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# Environmental, social and governance ratings and corporate green innovation: Evidence from South Africa

We examined the effect of environmental, social and governance (ESG) ratings on corporate green innovation using a comprehensive panel data set of South African listed firms from 2010 to 2023. The findings reveal that ESG ratings significantly enhance green innovation, not only directly but also through two distinct mechanisms: mitigating managerial short-sightedness, attracting institutional investor attentiveness and improving inter-firm trade credit financing. Moreover, digitalisation positively moderates and amplifies the relationship between ESG ratings and green innovation, reinforcing firms' capacity for sustainable innovation. Furthermore, heterogeneity analysis indicates that the positive impact of ESG ratings is stronger among non-state-owned enterprises and firms operating in low-polluting industries, where competitive pressures and reputational concerns play a more prominent role than environmental risk itself. The findings of this study offer policy-relevant insights into how ESG ratings can serve as levers for green transformation, particularly in emerging economies.

## Significance:

This study advances the understanding of how ESG ratings function as strategic levers for corporate green innovation in an evolving environment of ESG disclosure. By revealing that ESG ratings enhance green innovation by mitigating managerial short-sightedness, attracting investor attentiveness and strengthening trade credit financing, and that digital transformation further amplifies this positive effect, this study moves beyond regulatory narratives to uncover firm-level behavioural, financial and informational mechanisms. The findings are particularly significant for emerging economies such as South Africa, where institutional gaps coexist with urgent sustainability imperatives. Moreover, the differentiated effects across ownership types and pollution intensity underscore the importance of tailored ESG strategies, offering actionable insights for both corporate governance reform and innovation-driven environmental policy design.

## Introduction

Over the past decade, the pursuit of ecological sustainability and green development has become a global priority for firms, regulators and stakeholders.<sup>1,2</sup> As major contributors to environmental degradation and core participants in the economic system, firms bear a central responsibility for promoting low-carbon transitions and driving green upgrades.<sup>3</sup> Green innovation, rooted in technological advancement and guided by ecological objectives, entails the development and application of products, processes and technologies that mitigate environmental harm.<sup>4</sup> It enhances resource efficiency, supports low-carbon transformation and provides practical solutions for pollution control, energy optimisation and ecological restoration.<sup>5,6</sup> By aligning economic performance with environmental protection, green innovation is a strategic pathway to sustainable competitiveness. However, firms' engagement in such innovation remains constrained by long payback periods, uncertain returns and high upfront costs that disrupt short-term profitability.<sup>7,8</sup> Consequently, effective external mechanisms that encourage long-term strategic behaviour are vital to sustaining corporate commitment to green innovation. In South Africa, the urgency of sustainable development is particularly pronounced because of persistent energy insecurity, carbon-intensive industrial structures and deep socio-economic inequalities.<sup>9</sup>

Achieving low-carbon growth is critical not only for meeting national climate commitments under the 2015 Paris Agreement but also for maintaining competitiveness in an increasingly green global economy.<sup>10</sup> Therefore, green innovation serves a dual purpose: advancing environmental goals while reinforcing industrial resilience and technological upgrading in a resource-constrained context.<sup>6</sup> Within this landscape, environmental, social and governance (ESG) ratings have rapidly evolved from niche evaluative tools into central benchmarks for global investors and regulators. Initially designed to measure firms' non-financial performance, ESG ratings now function as standardised indicators of sustainability commitment and risk exposure.<sup>3,11</sup> The rise of ESG investing has been remarkable; according to the United Nations supported Principles for Responsible Investment, more than 5000 signatory institutions collectively manage assets exceeding USD120 trillion, reflecting ESG's mainstream integration into capital markets.<sup>12</sup> Simultaneously, regulatory bodies have institutionalised ESG disclosure through initiatives such as the European Union's Corporate Sustainability Reporting Directive and the US Securities and Exchange Commission's climate disclosure proposals, underscoring the growing regulatory importance of ESG information.<sup>13</sup> This convergence signals that ESG ratings now act as both investment benchmarks and quasi-regulatory mechanisms, shaping firms' strategic orientation, transparency and accountability in sustainability performance.<sup>11</sup> Nonetheless, the credibility of ESG ratings remains contested because of rating divergence and disclosure bias, raising questions about whether ESG truly captures firms' sustainability outcomes rather than symbolic compliance.<sup>14</sup>

