($\beta = 0.322$, $t = 5.023$, $p < 0.001$), and GPRP ($\beta = 0.433$, $t = 6.770$, $p < 0.001$), thus supporting Hypotheses 1a, 1b, and 1c respectively. The results of these findings exceed the suggested significance threshold ($t > 1.96$, $p < 0.05$), indicating that GDC has a significant direct effect on the dimensions of organizational performance.

The mediation analysis followed the guidelines by Preacher and Hayes (2008). The results from the mediation analysis showed that GDC has a significant mediation effect on the relationship between GTI and performance outcomes. In particular, the indirect effects of GDC on GMP ($\beta = 0.265$, $t = 6.488$, $p < 0.001$), GPDP ($\beta = 0.215$, $t = 4.635$, $p < 0.001$), and GPRP ($\beta = 0.138$, $t = 3.192$, $p = 0.001$) were significant, thus supporting Hypotheses 2a, 2b and 2c. The results suggest that GTI partially explains the link between GDC and GMP, GPDP, and GPRP, as the direct effects of GDC on these performance measures persist, along with significant indirect effects (see Table 5).

In addition, the moderation analysis found that the IS*GDC interaction moderates GTI ($\beta = 0.118$, $t = 2.114$, $p = 0.035$), supporting Hypothesis H3. This implies that IS mitigates the relationship between GDC and GTI and strengthens GDC's effect on technological innovation in the organization. Figure 2 plots the moderating effects, using the suggestions of Stone and Hollenbeck (1989), and the relationship between GDC and GTI when IS is high. Hence, H3 is further supported (see Table 6).

4.3.1 Moderated mediation results

Based on Process Macro Model-7, this paper examines the role of institutional support in moderating the mediating effect of GTI on the association between GDCs and green performance aspects (Hayes, 2017).

In Hypothesis 4a, the index of moderated mediation was 0.053 (SE = 0.023), which reflected that the indirect effect between GDCs and GMP through GTI is significantly moderated by institutional support. In particular, the indirect impact under high institutional support was 0.217 (SE = 0.045), indicating that companies operating in regulatory and policy environments that support them are more likely to transform their GDCs into improved manufacturing performance through GTI. Conversely, with low institutional support, the indirect effect decreased to 0.324 (SE = 0.057), indicating that in weak institutional contexts, although GDCs continue to support GMP by mediating GTI, the magnitude of this connection is weakened, most likely due to increased uncertainty and a lack of available resources for innovation.

Similarly, the moderated mediation index was 0.043 (SE = 0.019), indicating that institutional support also moderates the mediator effects of GTI in the associations between GDCs and GPDP. Therefore, Hypothesis 4b was supported. In the case of high institutional support, the indirect effect was 0.175 (SE = 0.045), indicating that positive institutional settings enable firms to transform their GDCs into innovative green products more efficiently. Moreover, the indirect effect also significantly rose to 0.261 (SE = 0.059) under low institutional support, indicating that without adequate institutional support, GDCs have less potential to develop product innovation through GTI, and this possibility is less consistent.

In the case of Hypothesis 4c, a moderated mediation effect was also confirmed with the index of 0.027 (SE = 0.014). Indirect impact of GDCs on GPPR through GTI was 0.111 (SE = 0.037) in high institutional supported condition, whereas 0.166 (SE = 0.052) in low institutional supported condition. This indicates that highly supportive institutional environments enable firms to leverage their capabilities in a more effective direction in terms of process development through GTI, whereas a less supportive institutional atmosphere hinders this possibility. Collectively, these findings suggest the existence of institutional support that acts as a vital boundary condition, enhancing or limiting the performance of GDCs in promoting green performance via GTI.

4.4 PLS-predict

We evaluated the predictive performance of the structural model using the PLS prediction algorithm, which measures the capability of a model to predict endogenous constructs (Shmueli et al., 2019). As seen in Table 7, all Q^2predict values were positive, from 0.054 to 0.277, which suggests that all indicators have a good degree of predictive relevance (Stone, 1974). Beyond this, the Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values of the PLS-SEM model were lower than those of the LM for all indicators, indicating better predictive accuracy. GMP1 had an RMSE of 0.778 and MAE of 0.584 in PLS-SEM and 0.791 and 0.589 in LM. Similar results were repeated with other indicators, with the PLS-SEM approach again demonstrating better predictive power. These results confirm the robustness of the model and the effectiveness of its prediction of organizational performance.

