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Green entrepreneurial orientation and technological green innovation: does resources orchestration capability matter?

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Abstract

Purpose – Although green entrepreneurial orientation (GEO) has received much attention, it is unclear whether it affects technological green innovation (GI). Therefore, this study aims to understand how GEO affects technological GI, with its dimensions green product innovation (GPRODI) and green process innovation (GPROCI), as well as to explore whether resource orchestration capability (ROC) moderates the relationships between them.

Design/methodology/approach – Based on a cross-sectional survey design, data were gathered from 177 managers of large manufacturing firms in Yemen and analysed using partial least squares structural equation modelling via SmartPLS software.

Findings – The results revealed that GEO positively affects both GPRODI and GPROCI, with a higher effect on GPROCI. Importantly, ROC does, in fact, positively moderate the link between GEO and GPRODI.

Research limitations/implications – This research adds to knowledge by combining GEO, ROC and technological GI into a unified framework, considering the perspectives of the resource-based view and the resource orchestration theory. However, the study's use of cross-sectional survey data makes it impossible to

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infer causes. This is because GEO, ROC and technological GI all have effects on time that this empirical framework cannot account for.

Practical implications – The findings from this research provide valuable insights for executives and decision makers of large manufacturing companies, who are expected to show increasing interest in adopting ROC into their organisations. This suggests that environmentally-conscious entrepreneurial firms can enhance their GI efforts by embracing ROC.

Social implications – By adopting the proposed framework, firms can carry out their activities in ways that do not harm environmental and societal well-being, as simply achieving high economic performance is no longer sufficient.

Originality/value – Theoretically, the results offer an in-depth understanding of the role of GEO in the technological GI domain by indicating that GEO can promote GPRODI and GPROCI. In addition, the results shed new light on the boundaries of GEO from the perspective of resource orchestration theory. Furthermore, the findings present important insights for managers aiming to enhance their comprehension of leveraging GEO and ROC to foster technological GI.

Keywords Technological green innovation, Green entrepreneurial orientation, Resource orchestration capability, Less developed countries

Paper type Research paper

1. Introduction

In the current business landscape, companies encounter challenges in striking a harmony between environmental preservation and sustainable consumption, challenges that are observed not only in developed nations but also in developing ones. Yemen is no different, with its manufacturing firms experiencing intense competition due to globalisation (Al-Swidi *et al.*, 2024). Moreover, the existing pollution in Yemen, stemming from manufacturing industries, the energy sector and ongoing conflicts, is resulting in economic, environmental and social repercussions, including the deterioration of the GDP (Al-Swidi *et al.*, 2022). Manufacturers currently acknowledge the necessity of identifying solutions that reconcile environmental sustainability objectives with financial viability (Shehzad *et al.*, 2023). One effective strategy is to boost the potential of technological green innovation (GI) in companies (Idrees *et al.*, 2023; Nuryakin and Maryati, 2022). By enhancing technological GI, organisations can fulfil their social responsibilities, accomplish economic success and align financial performance with environmental conservation. GI refers to "the process that contributes to creating new products and technologies to reduce environmental risks, like pollution and negative consequences of resource exploitation (Takalo and Tooranloo, 2021, p. 3)."

Considering the increasing significance of GI, past research has identified several factors for firms that are actively involved in GI (Song *et al.*, 2020). The majority of research has focused on examining external factors that impact GI, including but not limited to factors such as competitive pressures (Pondeville *et al.*, 2013), the industry's technological level (Singh *et al.*, 2015) and green supply chain integration (Al-Swidi *et al.*, 2023). However, these external factors are not the main drivers behind companies adopting GI, and they cannot fully clarify the early adoption behaviour of such practices by companies (Zhou *et al.*, 2020). Simply ascribing the adoption of GI in companies to outer factors is inadequate (Al-Swidi *et al.*, 2024). As a result, it is crucial to examine internal factors that influence such innovation. Within these internal factors, studies suggest that green entrepreneurial orientation (GEO) is critical to enhancing GI (e.g. Muangmee *et al.*, 2021). GEO is viewed as a strategic orientation within the firm centred on recognising and exploiting environmentally sustainable business opportunities (Covin and Slevin, 1989).

According to the resource-based view, GEO serves as:

> [. . .] a strategic resource, aligning with a company's culture and acting as a dynamic capability that aids in identifying, capturing, and sustaining environmental initiatives over time (Makhloufi *et al.*, 2022, p. 425).

Furthermore, Skordoulis *et al.* (2022), in their study of manufacturing large and medium-sized enterprises in developed countries, specifically Greece, confirm that GEO enhances a firm's GI, especially when combined with its business strategy. On the other hand, the concept of green entrepreneurship in less developed countries (LDCs), including Yemen, is not as advanced, where entrepreneurs often prioritise profit-making and adhering to more conventional approaches. In other words, business leaders in this context prioritise rapid results over factors such as corporate social responsibility, environmental preservation, the introduction of environmentally friendly innovations and striving for long-term sustainable growth, assigning lesser importance to these aspects (Batrancea *et al.*, 2021). Although GEO is crucial for securing the long-term success of companies (Al-Swidi *et al.*, 2024), academic literature has provided limited coverage of this topic. Studies on GEO indicate that it stands out as a highly effective strategy for boosting companies' GI (Guo *et al.*, 2020). However, research often focuses on developed countries (Skordoulis *et al.*, 2022), while there is a paucity of studies conducted in developing countries (Muangmee *et al.*, 2021). This is particularly notable for LDCs, including Yemen. Therefore, a substantial gap exists in this domain, especially concerning comprehending the role of GEO and its position within emerging countries (Demirel *et al.*, 2019).

Despite the close association between GEO and GI, it is crucial to recognise that firms with GEO may not automatically attain GI (Al-Swidi *et al.*, 2024). This is mainly attributed to the increased complexity and increased requirements linked to GI in comparison with traditional innovation (De Marchi, 2012). In addition, past research outcomes regarding the GEO–GI correlation have yielded inconsistent findings. Some researchers (Alshebami, 2023; Wang *et al.*, 2023) contend that there is a positive link between GEO and GI, but others (e.g. Majali *et al.*, 2022) found it to be statistically insignificant. These conflicting outcomes underscore the necessity for further investigation, specifically concentrating on potential moderating factors, to enhance our understanding of the contextual elements that connect GEO and GI. While prior studies on the GEO–GI relationship have determined several moderating factors that support or impede this relationship, organisational capabilities such as the resource orchestration capability (ROC) have been ignored. In light of this, this study concentrates on ROC as a possible moderator of the GEO–GI relationship.