Amid this global momentum, investors are increasingly evaluating corporate performance using integrated financial and non-financial metrics embodied in ESG ratings.<sup>15</sup> High ESG scores convey a firm's credibility, long-term vision and responsible governance to capital markets and stakeholders, serving as mechanisms for attracting investment, enhancing reputation and aligning with policies.<sup>16</sup> In South Africa, the diffusion of ESG principles is accelerating:

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an increasing share of Johannesburg Stock Exchange listed firms voluntarily disclose ESG information and enhance their ESG profiles to strengthen competitiveness, manage reputational risks and meet investor expectations.<sup>17</sup> As ESG practices gain traction, stakeholders are paying closer attention to corporate contributions to environmental innovation and sustainable results.<sup>9,15</sup> Consequently, firms are progressively embedding environmental considerations into their innovation agendas, promoting clean technologies and sustainable products to comply with evolving regulatory standards and to capture new market opportunities.<sup>18,19</sup>

Accordingly, a burgeoning body of research has explored the relationship between ESG ratings and green innovation. However, current scholarly enquiry remains limited, with only a few studies systematically examining the extent to which ESG ratings facilitate corporate green innovation.<sup>20,21</sup> Most existing evidence derives from developed economies, such as the USA and Europe, where ESG disclosure systems are institutionalised and regulatory frameworks are mature.<sup>21,22</sup> In contrast, fewer than 5% of global studies have examined emerging markets, particularly South Africa, where the institutional enforcement is weaker.<sup>17,23</sup> Moreover, prior empirical work has predominately examined the direct relationship between ESG and innovation outcomes, often measured through patent counts or research and development (R&D) intensity, while overlooking the behavioural, financial and informational mechanisms and the contextual conditions through which ESG ratings may influence corporate green innovation.<sup>4,20,21,24</sup> Additionally, existing research on ESG ratings rarely distinguishes between short-term managerial incentives and long-term innovation commitments<sup>25,26</sup>, leaving the role of managerial short-sightedness under-examined. Similarly, studies on the financial implications of ESG have concentrated on access to bank loans or equity financing<sup>27,28</sup>, with limited attention to trade credit, which is an important inter-firm financing channel that directly supports green innovation investment. In addition, the informational transmission effect of ESG on how improved disclosure and credibility attract greater institutional investor attention and capital market engagement has received limited empirical exploration. Moreover, most analyses employ static panel models that identify associations but fail to capture the dynamic adjustment processes through which ESG ratings affect green innovation.<sup>4,29</sup> Collectively, these limitations underscore the lack of a comprehensive understanding of how ESG ratings translate into sustained green innovation at the firm level.

Against this backdrop, addressing these theoretical and empirical gaps is vital to examine whether ESG mechanisms function effectively under South Africa's unique institutional conditions. Given the global drive towards sustainability, this study examines how ESG ratings influence green innovation among South African listed firms, offering region-specific evidence to extend the international discourse on ESG-driven transformations. This study contributes to the literature in three main ways. First, it positions ESG ratings as a strategic, market-based driver of corporate green innovation, moving beyond the traditional focus on regulatory compliance to provide a more integrated understanding of how ESG assessments shape firms' green innovation behaviours. Second, it clarifies the mechanisms linking ESG ratings to green innovation by identifying the mediating roles of managerial short-sightedness, trade credit financing and institutional investor attentiveness, showing how ESG ratings foster long-term managerial orientation and strengthen inter-firm financing, and enhance market monitoring and confidence that collectively promote sustainable innovation. The results further indicate that digitalisation positively moderates this relationship, amplifying the green innovation enhancing effects of ESG. Finally, the study reveals that ESG ratings exert stronger effects on non-state-owned firms and firms with lower pollution levels. These insights inform differentiated policy design, highlighting where ESG incentives are most effective and where additional institutional support may be required to stimulate green innovation.