Table 5. Hypotheses results

Hypotheses	Statistical paths	β	STDEV	T statistics	P values	2.5%	97.5%	Conclusion
+Ve	Control variables							
+Ve	Firm_age -> GMP	-0.060	0.043	1.380	0.168	-0.148	0.024	Not supported
+Ve	Firm_age -> GPDP	-0.029	0.046	0.622	0.534	-0.117	0.064	Not supported
+Ve	Firm_age -> GPRP	-0.025	0.046	0.546	0.585	-0.115	0.063	Not supported
+Ve	Firm_size -> GMP	0.047	0.043	1.100	0.271	-0.036	0.132	Not supported
+Ve	Firm_size -> GPDP	0.062	0.046	1.339	0.181	-0.025	0.154	Not supported
+Ve	Firm_size -> GPRP	0.027	0.046	0.590	0.555	-0.063	0.120	Not supported
+Ve	Ownership -> GMP	-0.025	0.044	0.569	0.569	-0.112	0.063	Not supported
+Ve	Ownership -> GPDP	-0.049	0.043	1.123	0.261	-0.134	0.038	Not supported
+Ve	Ownership -> GPRP	-0.003	0.043	0.070	0.944	-0.086	0.084	Not supported
+Ve	Firm_type -> GMP	0.001	0.043	0.032	0.974	-0.084	0.086	Not supported
+Ve	Firm_type -> GPDP	-0.075	0.043	1.743	0.081	-0.160	0.010	Not supported
+Ve	Firm_type -> GPRP	-0.023	0.045	0.517	0.605	-0.111	0.066	Not supported
Direct effects								
Hypothesis 1a	GDC -> GMP	0.261	0.055	4.790	0.000	0.152	0.370	supported
Hypothesis 1b	GDC -> GPDP	0.322	0.064	5.023	0.000	0.196	0.446	supported
Hypothesis 1c	GDC -> GPRP	0.433	0.064	6.770	0.000	0.305	0.558	supported
Mediating effects								
Hypothesis 2a	GDC -> GTI -> GMP	0.265	0.041	6.488	0.000	0.188	0.349	supported
Hypothesis 2b	GDC -> GTI -> GPDP	0.215	0.046	4.635	0.000	0.127	0.309	supported
Hypothesis 2c	GDC -> GTI -> GPRP	0.138	0.043	3.192	0.001	0.057	0.227	supported
Moderating effects								
Hypothesis 3	IS x GDC -> GTI	0.118	0.056	2.114	0.035	-0.016	0.206	supported
Effect size		GMP	GPDP	GPRP	GTI			
	GDC	0.071	0.105	0.183	0.571			
	GTI	0.206	0.131	0.052				
	IS x GDC				0.017			
R-square		GMP	GPDP	GPRP	GTI			
		0.405	0.386	0.360	0.373			
Predictive relevance		GMP	GPDP	GPRP	GTI			
SSO		1715.000	1372.000	1715.000	1372.000			
SSE		1386.854	1067.486	1337.235	1055.897			
Q^2 (=1-SSE/SSO)		0.191	0.222	0.220	0.230			

Table 6. Moderated mediation results

Hypotheses	Path	Index of moderated mediation	Levels of moderator	Indirect effect	SE	BCI LL; BCI UL
Hypothesis 4a	GDC->GTI->GMP	Index= 0.053, SE=0.023	High institutional support	0.217	0.045	0.137;0.317
		BCILL: 0.073, BCIUL: 0.097	Low institutional support	0.324	0.057	0..219;0.440
Hypothesis 4b	GDC->GTI->GPDP	Index=0.043, SE=0.019	High institutional support	0.175	0.045	0.098;0.275
		BCILL: 0.006, BCIUL: 0.083	Low institutional support	0.261	0.059	0.156;0.384
Hypothesis 4c	GDC->GTI->GPRP	Index=0.027, SE=0.014	High institutional support	0.111	0.037	0.044;0.189
		BCILL: 0.003, BCIUL: 0.058	Low institutional support	0.166	0.052	0.067;0.273