Based on resource orchestration theory, effectively managing resources is more crucial than mere possession of resources for a firm to gain a competitive edge (Shehzad *et al.*, 2023; Sirmon *et al.*, 2011). Many studies have emphasised the significance of the firm's abilities in coordinating, combining and leveraging its resource portfolio to carry out innovation (e.g. Wang *et al.*, 2020). Among various organisational capabilities, ROC plays a critical role in minimising conflicts and enhancing the integration of resources within the company while also serving as a dynamic capacity to facilitate knowledge transfer to support innovation (Shehzad *et al.*, 2023). In the present research, we view ROC as a crucial component for ecologically innovative firms and can be extremely important for strategy formulation and implementation. Therefore, we argue that ROC can strengthen the impact of GEO on GI.

In light of the aforementioned and to address the gaps that currently exist in the academic literature, the purpose of this study is to provide answers to the following research questions:

RQ1. How does a firm's GEO affect technological GI?

RQ2. Does ROC moderate the GEO–technological GI relationship?

The present paper's contribution to literature is twofold. Firstly, based on a firm's resource-based view, this paper provides a noteworthy addition to the existing literature on sustainability. Motivated by a core vision for societal transformation, businesses possessing GEO actively manage resources and embrace a positive stance to transition from traditional

systems to environmentally friendly processes. This research illuminates the correlation between GEO and GI. While past research has mainly focused on the external factors influencing the adoption of GI, there is a lack of studies investigating the internal factors related to GI. Furthermore, it examines the different dimensions of technological GI, specifically, green product innovation "GPRODI" and green process innovation "GPROCI". Secondly, despite limited research on the GEO–technological GI connection, earlier studies have raised the concern that relying solely on GEO might not be enough to propel technological GI, as well as contradictory results for this link (Guo *et al.*, 2020). Therefore, based on resource orchestration theory, this study investigates the moderating effect of ROC in the GEO–technological GI link, which has previously gone unexplored in the literature. Moreover, this study was conducted in the context of large manufacturing companies in LDCs, such as Yemen, which has not received adequate attention in previous studies, as many previous studies were conducted on SMEs (Majali *et al.*, 2022; Ullah and Danish, 2020). Hence, more research on GEO and GI in the context of large manufacturing firms is needed in LDCs.

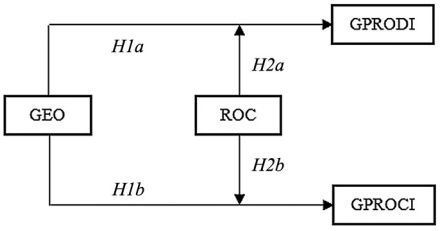
The remainder of the study is organised as follows: Section 2 encompasses the literature review and the development of the hypotheses. Section 3 outlines the used methodology, and Section 4 presents the results of the data analysis. Section 5 comprises the discussion, encompassing implications. Finally, the concluding section, Section 6, includes limitations and potential avenues for future research.

2. Literature review

2.1 Theoretical basis

Drawing on the resource-based view and resource orchestration theory, we constructed a theoretical model (Figure 1) to demonstrate the connections among the study's key constructs. According to the resource-based view, an organisation gets and keeps a competitive edge by developing and using its valuable resources (Wernerfelt, 1984). Because of this, the essential features of these resources are their rarity and value (Barney, 1991; Goaill and Al-Hakimi, 2021), where the value makes them complex and one-of-a-kind. These resources enhance competence creation in essential business areas (including operations, technology and marketing), which are the factors that decide where a company stands in relation to its competitors (Bag *et al.*, 2021). The resource-based view is the most popular framework for investigating how various organisational resources affect performance outcomes (Taleb *et al.*, 2023). In the scope of the current research, we address GEO as an essential organisational resource (Makhloufi *et al.*, 2022) that constitutes a potential source of competitive edge.

Along with the resource-based view, this study adopted resource orchestration theory, which is one of the research areas that has garnered considerable interest in recent years, which explores how organisations can effectively manage their resources to achieve competitive effectiveness (Teece, 2014; Wang *et al.*, 2020). As an extension of the resource-



Source: Authors' own work

Figure 1.
Research model

based view, resource orchestration theory aims to elucidate how managers contribute to converting resources into capabilities through capability-building processes (Sirmon *et al.*, 2011). Although having valuable and rare resources is a prerequisite, it does not guarantee achieving a competitive edge over rivals (Sirmon *et al.*, 2011). Resources must also be well-managed to generate stimulating benefits (Shehzad *et al.*, 2023). Applying logic from the resource-based view and resource orchestration theory, this study seeks to explore whether ROC moderates the relationship of GEO with GPRODI and GPROCI.

2.2 Technological green innovation

Recognising technological GI as a vital element of environmental management, it is considered a corporate response to environmental regulations (Lee and Kim, 2011), and investigations in this field have mainly witnessed an upward trend in recent years. In the present era, technological GI has emerged as a vital strategy for companies to foster their market share and ensure their sustained viability. A triumphant implementation of such innovations enhances market positioning, allures customers, offers environmentally conscious products and achieves a competitive edge (Takalo and Tooranloo, 2021). Studies on innovation typically revolve around Schumpeter's theory of innovation. As outlined by Schumpeter (1942), technological innovation aids in fulfilling customer needs while also safeguarding the environment in which these needs arise (Takalo and Tooranloo, 2021).

According to many researchers, technological GI is classified into GPRODI and GPROCI (e.g. Al-Swidi *et al.*, 2024; Xie *et al.*, 2019). GPRODI focuses on modifying product designs by incorporating biodegradable materials or non-toxic substances in production, with the goal of enhancing energy efficiency and reducing environmental waste (Lin *et al.*, 2013). GPRODI necessitates a rethinking of the product life cycle, spanning from manufacturing and distribution to use, disposal or reuse/recycling – an approach often referred to as a "cradle to grave" (Xie *et al.*, 2019). Specifically, GPRODI involves "enhancing product durability or recyclability, minimising the use of raw materials, selecting eco-friendly materials and eliminating hazardous substances" (Kivimaa and Kautto, 2010). On the other hand, GPROCI focuses on decreasing energy usage in the manufacturing process and converting waste into valuable products (Al-Swidi *et al.*, 2024). Notably, GPROCI entails minimising air and water emissions, conserving water, enhancing resource and energy efficiency and shifting to bioenergy as an alternative to fossil fuels (Xie *et al.*, 2019).