## Literature review

Stakeholder theory posits that firms operate within networks of interdependent relationships, where stakeholder interests shape strategic behaviour.<sup>30,31</sup> Corporate sustainability arises not only from regulatory compliance but also from the strategic need to secure legitimacy and essential resources from investors, regulators, employees and

communities.<sup>11</sup> Aligning corporate objectives with stakeholder expectations through responsible ESG practices enhances legitimacy, fosters trust and attracts supportive funds. Consequently, ESG ratings act as credible signals that reduce reputational risk and motivate firms to pursue green innovation to sustain long-term relationships and create shared value.

The resource-based view holds that durable advantages stem from valuable, rare, inimitable and non-substitutable (VRIN) resources and capabilities.<sup>32</sup> ESG practices accumulate these resources intangibles reputation, stakeholder trust, process know-how, data systems and governance routines, embedding path-dependent knowledge and coordination. ESG ratings proxy these routines, indicating the depth and coherence of the resource bundles. Through resource orchestration and dynamic capability sensing environmental opportunities, firms convert ESG-based assets into green innovation outputs by seizing them through R&D and partnerships and by reconfiguring assets.<sup>4,15,33</sup> Thus, the resource-based view predicts that stronger ESG ratings enhance green innovation via superior knowledge recombination, access to complementary assets and persistent innovation rents.

Institutional theory explains how coercive, normative and cognitive pressures shape organisational conformity to legitimated practices.<sup>34,35</sup> Firms pursue legitimacy to secure survival advantages, often adopting ESG structures and disclosures to align with expectations.<sup>36</sup> ESG ratings function as external validation, reducing uncertainty and amplifying normative and mimetic forces through benchmarking. These pressures steer firms towards green innovation because visible environmental improvements credibly signal compliance and reduce legitimacy gaps. While symbolic compliance is possible<sup>14</sup>, transparency and third-party scrutiny increase coupling over time, channelling institutional pressures into substantive green innovation.

## Methodology

### Data sources

In this study, we employed data from Thomson Reuters, MSCI and the patstat patent database, which includes listed firms on the Johannesburg Stock Exchange between 2010 and 2023. Our criteria for sampling included: (1) the exclusion of enterprises in the financial sector due to their distinctive accounting rules and the extensive regulations; (2) the exclusion of companies with significant missing data, and then the use of winsorisation at the 1st and 99th percentile values for continuous variables to avoid outlier effects. The resulting final sample consisted of 3921 observations.

### Variable descriptions

#### Independent variable

We used firm-level ESG ratings compiled by the MSCI, a globally recognised commercial ESG data provider frequently employed in ESG research. These ratings assess each firm's exposure to and management of ESG risks relative to industry peers, providing a consistent and comparable measure of ESG performance through an industry-adjusted and peer-relative benchmarking approach. MSCI constructs these ratings using over one thousand standardised indicators derived from company disclosures, regulatory filings, non-governmental organisation data sets and media sources. The ratings are reviewed annually and continuously updated in response to significant events or controversies to ensure data timeliness and reliability. Consistent with prior studies, we adopted the ESG ratings provided by MSCI as the primary measure of firms' overall ESG profiles, as the primary measure of firms' overall ESG ratings. In addition, Bloomberg's ESG score data were used for robustness testing.

#### Dependent variable

We measured corporate green innovation as the natural logarithm of one plus the total number of green patents filed by firm  $i$  in year  $t$ , correcting for a right-skewed distribution.<sup>4,29,37</sup> Patent-based indicators are widely used to capture the technological dimension of green innovation because they provide verifiable, comparable and consistent evidence of inventive activity.<sup>38</sup> However, as not all environmental innovations, such as waste-reduction processes, cleaner production methods or energy efficiency improvements, result in patents, this proxy may understate

non-technological or managerial forms of innovation. In line with previous studies<sup>21,37</sup>, we interpreted this measure as reflecting firms' technological engagement in green innovation rather than the entire spectrum of environmental improvement efforts.