Table 7. PLS predict

	Q^2predict	PLS-SEM_RMSE	PLS-SEM_MAE	LM_RMSE	LM_MAE
GMP1	0.104	0.778	0.584	0.791	0.589
GMP2	0.171	0.666	0.528	0.680	0.536
GMP3	0.113	0.778	0.588	0.788	0.604
GMP5	0.117	0.910	0.702	0.920	0.715
GMP6	0.114	0.889	0.683	0.902	0.692
GPDP1	0.277	0.663	0.507	0.665	0.510
GPDP2	0.144	0.966	0.718	0.981	0.734
GPDP3	0.054	1.122	0.897	1.129	0.913
GPDP4	0.172	0.838	0.628	0.852	0.642
GPRP1	0.268	0.619	0.485	0.629	0.492
GPRP2	0.166	0.726	0.556	0.737	0.561
GPRP3	0.213	0.682	0.510	0.697	0.521
GPRP4	0.141	0.745	0.556	0.751	0.569
GPRP5	0.150	0.888	0.712	0.902	0.721

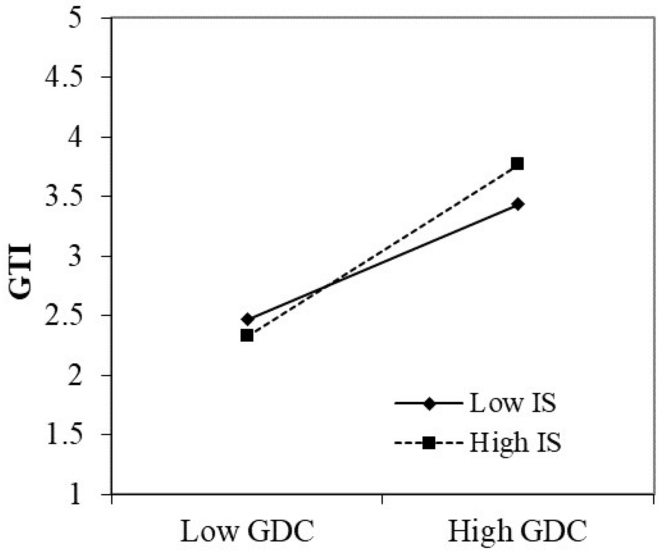

Figure 2. Moderating effects of Institutional support in the relationship between GDCs and GTI

5 Discussion

The present study focuses on examining the connections between GDCs, GTI, institutional support, and aspects of green performance, namely GMP, GPDP, and GPRP, in Spanish manufacturing firms. Based on DCT and the RBV, the results make significant contributions to our understanding of how internal capabilities interact with the external institutional environment to enhance the environmental performance of firms.

First, aligned with the DCT, the findings demonstrate that GDCs (i.e., organizational green strategic capability, R&D-based green innovation capability, and organizational green management) have a positive influence on GMP, GPDP, and GPRP. Interestingly, the findings reveal that the magnitude of the direct effects of GDCs varies across several dimensions of GP, and GPRP exhibits a stronger direct relationship than GMP and GPDP. Such variation may be an indication of differences in the ease of applying dynamic capabilities in actual processes compared to manufacturing structures. In practice, this implies that companies can achieve faster gains in their performance by focusing on small-scale innovations in green processes rather than opting for radical transformations of their manufacturing operations in contexts where resources are limited. The results support existing research (Wan et al., 2025; Zhou et al., 2018), highlighting the role of dynamic capabilities in promoting the integration of strategic resources, the process of continuous improvement, and the search for innovative environmental solutions.