2.3 Green entrepreneurial orientation

As per current literature, entrepreneurial orientation is a critical strategic resource that reflects a firm's overarching approach towards its operations in relation to the external environment (Al-Hakimi *et al.*, 2022b). Miller (1983, p. 771), recognised as a trailblazer in the concept of entrepreneurial orientation, views that "An entrepreneurial firm is one that engages in product market innovation, undertakes somewhat risky ventures and is first to come up with "proactive" innovations, overtaking competitors". Related to this, GEO is a relatively recent and highly valuable subject of study in both sustainability and entrepreneurship literature. In line with Dean and McMullen (2007), GEO signifies the propensity to recognise potential opportunities that can yield financial and ecological benefits by initiating environmentally friendly initiatives. Generally, entrepreneurial orientation refers to a company's decision-making stance in key tasks at the organisational level, the process of developing strategies and managerial concepts aimed at identifying new opportunities for growth and rejuvenation (Habib *et al.*, 2020).

Over time, scholars have held divergent opinions regarding the constituents of GEO. For instance, Lumpkin and Dess (1996) explicitly reported that entrepreneurial orientation is a mix of competitive aggressiveness of the firm and initiatives that facilitate novel behaviours. In the context of GEO, it combines initiative with an environmental focus

(Muangmee *et al.*, 2021). Cohen and Winn (2007) point to environmental orientation and social orientation as crucial elements of GEO. In general, research on green entrepreneurship underscores its significance due to the dynamic nature of the decision-making process (e.g. Jiang *et al.*, 2018). In addition, prior research indicates that GEO is firmly embedded in an organisation's proactive mindset, thereby bolstering its capacity to launch environmentally friendly projects and improve performance (Muangmee *et al.*, 2021).

2.4 Green entrepreneurial orientation and technological green innovation

From the resource-based view, entrepreneurial orientation represents the tendency of enterprises to identify and capitalise on opportunities (Al-Hakimi and Borade, 2020; Guo *et al.*, 2020). Furthermore, the prevalent entrepreneurial philosophy encourages businesses to continually explore new ideas and implement innovations that improve performance (Al-Hakimi *et al.*, 2021). As such, entrepreneurial orientation can exert both direct and indirect influences on corporate innovation (Pérez-Luño *et al.*, 2011), and innovation is often considered a fundamental aspect of entrepreneurial orientation (Covin and Miles, 1999). According to Schuler (1986), the speed at which innovation occurs sets entrepreneurial firms apart from others, describing entrepreneurship as a catalyst for advancing innovation. In addition, several studies have consistently demonstrated that companies with a strong entrepreneurial orientation tend to exhibit higher levels of innovation (e.g. Al-Hakimi *et al.*, 2021, 2022b).

According to current literature, green entrepreneurship is pivotal in fostering a sustainable trajectory for transition economies (Silajdžić *et al.*, 2015). This is achieved by embracing cleaner technologies and processes in manufacturing and product marketing (Sher *et al.*, 2019). GEO enhances operational efficiency, stimulates new ideas and innovations and reduces inefficiencies and waste resources (Huang and Li, 2017). Importantly, green entrepreneurship-oriented firms can develop eco-friendly innovative products, thereby improving sustainable business performance (Teece, 2016). Based on a resource-based view, green entrepreneurship-oriented firms tend to value-creating strategies that foster their sustainable performance (Habib *et al.*, 2020), including providing green products (Muangmee *et al.*, 2021). Consequently, the primary objective of GEO is to enhance sustainable manufacturing processes and provide eco-friendly products. GEO is a strategic approach that empowers enterprises to cultivate an internal organisational drive to produce more innovative green products. Although the primary objective of firms with GEO is to attain economic advantages (Al-Swidi *et al.*, 2024), they perceive pursuing GI as more viable in comparison with those exclusively concentrated on economic interests (Alshebami, 2023). In other words, although GEO is centred around enhancing technology and minimising costs, it can intentionally or inadvertently stimulate the GI of products and processes (Bos-Brouwers, 2010). On the basis of a resource-based view, Muangmee *et al.* (2021) argue that GEO is a critical resource for environmental management practice in companies by enhancing their GI. Therefore, GEO is acknowledged as a vital component in addressing environmental issues and bolstering a firm's capability to work in an eco-friendly manner (Muangmee *et al.*, 2021). According to Guo *et al.* (2020), companies with a robust GEO demonstrate responsible ecological stewardship and offer innovative products and processes. Numerous recent studies have highlighted the positive association between GEO and both GPRODI and GPROCI (see Table 1). For example, Wang *et al.* (2023) found that GEO has positive effects on GPRODI and GPROCI. Similarly, Tuan (2023) pointed out that GEO has a crucial role in improving GPRODI. Accordingly, we assume that:

H1a,b. GEO is positively associated with (a) GPRODI and (b) GPROCI.

Table 1. Overview of empirical studies on the GEO–GI relationship

Authors/year	Sampling	Antecedents				Key findings
		Independent variables	Mediator variables	Dependent variables	Moderator variable	
Guo *et al.* (2020)	Chinese enterprises	• GEO	• Supply chain learning	• Incremental GI • Radical GI		GEO affects incremental and radical GI. Moreover, supply chain learning mediates between GEO and incremental and radical GI
Ullah and Danish (2020)	SMEs of Pakistan	• GEO	• GPRODI • GPROCI	• Firm performance	• Strategic green marketing orientation	GEO directly affects firm performance and indirectly through GPRODI. Moreover, strategic green marketing orientation positively moderates the GEO–FP link
Li *et al.* (2021)	Chinese firms	• Entrepreneurial orientation		• Green management	• Social legitimacy Ownership type	There is a positive link between entrepreneurial orientation and green management, which is reinforced by social legitimacy and is stronger in the context of state-owned firms compared to non-state-owned firms
Muangmee *et al.* (2021)	SMEs in the automotive parts industry in Thailand	• GEO	• GI	• Sustainable performance		GEO has a direct impact on sustainable performance as well as an indirect impact through GI
Andersén (2022)	Swedish small manufacturing firms	• Entrepreneurial orientation • Environmental sustainability orientation		• GPRODI	• Competitive intensity	Entrepreneurial orientation and environmental sustainability orientation positively affect GPRODI. Moreover, competitive intensity moderates the entrepreneurial orientation-GPRODI link
Majali *et al.* (2022)	Manufacturing SMEs in Amman, Jordan	• GEO • Green transformational leadership	• GPRODI	• SME performance		The effect of GEO on PRODI is insignificant, while the effect of green transformational leadership on GPRODI is significant. In contrast, GEO affects SME performance, unlike green transformational leadership
Guo (2022)	SMEs in China	• Green entrepreneurial self-efficacy	• GI	• Sustainable performance	• Green knowledge-sharing culture	Green entrepreneurial self-efficacy directly affects firms' sustainable performance and indirectly through GI. Importantly, green knowledge-sharing culture does not moderate the relationship between green entrepreneurial self-efficacy and GI
Guo and Wang (2022)	Chinese firms	• GEO	• GI	• Firm performance	• Stakeholder pressure	GI mediates the GEO–firm performance link. Importantly, stakeholder pressure positively moderates between GEO and GI

(*continued*)

Table 1.