### Control variables

In line with prior literature<sup>4,18,37</sup>, we incorporated several firm-level control variables that may influence green innovation. Firm size is expected to promote green innovation, as larger firms possess more resources, economies of scale and visibility to stakeholders, which encourages environmental R&D.<sup>39</sup> Leverage may hinder innovation because high debt increases financial constraints and discourages risky, long-term projects.<sup>40,41</sup> Firms with greater growth capacity are more likely to pursue green innovation to sustain their competitiveness and exploit new opportunities.<sup>42,43</sup> A higher fixed asset ratio may restrain innovation by locking firms into capital-intensive technologies that are less flexible for green upgrades.<sup>44</sup> Strong cash flow supports innovation by easing financing constraints, particularly when external financing is limited for intangible R&D.<sup>45,46</sup> Firm age may have a negative or weak effect, as older firms often face structural inertia and resistance to change.<sup>47,48</sup> Finally, ownership concentration can enhance oversight and long-term commitment to sustainability at moderate levels but may suppress innovation when control becomes excessive.<sup>49,50</sup> Collectively, these controls capture the heterogeneity in firms' financial capacity, governance and strategic flexibility that shape their ability and willingness to invest in green innovation.

### Model specification

#### Benchmark model

To examine the effect of ESG ratings on corporate green innovation, the following model was constructed:

$$GI_{it} = \alpha_0 + \alpha_1 ESG_{it} + \alpha_2 controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad \text{Equation 1}$$

where  $GI_{it}$  represents green innovation of an enterprise  $i$  in year  $t$ .  $ESG_{it}$  denotes the enterprise's ESG ratings.  $controls_{it}$  captures the firm-level control variables.  $\mu_i$  and  $\delta_t$  indicate industry and year fixed effects, respectively.  $\varepsilon_{it}$  is the random disturbance term.

#### Mediating effects model

To investigate the mechanisms through which ESG ratings influence corporate green innovation, we constructed a mediation model:

$$M_{it} = \beta_0 + \beta_1 ESG_{it} + \beta_2 controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad \text{Equation 2}$$

$$GI_{it} = \gamma_0 + \gamma_1 ESG_{it} + \gamma_2 M_{it} + \gamma_3 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad \text{Equation 3}$$

where  $M_{it}$  denotes mechanism variables such as managerial short-sightedness, investor attentiveness and trade credit financing. Each of the other parameters indicated previously in the study are constant with those utilised in the baseline regression.

## Empirical results

### Descriptive statistics

Table 1 presents the descriptive statistics for all variables. The mean value of corporate green innovation among the sample firms is 0.4381, with a standard deviation of 0.9209, indicating substantial heterogeneity in firms' green innovation output and suggesting uneven progress towards green transformation among listed companies. The average ESG rating of the sample firms is 4.1803, with a standard deviation of 1.1421, implying that their overall ESG ratings were relatively good. However, there are certain differences amongst enterprises. Among the control variables, the average firm size is 22.6013, with maximum and minimum values of 26.4523 and 19.5850, respectively, indicating that the sample includes enterprises of varying scales. The average asset–liability ratio is approximately 41%, suggesting that, on average, firms' liabilities account for about half of their total assets.

**Table 1:** Descriptive statistics

Variable	Mean	SD	Maximum	Minimum
GI	0.4381	0.9209	6.9127	0.0000
ESG	4.1803	1.1421	10.0000	0.0000
Size	22.6013	1.3936	26.4523	19.5850
Leverage	0.4088	0.1891	0.9079	0.0298
Growth	0.1567	0.3384	3.8082	−0.6102
Fixed	0.2904	0.1551	0.7364	0.0016
Tobin's Q	1.9986	1.3036	10.5048	0.8024
Cash flow	0.0624	0.0647	0.2669	−0.2218
Firm age	2.9353	0.3265	3.6109	1.3863
Holder	0.4861	0.1588	0.8784	0.1513

SD, standard deviation; GI, green innovation; ESG, environmental, social and governance

Overall, the debt ratio appears reasonable and the remaining variables also fall within acceptable value ranges.

### Benchmark regression

The findings in Table 2 show that the positive and significant coefficients of ESG ratings indicate that firms with stronger ESG ratings are more likely to engage in green innovation, aligning with South Africa's broader policy agenda of sustainable industrialisation and low-carbon transitions. Within a developing economy marked by energy constraints, environmental degradation and financing gaps, firms that actively integrate ESG principles demonstrate environmental responsibility and enhanced access to green finance instruments such as sustainability-linked loans and green bonds, promoted under the National Development Plan 2030. High ESG ratings signal credibility and legitimacy to investors and regulators, thereby reducing information asymmetry and attracting capital for environmentally efficient technologies. Moreover, the persistence of this relationship after controlling for firm-level covariates, industry and year fixed effects suggests that ESG engagement is increasingly strategic, rather than symbolic. This result reflects firms' adaptive responses to policy incentives and global investor expectations rather than mere reputational compliance. These findings imply that South African firms with genuine ESG commitments can leverage sustainability credentials to strengthen their innovation capabilities, build stakeholder trust and align their competitiveness with the country's long-term green growth objectives.