Secondly, the study further finds that GTI is a significant mediating mechanism in the relationship between GDCs and the different dimensions of green performance (GMP, GPDP, and GPRP). The results affirm that GTI is a significant channel through which dynamic capabilities can lead to tangible environmental benefits in all GP dimensions. This aligns with the RBV approach, which holds that due to the value, rarity, and inimitable nature of innovation capabilities, they are key to achieving a sustained competitive advantage (Barney, 1991). In line with existing literature, evidence suggests that companies with good GDCs are better positioned to develop green innovations, whether products, processes, or management systems that comply with regulations and respond to market demand for sustainability (Abbas, 2024; Wan et al., 2025). Managing this aspect requires an emphasis on integrating innovative-centered attitudes and behaviors into organization-wide activities to maximize the potential of the GDCs, in line with managerial considerations.

Third, the moderation analysis offers vital information regarding the interaction between internal capabilities and external institutional environment. In particular, institutional support plays a crucial moderating role in the interrelationship between GDCs and GTI, implying that the environmental innovation of firms is contingent upon exogenous regulatory, policy, and societal constraints. This aligns with institutional theory, which posits that external pressures and supporting systems influence the behavior of firms (Abid et al., 2024). Improved institutional support influences the willingness and ability of firms to invest in green technologies, thereby facilitating the translation of GDCs into GTI (Ishaq et al., 2024).

Finally, the moderated mediation outcomes reveal that the indirect impacts of GDCs on the various GP dimensions via GTI get more robust when institutional support is high. As a nuanced finding, this reveals a key boundary condition whereby institutional contexts are paramount in ensuring the maximization of dynamic capabilities' effectiveness. Existing literature on the institutional theory and dynamic capabilities also acknowledges that the external sources and confirmations enhance the effects of internal strategic efforts Dong et al. (2024); Zhu et al. (2013) and Ishaq et al. (2024). Logically, it means that the development and implementation of policy advocacy and stakeholder engagement strategies are crucial, and companies operating in favorable environments are better positioned to leverage their internal strengths further and deliver improved sustainability performance.

5.1 Theoretical implications

Within the context of green performance in manufacturing firms, this study contributes to the existing body of knowledge by extending and integrating the theory of dynamic capabilities and the RBV. The DCT and RBV combination offers a complete framework for explaining organizational sustainability and green performance. DCT stresses the ability of a firm to adapt a competency in an ever-changing environment (Teece, 2018; Teece et al., 1997); the RBV emphasizes that leveraging valuable, rare, and inimitable resources will yield sustained competitive advantage (Barney, 1991). These theories are integrated to show how GDCs are useful as adaptive resources to conform to environmental changes and meet the demands for sustainable competitive advantage through innovation and performance improvement.

By focusing on GTI as a key mediator between GDCs and green performance, this study deepens our knowledge regarding how GDCs lead to tangible results. Prior research has acknowledged the role of innovation in improving environmental performance (Idrees et al., 2023; Wang & Juo, 2021), but this study specifically incorporates GDC with GTI to stimulate sustainable performance. Innovation operationalizes the development of dynamic capabilities as a strategic resource and connects its development with performance improvement. From this perspective, it is consistent with the firm's RBV regarding how innovations leverage other capabilities to provide a competitive advantage.

This study advances DCT and RBV literature by introducing institutional support as a moderator that alters the interrelationships among GDCs, GTI, and green performance, where external factors such as regulations, norms, and incentives lead to capabilities pursuing different sources of innovation and, subsequently, divergent performance outcomes. We integrate institutional support to show how the external environment can enhance or constrain internal capabilities and innovation processes. This moderated mediation model paints a more nuanced and realistic picture of how firms maneuver around their external contexts. Building on prior studies of Appiah (2024); Singh et al. (2022), and Abbas (2024), this study enriches the theoretical understanding of the interplay between internal resources and external pressures, extending the literature in strategic management.

Furthermore, most studies on green performance from dynamic capabilities and RBV perspectives are conducted in developing economies or particular industries (Abbas, 2020; Shehzad et al., 2023a; Wang & Juo, 2021). Hence, this study broadens these theories to Spanish manufacturing firms. Testing the theories' generalizability in different regulatory, cultural, and economic environments is important as this geographical and industrial expansion occurs. We validate that the integrated theoretical framework continues to be robust across various contexts, extending the dynamic capabilities and RBV to understanding green performance irrespective of the context.