Authors/year	Sampling	Antecedents				Key findings
		Independent variables	Mediator variables	Dependent variables	Moderator variable	
Skordoulis *et al.* (2022)	Large and medium firms in Greece	• Green entrepreneurship	• Firm strategy • GI	• Competitive advantage		Green entrepreneurship positively affects GPRODI and GPROCI. Moreover, firm strategy serves as a mediator between both green entrepreneurship and green innovation with competitive advantage
Wang *et al.* (2023)	173 middle-senior managers	• GEO	• Knowledge creation process	• GI	• Green absorptive capacity	GEO directly affects GI and indirectly through knowledge exchange and knowledge integration. Moreover, Green absorptive capacity moderates the positive effect of GEO on the knowledge creation process
Tuan (2023)	Manufacturing firms in an Asia-Pacific market	• GEO	• Employee green creativity	• Green product innovation	• Employee green role identity • Organisational transactive memory system	GEO directly affects GPRODI and indirectly through employee green creativity. Moreover, employee green role identity and organisational transactive memory system strengthen the association of GEO with employee green creativity
Shehzad *et al.* (2023)	Manufacturing firms in Pakistan	• GEO	• Green knowledge management	• Ambidextrous green innovation	• ROC	GEO directly affects exploitative and exploratory GI and indirectly through green knowledge management. Importantly, ROC not only moderates the link between GEO and green knowledge management but also the relationship of green knowledge management to exploratory GI
Wu and Yu (2023)	Chinese firms	• Environmental CSR	• GEO	• Technological innovation	• Green intellectual capital	Environmental CSR positively affects technological innovation, in the presence of GEO as a mediator. Importantly, green intellectual capital positively moderates the mediating role of GEO

Source: Prepared by authors based on literature review

2.5 Resources orchestration capability

While many researchers have demonstrated that the GEO–GI link is positive, others do not entirely endorse this connection (e.g. Majali *et al.*, 2022; see Table 1). The variability in these results can be ascribed to the complex nature of the GEO–GI association, a relationship that is not entirely comprehended. One potential explanation for this lack of consistency can be found in resource orchestration theory, which suggests that simply possessing resources is not enough to outperform competitors (Sirmon *et al.*, 2011) but that resources must also be well-managed to generate stimulating benefits (Shehzad *et al.*, 2023). Researchers have emphasised the significance of a strong ROC in driving innovation and adapting to dynamic market circumstances (Wong *et al.*, 2018). For example, Teece (2014) argues that ROC plays an essential role in mitigating internal conflicts and improving the alignment of resources within a firm, while Wang *et al.* (2020) advocate for dynamic capacities that enable growth initiatives. According to Sirmon *et al.*'s (2011) framework, firms can fully harness the abilities and value of their resources when they are effectively used in conjunction with competencies and management expertise. ROC refers to "a business's capacity to arrange efficiently, bundle and leverage its resource portfolio toward firm performance" (Shehzad *et al.*, 2023, p. 5).

Indeed, firms, especially green-oriented ones that typically focus on GI require more resources and a longer period to recuperate expenses (Zhang and Walton, 2017). This is due to the elevated novelty and uncertainty associated with GI compared to conventional innovation, as highlighted by Cainelli *et al.* (2015). According to Berrone *et al.* (2013), resource allocation allows environmentally-conscious companies the flexibility to pursue long-term strategic goals related to GI, thereby reaping its advantages. Firms with a high level of ROC have the ability to allocate and employ resources more efficiently, leading to improved performance through entrepreneurial endeavours (Shehzad *et al.*, 2023). As such, we argue, based on resource orchestration theory, that organisations can leverage their resources (in this case, GEO) to drive innovation and adapt to dynamic market conditions if they have the ability to orchestrate those resources effectively. A high level of ROC enables firms to effectively use their knowledge sources, including GEO, to acquire pertinent environmental information from various external channels, consequently fostering innovation in products and processes (Wang *et al.*, 2023). This enables firms to manage, incorporate and effectively leverage strategically valuable knowledge to generate distinctive concepts and ideas, thereby facilitating GI initiatives more successfully (Wang *et al.*, 2020). Based on the foregoing, we suggest:

H2a,b. ROC moderates the association of GEO with (a) GPRODI and (b) GPROCI.

Building on the above discussion and guided by the resource-based view and resource orchestration theory, this research attempts to investigate the moderating role of ROC in the GEO–technological GI link in the context of large Yemeni manufacturing firms. Figure 1 depicts the research model.

3. Methods

3.1 Sample and data collection

The suggested model was evaluated using a survey-based approach with data gathered from managers in Yemeni large manufacturing companies. The data collection was done by collaborating with HR departments, using a "convenience sampling" method, which was chosen because there was no available sampling frame. The technique mentioned above is widely used in similar studies (e.g. Al-Swidi *et al.*, 2024). In Yemen, large companies are defined as companies with more than 50 employees (Yemeni Ministry of Industry and

Trade, 2018). The research population includes various manufacturing sectors, including but not limited to "food and beverage, plastics, packaging, pharmaceuticals, and chemical and petrochemical industries".

Prior to gathering data, and with the aim of ensuring the reliability and validity of the scale while preventing data bias, the questionnaire underwent scrutiny by three academics and four practitioners. Based on their feedback and suggestions to enhance the appropriateness and clarity of the items, the questionnaire was revised. To motivate the participants to complete the questionnaire and enhance the response rate, a statement ensuring anonymity was incorporated into the survey. Furthermore, the companies' HR departments were contacted via phone and email to collect responses. This study involved the participation of 400 individuals. Out of 400 questionnaires distributed, 181 were returned, while 177 were deemed complete and suitable for analysis. The final sample consisted of 177 responses, meeting the prerequisites for partial least squares structural equation modelling (PLS-SEM), as Henseler *et al.* (2016) indicated. The literature on PLS-SEM has also indicated that the sample size should be at least 10 times the count of structural paths used for forecasting reflective constructs, and it should also be 10 times the number of formative indicators used for construct measurement, as Hair *et al.* (2021) emphasised. To accurately estimate the minimum sample size, G*Power was used to evaluate the statistical power of the sample size (Faul *et al.*, 2007). By setting a statistical power of 80%, a significance level of 5% and an effect size of 0.15 (Cohen, 2013), we calculated the minimum sample size necessary for 85 cases. As a result, the sample size for this study, comprising 177 cases, was considered sufficient.