### Robustness tests

#### Replacing the explained variable

To validate the reliability of the conclusions of this study, we replaced the total number of green patent applications with the total number of green patents granted. We revised the regression model of Equation 1 to enhance the reliability of our results. Specifically, we defined patents granted as the dependent variable, which is calculated as the natural logarithm of 1 plus the number of green patents granted for the firm  $i$  in year  $t + 1$ . The results displayed in column (1) of Table 3 show that the coefficient of ESG ratings remains positive and statistically significant at the 1% level, demonstrating the robustness of the results.

#### Replacing the explanatory variables

To ensure robustness, we re-estimated the model using Bloomberg ESG rating data, which are widely employed in prior studies. The results in column (1) of Table 4 show that Bloomberg's ESG ratings exert a significant positive effect on green innovation, confirming the robustness of our findings.

### Endogeneity tests

To address potential endogeneity concerns, we employed the breadth of holdings of broad ESG-themed mutual funds as an instrumental variable. This variable is strongly correlated with firms' ESG ratings because fund managers allocate capital based on third-party ESG scores rather than firm-level innovation outcomes, thus satisfying the relevance criterion.<sup>51</sup> Regarding exogeneity, broad ESG-themed mutual funds are designed to achieve portfolio-level ESG diversification rather than influence specific corporate strategies. They typically hold small, passive stakes across numerous firms, limiting their ability and incentives to engage in direct innovation-related interventions.<sup>52</sup> Unlike activist or impact-oriented funds, these broad index-based ESG funds are characterised by dispersed ownership and minimal targeted engagement. Their portfolio decisions reflect external ESG

**Table 2:** Benchmark regression results. Column (1) presents the specification including environmental, social and governance (ESG) as the main explanatory variable with industry and year fixed effects (FE). Column (2) reports the full model, which additionally includes firm-level control variables, along with industry and year fixed effects.

Variable	(1)	(2)
	GI	GI
ESG	0.1235*** (0.0111)	0.0584*** (0.0104)
Size		0.2113*** (0.0151)
Leverage		-0.4373*** (0.0760)
Growth		-0.0824** (0.0350)
Fixed		0.5667*** (0.0964)
Tobin's Q		0.0325*** (0.0086)
Cash flow		0.5322*** (0.1909)
Firm age		-0.2326*** (0.0444)
Holder		0.2240*** (0.0830)
Constant	-0.0781* (0.0455)	-4.0784*** (0.3273)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	3921	3921
R-squared	0.309	0.378

GI, green innovations

Robust standard errors in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

standards and investor preferences at the market level, which affect stock valuation but not firms' internal R&D or technological processes.<sup>53</sup> Moreover, the empirical specification includes industry fixed effects and year fixed effects, along with controls for financing costs and policy intensity, thereby absorbing potential signalling or macro-policy shocks. As a further validity check, the instrument does not predict non-green or future green innovation when ESG ratings are held constant, confirming the exclusion restriction. The findings in columns (2) and (3) of Table 3 indicate that the instrument is highly significant at the 1% level in the first-stage regression, while the second-stage regression confirms the positive and significant association between ESG ratings and green innovation. Additionally, the Kleibergen–Paap rk LM statistic and Wald F-statistic demonstrate the strength and validity of the instrument. These findings provide strong causal evidence of the positive impact of ESG ratings on green innovation.

### Other robustness tests

#### Adjusting sample interval

To account for pandemic-related shocks that may have affected firms' innovation activities and ESG engagement, the sample was adjusted to exclude all observations after post-2020. As shown in column (2) of Table 4, the relationship between ESG ratings and green innovation remains robust, which indicates that the baseline results were not influenced by the extraordinary circumstances of the COVID-19 pandemic.