5.2 Practical implications

The results of this study provide insights for improving the environmental performance of manufacturing firms. Regarding the development of GDCs, top priorities for managers and organizational leaders include the development of organizational green strategic capability, organizational green R&D innovation capability, and organizational green management. Investments in these areas will allow firms to have better environmental challenges and green opportunities for green management and product and process performance. Moreover, since dynamic capabilities are associated with GTI, fostering a culture that stimulates GTI is necessary because it connects dynamic capabilities with performance outcomes. It requires allocating resources to research and development with the theme of environmentally friendly technologies and maintaining continuous innovation of the organization. In addition, institutional support greatly improves internal capabilities. Managers are called to use external resources such as government incentives, subsidies, and supportive regulations to reinforce GI efforts. Green technology can be implemented and scaled more easily if organizational strategies align with institutional support. Policies should be designed to support GI by providing financial incentives, transparent environmental regulations, and collaboration between industry, research institutions, and government agencies.

Besides, the effects of GDCs of Spanish manufacturing companies can be enhanced through the coordination of three complementary efforts:

1. The Spanish industrial-decarbonisation PERTE framework provides a mix of grants and subsidised loans to electrify processes, decarbonise boilers with hydrogen, and retrofit carbon-capture systems, with a predictable cycle of funding rounds over which

manufacturers can secure long-term funding so long as they commit to transparent emission-reduction pathways. Circular-economy upgrades, energy-efficiency retrofit, and on-site renewables can be funded with long tenors at below-market rates by complementary soft-loan windows, including the state-owned ICO Green credit line. Managers should design GTI projects in a way that conforms to the eligibility criteria of at least one national grant and one concessional-debt instrument, thereby reducing the weighted cost of capital and increasing payback times.

2. Consortium initiatives with Spanish technology centres (e.g., advanced-materials or plastics institutes) raise the score of evaluations in PERTEs and Horizon Europe calls, and cluster-wide "green clubs" share the fixed costs of R&D, compliance, and certification. The case of successful industrial partnerships under the existing rounds of the PERTE highlights how bidding collaboration can unlock substantial amounts of public co-funding in support of sector-level decarbonization sites. Companies without in-house R&D strength, therefore, ought to target becoming pilot locations or suppliers of parts in such groupings instead of seeking stand-alone products.
3. Investors and lenders can maximize due diligence by auditing the scope and development of a company, sensing, seizing, transforming routines, and basing coupon stepdowns or interest-rate decreases on outer GTI standards accepted by national organizations. The tendency manifests the general trend in the European sustainable-finance markets, where public capital of the Recovery and Resilience Facility funds is combined with private funding to finance low-carbon projects on a large scale.

5.3 Research limitations

Although the results have various implications, it is also essential to address some limitations to carry out further studies that improve the applicability of the findings. First, the research is limited to Spanish manufacturing companies, which may restrict its generalizability to other industries or regions. Further studies should extend the findings to non-manufacturing industries, including services, agriculture, and tourism, where GDCs can take different forms due to sector-specific innovation patterns and regulatory constraints. Multi-industry comparative studies can serve to make the operationalization of GDCs more precise and provide broader practical applicability. Second, the study is cross-sectional and this limits causal interpretation. Future studies are advised to adopt a longitudinal design due to the nature of GDCs being evolutionary in nature and further due to its compound effect to green performance. It would enable researchers and practitioners to monitor the progress of capability development over time and gain a better understanding of the dynamics of time, learning processes, and feedback loops that underpin green transformation. Third, there is reverse causality between the green GTI and GP relationships. Better-performing environmental firms may be more likely to invest in GTI, creating a circular association. Future studies may attempt to overcome this bias with more sophisticated econometric methods, such as the use of instrumental variables, two-stage least squares, and panel data methods, which can more effectively isolate causation. Finally, there might be restricted transferability due to the cultural and institutional uniqueness of Spain. The nature of institutional support systems (e.g. subsidies, regulations, market pressures) significantly differs in different regions. To enhance external validity, researchers need to confirm the model in the developed and developing economies to determine contextual contingencies. Cross-country research may also be used to demonstrate how institutional arrangements affect the performance of GDCs in various regulatory or economic environments.

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