Overall, the response rate was approximately 44%. According to Malhotra and Grover (1998), a response rate of 20% is the minimum acceptable level for operations management research. Baruch and Holtom (2008), in their analysis of 1,607 studies published in 17 reputable journals, determined that the average response rate from firms was 35.7%, at a standard deviation of about 18.8. Hence, a response rate of 44% in this study is considered enough for performing statistical analysis and deriving trustworthy findings. Data for this research was gathered throughout two months, from mid-February to mid-April 2023. Table 2 displays the attributes of the participants.

3.2 Measurement

The items to measure the constructs were adopted from earlier research; Measuring GEO involves the use of five items adopted from Habib *et al.* (2020). Technological GI was measured using eight items adopted from Xie *et al.* (2019) and Frondel *et al.* (2007), which evaluate GPRODI and GPROCI. Finally, ROC was measured with three items adopted from Shehzad *et al.* (2023). To ensure consistency among all items in the questionnaire, a Likert scale that ranges from "1 – Strongly Disagree" to "5 – Strongly Agree" was used to evaluate the responses. Appendix includes the constructs along with items used for measurement.

Since the participant's native language is Arabic, the questionnaire was distributed in Arabic. To ensure accuracy and consistency, "an initial version of the questionnaire was created in English and then translated into Arabic. Subsequently, a third party translated it back into English".

3.3 Common method bias

Before conducting hypothesis testing, a "Harman's single-factor" test, recommended by Sarstedt *et al.* (2016), was used to detect any potential common method bias (CMB) issue, as advised by Podsakoff *et al.* (2012). The findings indicate that the data is not affected by CMB, as the variance percentage explained by a single factor is reported at 32.15%, which is

Category	Frequency	%
Gender		
Male	174	98.3
Female	3	1.7
Education		
Secondary and below	7	3.95
Diploma	8	4.52
Bachelor	143	80.8
Master and above	19	10.73
Years of experience		
Below 5 years	36	20.34
5–10 years	52	29.38
More than 10 years	89	50.28
Job position		
Factory manager	2	1.13
Sector manager	8	4.52
Research and development manager	18	10.17
production/manufacturing manager	55	31.07
Financial manager	31	18.08
Marketing manager	63	35.03

Source: Derived from the statistical analysis of this study (SPSS 25)

Table 2. The sample characteristics

less than the threshold of 50%, which confirms the absence of CMB. Consequently, CMB does not pose a concern in the data set.

4. Data analysis and results

For the analysis of the proposed model in the current study, PLS-SEM approach using SmartPLS 4 was applied, adhering to the procedures provided by Ringle *et al.* (2005). The extensive adoption of PLS-SEM in management studies is due to its manifold benefits (Gelaidan *et al.*, 2023). Specifically, when working with smaller sample sizes (Henseler *et al.*, 2009) and emphasising prediction in the research (Al-Swidi *et al.*, 2023), PLS-SEM demonstrates higher statistical power in comparison with "covariance-based SEM" (CB-SEM) when applied to intricate models with constrained sample sizes (Al-Swidi *et al.*, 2023). Overall, the PLS model comprises two interconnected models: the "measurement model" and the "structural model".

4.1 Measurement model

To evaluate the measurement model, the "confirmatory composite analysis (CCA)" approach was used, as described by Hair *et al.* (2018). Both CCA and "Confirmatory Factor Analysis (CFA)" serve to enhance the reliability of items and scales, pinpoint items needing revision or potential elimination for content validity, aid in attaining convergent and discriminant validity and minimise error variance. In comparison to CFA, CCA offers distinct advantages, namely:

- greater retention of items for construct measurement, enhancing both construct validity and content coverage;
- availability of determinant construct scores; and
- applicability of CCA to formative measurement models as well (Hair *et al.*, 2020).

According to Nunnally and Bernstein (1994), reliability requires values over 0.70 for "Cronbach's alpha" and "composite reliability". In addition, the construct validity was assessed using the "convergent validity" and "discriminant validity", according to the procedures suggested by Hair *et al.* (2018). Convergent validity was confirmed by ensuring that the "average variance extracted" for each construct surpassed 0.50, in accordance with the recommendation by Hair *et al.* (2018). Moreover, the factor loadings of items displayed in Table 3 and Figure 2 needed to surpass a minimum threshold of 0.70 (Hair *et al.*, 2018).

Furthermore, the "Heterotrait–Monotrait (HTMT)" criteria were used to evaluate discriminant validity. As per Henseler *et al.* (2015), HTMT matrix values, particularly among the constructs, should not exceed 0.90. As shown in Table 4, all values did not exceed the threshold, which indicates the discriminant validity of the model.

The fulfilment of the validity and reliability criteria can be observed in Tables 3 and 4, which indicates that the measurement model is indeed valid.

4.2 Structural model

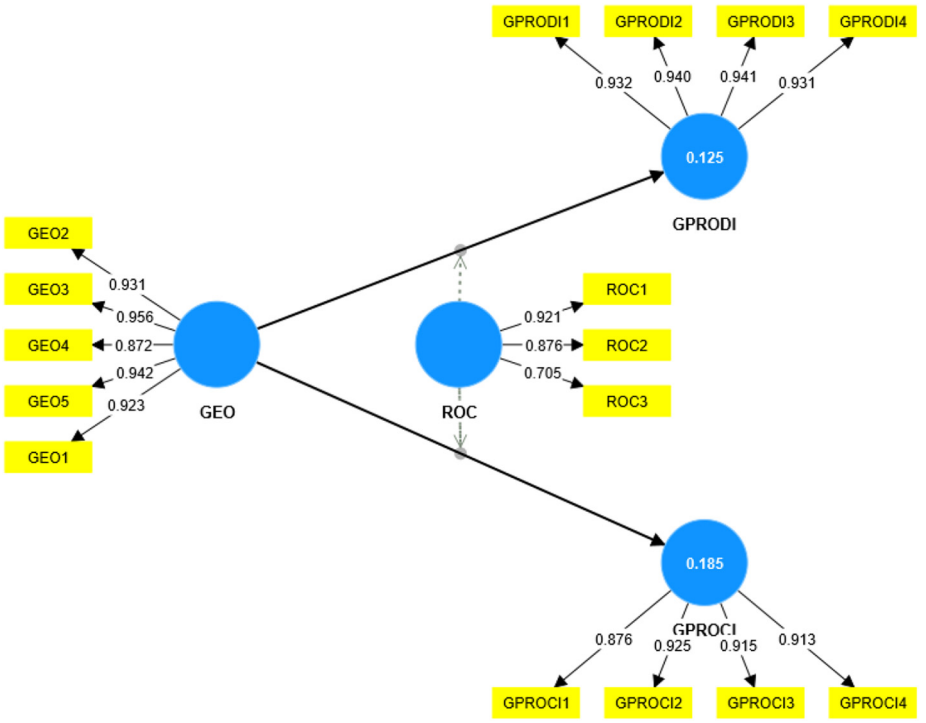
Before testing the proposed relationships through structural model, the model fit is evaluated in SEM-PLS using the "standardised root mean square residual (SRMR)". As recommended by Henseler *et al.* (2015), the SRMR value should be below 0.08 to ensure an accurate model fit. The results demonstrate that the SRMR value was 0.06, which reflects a satisfactory level of goodness of fit (Hu and Bentler, 1999).