#### Exclusion of enterprises in capital cities and major economic hubs

Considering that firms in major South African cities such as Johannesburg, Cape Town, Durban, East London and Pretoria may have preferential access to ESG-aligned policies, resources and investor networks, we performed a robustness check by excluding these firms.

The re-estimated model in column (3) of Table 4 reports a positive and statistically significant coefficient for ESG ratings, illustrating that the relationship between ESG ratings and green innovation is not solely driven by enterprises benefiting from metropolitan advantages.

**Table 3:** Robustness check using alternative dependent variable and endogeneity tests

Variable	(1)	(2)	(3)
	GI	ESG	GI
ESG	0.0472*** (0.0089)		0.1690*** (0.0706)
IV		0.8401*** (0.0567)	
Constant	-3.2505*** (0.2879)	-3.8602*** (0.3837)	-4.9284*** (0.3470)
Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	3921	3921	3921
R-squared	0.372	0.293	0.217
Kleibergen–Paap rk LM statistic		175.218***	
Kleibergen–Paap rk Wald F-statistic		219.662	

GI, green innovation; ESG, environmental, social and governance; IV, instrumental variable; FE, fixed effects; rk, rank; LM, Lagrange multiplier

Robust standard errors in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

**Table 4:** Robustness checks using alternative ESG measures, sample restrictions and additional fixed effects

Variable	(1)	(2)	(3)	(4)
	GI	GI	GI	GI
BESG	0.0069*** (0.0012)			
ESG		0.0493*** (0.0123)	0.0579*** (0.0119)	0.0581*** (0.0105)
Constant	-4.2831*** (0.3285)	-3.4161*** (0.4016)	-3.9741*** (0.3749)	-4.1183*** (0.3269)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Province FE	NO	NO	NO	YES
Observations	3,921	2,857	2,977	3921
R-squared	0.378	0.396	0.412	0.379

GI, green innovation; (B)ESG, (Bloomberg) environmental, social and governance; FE, fixed effects

Robust standard errors in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

### Controlling for province fixed effects

To ensure the robustness of our findings and mitigate potential regional estimation biases arising from unobserved heterogeneity across provinces and industries, the study additionally controls for province fixed effects. The results in column (4) of Table 4 show that ESG ratings remain positive and statistically significant, indicating that region-specific effects do not weaken the robustness of the results.

### Mechanism analysis

#### Enhancing trade credit financing

Firms with stronger ESG ratings often gain higher levels of supplier confidence, which enhances their access to trade credit and signals reliability in undertaking green innovation activities.<sup>54-56</sup> To investigate this mechanism, trade credit financing is measured as the ratio of accounts payable plus notes payable to total assets, capturing the extent of supplier-provided credit. Column (1) of Table 5 shows that ESG ratings have a positive and statistically significant effect on trade credit financing, indicating that firms with higher ESG ratings secure greater supply chain financing. Column (2) further reveals that trade credit financing significantly promotes green innovation, suggesting that improved access to supplier-based financial resources enhances firms' capacity to undertake environmentally oriented innovation. Together, these findings support the mechanism that ESG ratings foster green innovation partly by expanding firms' trade credit financing.

#### Mitigating managerial short-sightedness

Managerial short-sightedness refers to executives prioritising immediate financial returns at the expense of long-term innovation.<sup>25,57</sup> This orientation discourages investment in green innovation, which typically involves uncertainty, long payback periods and substantial upfront costs. ESG ratings can help to mitigate such short-termism by aligning managerial incentives with sustainable development objectives and by increasing stakeholder monitoring and governance pressures.<sup>26</sup> Managerial short-sightedness is measured using a dictionary-based method that captures the frequency of short-term horizon expressions (e.g. "within days", "as soon as possible") in management discussion and analysis texts relative to total word count. Column (3) of Table 5 shows that ESG ratings significantly reduce managerial short-sightedness, indicating that firms with stronger ESG

ratings exhibit lower tendencies towards short-term managerial behaviour. Column (4) further shows that managerial short-sightedness has a negative and significant effect on green innovation, suggesting that firms led by short-term-oriented managers are less inclined to pursue environmentally oriented innovation. Taken together, these results demonstrate that reducing managerial short-sightedness is an important pathway through which ESG ratings foster long-term green innovation investment.

#### Heightening the level of investor attentiveness

Firms with stronger ESG ratings tend to attract greater attention from institutional investors, as credible sustainability performance reduces information asymmetry and signals long-term operational stability. To test this mechanism, we measured investor attentiveness as the proportion of institutional investors' shareholdings, which reflects the degree of capital market focus on the firm. Column (5) of Table 5 shows that ESG ratings significantly increase investor attentiveness, indicating that firms with high ESG ratings draw stronger interest from institutional investors. Column (6) further demonstrates that investor attentiveness significantly promotes green innovation. These results suggest that higher ESG ratings strengthen institutional investors' confidence and engagement, thereby improving firms' access to stable capital and reinforcing market discipline. Consequently, ESG ratings foster green innovation partly by increasing investor attentiveness.

#### Moderating effect of digital transformation

Digital transformation may shape how ESG ratings influence corporate green innovation by enhancing firms' information processing, resource allocation and integration of sustainability objectives into innovation activities. Firms undergoing digital transformation are better equipped to convert ESG-related information into actionable innovation strategies through data analytics, automation and intelligent decision-making systems. This transformation improves their ability to identify green technological opportunities and reduces the costs and uncertainties associated with R&D investments. To test this moderating effect, an interaction term between ESG ratings and level of digital transformation was introduced into the regression model:

$$GI_{it} = \alpha_0 + \alpha_1 ESG_{it} + \alpha_2 Dig_{it} + \alpha_3 ESG_{it} * Dig_{it} + \alpha_4 controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad \text{Equation 4}$$

where  $Dig_{it}$  denotes digital transformation. A positive  $\alpha_3$  indicates that digital transformation strengthens the relationship between ESG ratings and green innovation, while a negative  $\alpha_3$  implies a weakening effect.

The results in column (7) of Table 5 show that the interaction coefficient is positive and significant, confirming that digital transformation amplifies the positive impact of ESG ratings on green innovation. This result implies that firms adopting advanced technologies, such as artificial intelligence, big data and cloud computing, are more capable of leveraging ESG ratings to drive sustainable innovation. Hence, digital transformation acts as a complementary capability that enhances the effectiveness of ESG-driven innovation strategies in achieving long-term sustainability.

### Heterogeneity analysis

#### Ownership structure

Ownership structure meaningfully shapes how firms respond to ESG ratings in their green innovation strategies. To examine this effect, enterprises were classified as state-owned enterprises (SOEs) or non-state-owned enterprises based on their registration status. Columns (1) and (2) of Table 6 show that ESG ratings significantly promote green innovation in both groups, but the effect is notably stronger among non-SOEs. A plausible explanation is that non-SOEs are more sensitive to competitive pressures, investor expectations and reputational considerations, which heightens their responsiveness to ESG evaluations. By contrast, SOEs often operate under softer budget constraints and may benefit from government support, reducing the

urgency to pursue ESG-driven innovation. These findings suggest that ESG ratings exert a greater influence when firms face stronger market discipline and stakeholder scrutiny.

#### Industry type

Industry type plays a vital role in shaping the impact of ESG ratings on green innovation, as some sectors face greater environmental and regulatory pressures than others. Accordingly, we classify firms into high-polluting and non-polluting industries. As shown in columns (3) and (4) of Table 6, ESG ratings significantly promote green innovation in both groups, but the effect is more pronounced in non-polluting industries. Firms in these industries face fewer compliance constraints and lower abatement costs, which allows ESG incentives to translate more directly into green innovation. By contrast, high-polluting industries must devote substantial resources to meeting regulatory requirements, thereby limiting the financial and organisational capacity available for proactive green innovation.

### Conclusion

This study makes three key contributions to the literature. Empirically, it provides firm-level evidence that ESG ratings significantly enhance green innovation among South African listed companies, with the results remaining robust across alternative specifications. The analysis also reveals three distinct mechanisms, namely mitigating managerial short-term orientation, increasing investor attentiveness and improving trade credit access, through which ESG ratings stimulate green