After that, the study model's explanatory power was assessed by examining the explained variance (R^2) of the endogenous constructs, were the R^2 values for GPRODI and GPROCI were (0.125) and (0.185), respectively, as presented in Table 5. To assess these results, we can refer to Chin's guidelines for prediction, where an R^2 value of 0.10 signifies weak prediction, 0.33 indicates moderate prediction and 0.67 suggests large prediction (Chin, 1998). In addition, we used Cohen's f^2 guidelines, as proposed by Cohen (2013), to assess the effect size of each predictor. The f^2 values of 0.35, 0.15 and 0.02, as classified by Cohen (2013), are considered "large", "medium" and "small", respectively (refer to Table 5).

Table 3.
Loadings, reliability and convergent validity

Construct	Code	Loading	α	CR	AVE
GEO	GEO1	0.923	0.958	0.959	0.856
	GEO2	0.931			
	GEO3	0.956			
	GEO4	0.872			
	GEO5	0.942			
ROC	ROC1	0.921	0.805	0.993	0.704
	ROC2	0.876			
	ROC3	0.705			
GPRODI	GPRODI1	0.932	0.953	0.959	0.876
	GPRODI2	0.940			
	GPRODI3	0.941			
	GPRODI4	0.931			
GPROCI	GPROCI1	0.876	0.928	0.932	0.824
	GPROCI2	0.925			
	GPROCI3	0.915			
	GPROCI4	0.913			

Notes: α = Cronbach's alpha; CR = composite reliability and AVE = average variance extracted
Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)



Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)

Figure 2.
Measurement model

Construct	GEO	ROC	GPRODI	GPROCI
GEO				
ROC	0.091			
GPRODI	0.205	0.115		
GPROCI	0.403	0.185	0.072	

Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)

Table 4.
Heterotrait–monotrait ratio (HTMT)

Constructs	R^2	Q^2	f^2 in relation to GPRODI	f^2 in relation to GPROCI
GEO			0.040	0.177
ROC			0.001	0.027
GPRODI	0.125	0.087		
GPROCI	0.185	0.137		

Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)

Table 5.
R^2, prediction and effect size

Along with R^2, the predictive quality of the model was evaluated using the Q^2 measure. The Q^2 measure is obtained through the blindfolding technique, which involves using resampling procedures to compare the original and estimated data (Stone, 1974). This technique helps determine the predictive relevance of the model. Fornell and Cha (1994) suggested that to validate predictive relevance, the values of Q^2 for the predictive variables should exceed zero. In line with this, the results of Q^2 for GPRODI and GPROCI were above zero (see Table 5).

The findings of the hypotheses testing are displayed in Table 6, where the results reveal that direct paths in the model were positively and significantly related (refer to Figure 3). As a result, *H1a*, *H1b* are supported.

Table 6.
Direct and interactive effects

H	Path	β	*t*-value	*p*-Value	Result
H1a	GEO → PRODI	0.187***	2.514	0.012	Supported
H1b	GEO → PROCI	0.380***	6.114	0.000	Supported
H2a	ROC * GEO → GPRODI	0.267***	2.814	0.005	Supported
H2b	ROC * GEO → GPROCI	−0.114	1.432	0.152	Not supported

Notes: *t*-values > 1.96; *** $p < 0.05$
Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)

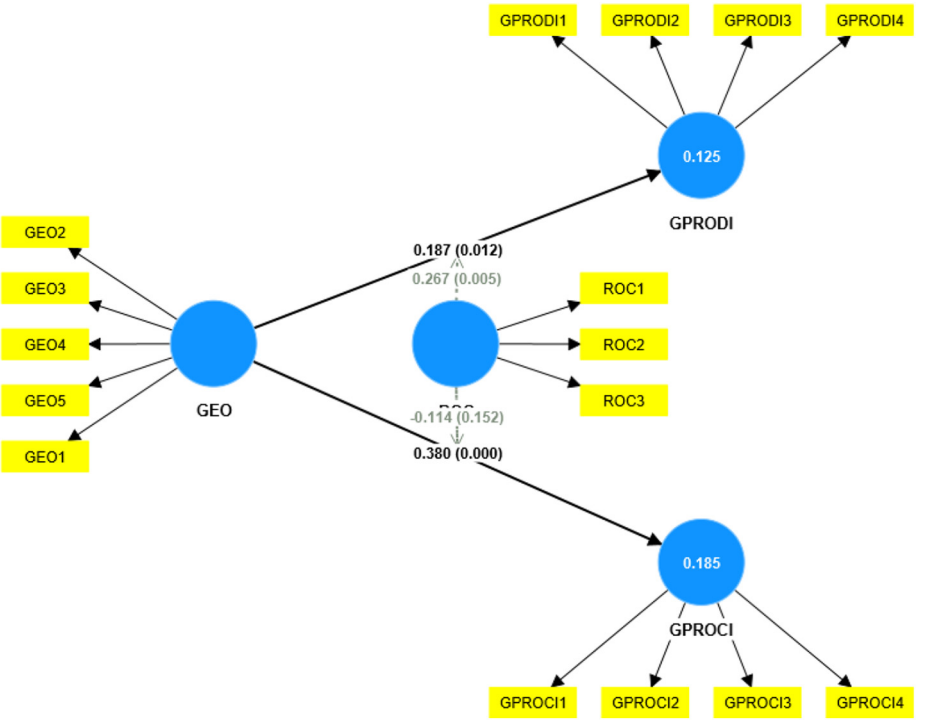


Figure 3.
Structural model

Source: Derived from the statistical analysis of this study (Smart-PLS 4.0)

In addition to the direct effects, we looked into the interactive effects of ROC and GEO on both GPRODI and GPROCI. The findings demonstrated that ROC has a positive and significant moderating effect on the GEO–GPRODI link ($\beta = 0.267$, $p < 0.05$); therefore, *H2a* is supported (refer to Figure 4). On the contrary, the moderating effect of ROC on the GEO–GPROCI path ($\beta = -0.114$, $p > 0.05$) is not significant and, therefore, *H2b* is not supported.

5. Discussion

Guided by the resource-based view and resource orchestration theory, the current study examined the effect of GEO on technological GI. Notably, the moderating effect of ROC between GEO and technological GI (with its dimensions GPRODI and GPROCI) was investigated. Through a quantitative research approach with data collected from Yemeni large manufacturing companies, this research presented responses to these questions:

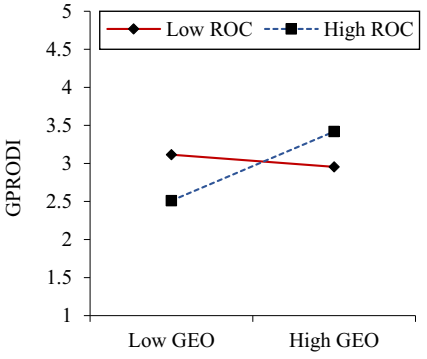
RQ3. How does GEO affect technological GI (GPRODI and GPROCI)?

RQ2. Does ROC moderate the GEO–technological GI relationship?

Overall, the findings of the present research confirmed that GEO significantly and positively affects GPRODI. This is consistent with the findings of Tuan (2023) and Ullah and Danish (2020), who identified the same link between GEO and GPRODI for manufacturing enterprises. This suggests that GEO adoption in companies plays a vital role in improving their GPRODI. Therefore, many firms view GEO as an important strategy to boost GPRODI and mitigate potential ecological damage (Mazzucato, 2016).

Similarly, the findings confirm that GEO positively and significantly affects GPROCI, which is in line with the previous studies (e.g. Frare and Beuren, 2022). Interestingly, we found that GEO's effect on GPROCI is higher than on GPRODI. These results reflect the importance of GEO for promoting sustainability, for example, in thinking, creation, innovations, motivations and operations, which bring superior competitive advantages in emerging economies (Alshebami, 2023; Asadi *et al.*, 2020; Guo *et al.*, 2020; Majali *et al.*, 2022; Jiang *et al.*, 2018), and developed economies (Skordoulis *et al.*, 2022).

Furthermore, our study highlights the importance of ROC, illustrating that ROC moderates the GEO–GPRODI relationship, as GOC adoption can aid firms to tap the full potential of GEO, which is crucial for GPRODI. Firms with a low level of ROC are likely to



Source: Authors' own work based on the statistical analysis

Figure 4.
Interactive effect of ROC and GEO on GPRODI

have a limited scope for exploration and may experience difficulties in discovering valuable knowledge, as noted by Zhou and Li (2012). Consequently, these firms might face reduced opportunities to absorb and apply knowledge for the generation of innovative ideas (Lane *et al.*, 2006), which reduces their GPRODI. On the contrary, when ROC is high (Luo *et al.*, 2017; Wang *et al.*, 2020). This suggests that the variations in GPRODI across firms in the same market and industrial environment can be attributed to firms' internal capabilities in resource use. Accordingly, our study supports the viewpoint presented by Wang *et al.* (2020), that ROC has a moderating role in facilitating GI.

However, the findings reveal that ROC does not significantly moderate the GEO–GPROCI link, i.e. firms with higher ROC are less likely to enhance their GPROCI from higher GEO.

5.1 Theoretical implications

This research makes notable contributions to the extant literature in many ways. By combining the theoretical lens of the resource-based view and resource orchestration theory frameworks, this study contributes to the expanding body of knowledge on the link among GEO, ROC and technological GI. In addition, this research highlights the internal factors associated with GI. While previous studies primarily concentrate on the external factors that impact the adoption of GI practices, there is a scarcity of research examining the internal factors associated with GI. Despite GEO being an important internal factor for a company, there is limited research on its relationship to technological GI (GPRODI and GPROCI). Consequently, this research contributes to the existing body of knowledge in the field of GI theory by providing valuable insights into this area.

Furthermore, while some studies have empirically explored the GEO–GI link (e.g. Alshebami, 2023; Muangmee *et al.*, 2021), their attention has mostly been on the direct effect of GEO on GI, without delving into the conditions under which GEO affects GI, particularly GPRODI and GPROCI. On the other hand, our study extends the work of Guo *et al.* (2020), who investigated the mechanisms through which GI can be fostered in green entrepreneurship-oriented firms by revealing that ROC moderates the GEO–GPRODI link. In comparison to the study by Shehzad *et al.* (2023) on the moderating role of ROC, our findings suggest that the GEO–GI link is more likely to be complex and holistic than narrow-scoped. Likewise, the adoption of ROC enables firms to exploit their resources (in our case, GEO) internally and externally to drive innovation and adapt to dynamic market conditions. As such, based on resource orchestration theory, this research investigates this unknown part in the existing literature by exploring the interactive effect of ROC and GEO on technological GI.

Finally, the present study enriches knowledge about GEO, ROC and technological GI in the context of manufacturing firms in LDCs. Because a research discovery is confined to its particular context, its applicability to a wider context is limited. In line with Eisenhardt's (1989) fundamental principles, the broader generalisation should pertain to theory and knowledge rather than the specific findings. Therefore, the study outcomes are anticipated to present useful insights applicable not only to the specific context but also to both developed and developing economies in a broader sense.

5.2 Practical implications

This study has many practical and managerial implications that are noteworthy for managers and policymakers in various fields. From an industry standpoint, the results confirm GEO's important role in the manufacturing industries to achieve GI goals. Therefore, the managers and policymakers should adopt GEO as a practice and culture for GI within the organisation, motivating teams to devise environmentally conscious solutions for products and processes. This, in turn, boosts the company's reputation as an eco-friendly industry leader, attracting

environmentally-conscious customers and investors. Overall, embracing GEO empowers manufacturing firms to drive innovation, gain competitive advantage and contribute positively to the environment and society. Therefore, manufacturers must integrate sustainability principles into their strategic and operational plans. This aims to enhance financial outcomes, safeguard the environment and enhance societal well-being (Al-Koliby *et al.*, 2022). For policymakers, especially those aiming to promote technological GI among local companies, particularly in the initial phases, it is crucial to emphasise the adoption of GEO by companies. One strategy can involve formulating training program policies strategically designed to encourage companies to foster their GEO. This can be facilitated through absorbing, incorporating and effectively leveraging strategically valuable knowledge to generate distinctive concepts. In doing this, policymakers can effectively create a favourable environment for GI, while strengthening GPRODI and GPROCI.