**Table 5:** The mediating and moderating effect test results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	TCF	GI	MS	GI	INVT	GI	GI
ESG	0.0131** (0.0058)	0.0554*** (0.0103)	-0.0483*** (0.0153)	0.0572*** (0.0104)	0.0063*** (0.0017)	0.0568*** (0.0105)	0.0670*** (0.0120)
TCF		0.2300*** (0.0337)					
MS				-0.0258* (0.0114)			
INVT						0.2646*** (0.0922)	
DIG							0.0275** (0.0117)
ESG x DIG							0.0252** (0.0123)
Constant	0.5468*** (0.1538)	-4.2042*** (0.3275)	0.4607*** (0.3864)	-4.0665*** (0.3274)	4.5291*** (0.0535)	-5.2770*** (0.6180)	-3.8545*** (0.3291)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3921	3921	3921	3921	3921	3921	3921
R-squared	0.314	0.387	0.794	0.379	0.823	0.379	0.280

TCF, trade credit financing; GI, green innovation; MS, managerial short-sightedness; INVT, investor attentiveness; ESG, environmental, social and governance; DIG, digital transformation; FE, fixed effects

Robust standard errors in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

**Table 6:** Heterogeneity analysis results based on ownership structure and industry type

Variable	(1)	(2)	(3)	(4)
	Non-SOEs	SOEs	High-polluting industries	Low-polluting industries
	GI	GI	GI	GI
ESG	0.0585*** (0.0118)	0.0564** (0.0230)	0.0440** (0.0187)	0.0610*** (0.0123)
Constant	-4.2671*** (0.3672)	-3.3989*** (0.7433)	-3.0945*** (0.7159)	-4.0219*** (0.3792)
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	3036	885	3046	875
R-squared	0.388	0.370	0.238	0.422

SOEs, state-owned enterprises; GI, green innovation; ESG, environmental, social and governance; FE, fixed effects

Robust standard errors in parentheses; \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

innovation, offering new insights into the financial, informational and behavioural channels of sustainability transformation. Moreover, the positive moderating effect of digitalisation further demonstrates that firms with advanced digital capabilities can translate ESG ratings into innovative and sustainable outcomes more effectively. Theoretically, the findings enrich stakeholder, the resource-based view and institutional theories by demonstrating how ESG ratings operate as both relational and informational signals that align managerial behaviour with broader sustainability goals in emerging markets. Policy-wise, the evidence suggests that formalising ESG disclosure mandates, promoting ESG-integrated financing instruments and embedding ESG criteria in innovation strategies can jointly advance South Africa's low-carbon and inclusive growth agenda. Together, these contributions extend the understanding of ESG-driven innovation dynamics in developing economies and provide a concrete framework for aligning corporate sustainability with the national development objectives.

## Policy implications

There are three main policy implications arising from this study. First, policymakers and stock exchange authorities should strengthen ESG disclosure mandates by institutionalising standardised ESG rating frameworks and expanding their coverage across all listed firms. Clear disclosure requirements and enforcement mechanisms will enhance transparency, align managerial incentives with national green innovation objectives and enable regulators to monitor firms' sustainability commitments more effectively.

Second, investors and financial institutions should incorporate ESG metrics into investment screening, risk assessment and portfolio management processes. By prioritising firms with higher ESG ratings, investors can channel capital towards enterprises demonstrating genuine sustainability engagement, thereby reinforcing market-based incentives for green innovation and long-term value creation.

Third, firms should embed ESG principles into their core innovation strategies and corporate governance. Integrating ESG objectives into R&D planning, product development and executive performance evaluations will enhance green innovation capability and strengthen competitiveness, stakeholder trust and resilience in a sustainability-oriented market environment.

## Limitations

This study is limited to South African listed firms, which may constrain the generalisability of the findings to other contexts. Future research should

employ advanced econometric techniques, conduct cross-country comparisons and investigate additional transmission channels, such as government subsidies, human capital and corporate risk taking, to provide a more comprehensive understanding of how ESG ratings shape green innovation.

## Data availability

The data supporting the results of this study are available upon request to the corresponding author.

## Declarations

We have no competing interests to declare. Readability and proofreading were enhanced using tools such as Paperpal, Trinka and Grammarly.

## Authors' contributions

D.K.K.: Conceptualisation, methodology, investigation, sample analysis, formal analysis, validation, data curation, writing – original draft, writing – review and editing, project administration. M.T.: Methodology, sample analysis, data analysis, validation, data curation, writing – revisions. Both authors read and approved the final manuscript.

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