Furthermore, research confirms that ROC is crucial in promoting technological GI, particularly GPRODI. In the context of large manufacturing enterprises in Yemen, ROC can foster the positive impact of GEO on GPRODI. Therefore, the adoption of GEO by manufacturing firms becomes even more impactful in supporting GI. Overall, through its interaction with GEO, ROC enables firms to transform their eco-friendly intentions into tangible innovations, enhancing their competitiveness in sustainability-focused markets. This result addresses the query of when, even with GEO's high level adopted in the company, there might be a deficiency in the advancement of GI, specifically in relation to GPRODI. Such heterogeneity can be linked to the different levels of firms' adoption of ROC.

5.3 Social and economic implications

This study carries significant social and economic implications, particularly for LDCs like Yemen, characterised by economic instability, fierce competition and diversity in its emerging economy. In Yemen, manufacturers operate within a competitive landscape where differentiation through unique value offerings at a lower cost is pivotal (Al-Hakimi *et al.*, 2021, 2022b). From an economic perspective, this research underscores the role of green entrepreneurs in addressing critical issues such as unemployment, poverty and environmental stewardship. Unlike large manufacturing firms with a strong GEO can make substantial contributions to their society by implementing green practices. These practices include reducing hazardous waste, offering green education programs, conducting green workshops, organising eco-friendly practices and developing green products that add value to ecological initiatives. By embracing green practices, manufacturers in both less developed and developing economies can promote sustainability, alleviate poverty, reduce stakeholder pressure and enhance their GDP (Karikari Appiah *et al.*, 2023). Large firms that adopt such practices significantly foster job creation, increase income levels and drive economic growth. Furthermore, this study introduces a novel model that underscores the interdependent relationship between GEO, technological GI and ROC. It emphasises the importance of firms being able to swiftly respond to the environmental needs of their stakeholders in emerging economies. Through ROC, companies can implement technological GI to meet those needs effectively and efficiently. By enhancing their systems and processes, businesses can reduce environmental impact, thus, benefitting both society and the economy.

From a social perspective, manufacturing firms in Yemen confront intense global market competition (Battour *et al.*, 2021). This study recognises the prevailing environmental challenges in Yemen, resulting from the energy sector, manufacturing industries and ongoing conflicts. These challenges have contributed to adverse economic, environmental and social consequences, including a decline in GDP (Al-Swidi *et al.*, 2022). It is essential to recognise the limited availability of resources in such contexts. Thus, the study seeks to

identify the critical resources that can enable Yemeni manufacturers to thrive in emerging economies and societies.

In addition, integrating social and environmental advantages via resource-efficient initiatives can substantially benefit the environment (Rus-Casas *et al.*, 2020). There is substantial evidence suggesting that the business environment profoundly affects manufacturing success. The social environment's stability can positively and negatively affect manufacturing activities (Bu, 2023). Prioritising technological GI can help mitigate the adverse ecological effects of business activities and enhance social well-being (Borghesi *et al.*, 2015). Manufacturers can achieve increased production efficiency, better decision-making and enhanced business performance by focusing on technological GI, leading to more significant environmental and social contributions. Thus, supporting and promoting GEO and technological GI can empower businesses to remain competitive in traditional entrepreneurship while simultaneously making meaningful economic, social and environmental contributions.

6. Conclusions and limitations

This empirical research was conducted on large manufacturing companies located in Yemen. The findings from this research enrich our comprehension of the topic and fill a substantial void in the existing sustainability literature. Overall, this study puts forward a novel framework, drawing on the resource-based view and resource orchestration theory as theoretical lenses, which provides a more comprehensive perspective on the connection between GEO and technological GI (specifically GPRODI and GPROCI), considering the moderating influence of ROC. The results of the research offer convincing proof that GEO is the best option for firms aiming to increase their innovation in going green. Firstly, GEO enhances both GPRODI and GPROCI, with a more pronounced impact observed on GPROCI. Secondly, the most intriguing conclusion was the empirical evidence of the moderating impact of ROC on the relationship between GEO and GPRODI, in contrast to a firm's GPROCI, which is significantly influenced by GEO regardless of its GOC level.

In line with the work of Eisenhardt (1989), this finding transcends its particular context and holds importance in its potential impact on a significant segment of society, as highlighted by Jordão *et al.* (2022). From this standpoint, it is anticipated that this research will provide valuable insights relevant to various domains, encompassing economics, management, technological advancements, societal dynamics and environmental considerations, applicable to both mature and emerging markets.

Similar to other research, this research is subject to some limitations. Firstly, the survey used in this study relies on "self-reported measures" that are likely subject to CMB. Despite implementing various procedures to minimise this bias, this issue may persist (Hair *et al.*, 2018). Therefore, future studies could use longitudinal data to prove these results. Secondly, given that this research solely concentrated on large enterprises in LDCs, like Yemen, future research could explore SMEs or firms operating within other environments, including developed and developing, to generalise the findings. Thirdly, in terms of variables, our study solely focused on examining ROC as a moderator in the GEO–technological GI relationship without delving into the possible mediating mechanism. Subsequent investigations may consider incorporating additional variables to provide a more holistic insight into this connection. In addition, future studies could delve into the potential mediating role of ROC within this specific context.

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Further reading

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Appendix. Questionnaire items

Items

(1) Green entrepreneurial orientation:
- GEO1. In general, our firm favours a strong emphasis on green practices, such as R&D, technological leadership and innovation.
- GEO2. When facing uncertainty, we typically adopt a proactive posture to catch potential green opportunities.
- GEO3. In dealing with competitors, we typically initiate green actions that competitors respond to.
- GEO4. Our firm favours a tendency to be a leader, and always introduce green products, service or technology first.
- GEO5. In dealing with competitors, we typically adopt a competitive "undo-the competitors" posture.

(2) Resources orchestration capability:
- ROC1. Our firm has the capability to absorb all kinds of knowledge resources.
- ROC2. Our firm has the capability to integrate all kinds of knowledge resources.
- ROC3. Our firm has the capability to use all kinds of knowledge resources.

(3) Green product innovation:
- GPRODI1. Our firm makes changes to product designs to avoid polluting or toxic compounds within production processes.
- GPRODI2. Our firm improves and designs eco-friendly packaging for existing and new products.
- GPRODI3. Our firm makes product design modifications aimed at improving energy efficiency during usage.
- GPRODI4. Our firm uses eco-friendly material.

(4) Green process innovation:
- GPROCI1. Our firm designs processes that reduce the consumption of resources and energy.
- GPROCI2. Our firm uses environmental technologies.
- GPROCI3. Our firm uses pollution-control equipment.
- GPROCI4. Our firm adopts pollution-control projects and technologies.

Source: Authors' own work based on the literature review

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