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Tackling grand societal challenges: Understanding when and how reverse engineering fosters frugal product innovation in an emerging market

Samuel Adomako[1] | **Michael Asiedu Gyensare**[2] | **Joseph Amankwah-Amoah**[3] | **Pervaiz Akhtar**[4] | **Nazim Hussain**[5]

[1]Birmingham Business School, University of Birmingham, Birmingham, UK
[2]School of Business and Law, Edith Cowan University, Joondalup, Western Australia, Australia
[3]Kent Business School, University of Kent, Canterbury, UK
[4]University of Aberdeen Business School, University of Aberdeen, Aberdeen, UK
[5]Faculty of Economics and Business for Nazim, University of Groningen, Groningen, The Netherlands

Correspondence
Joseph Amankwah-Amoah, Kent Business School, University of Kent, Canterbury, UK.
Email: j.amankwah-amoah@kent.ac.uk

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Abstract

Societies are confronted with grand challenges that require the efforts and coordination of diverse stakeholders. In this context, the role of for-profit organizations has become vital in addressing such challenges. Drawing on the strategy tripod perspective, this study investigated the influence of reverse engineering on frugal product-innovation performance (PIP) through the mediating effect of frugal innovation (i.e., cost innovation, and affordable value innovation). In addition, we examined the moderating impact of the industry environment (i.e., technological turbulence) and institutional context (i.e., legal inefficiency) on this relationship. We tested our hypotheses using time-lagged data from 243 small to medium-sized enterprises (SMEs) in an emerging economy—Ghana. Results from our analyses show that several of our hypotheses are supported which offers important implications for the indirect impact of reverse engineering on frugal product-innovation performance in the context of resource-constrained emerging markets. These findings extend the grand challenges, strategy, and innovation literature.

KEYWORDS
frugal innovation, Ghana, grand challenges, innovation, institutional environment

1 | INTRODUCTION

Policymakers, nongovernmental organizations as well as for-profit businesses have recognized the need to tackle the societal grand challenges (Olsen et al., 2016; Voegtlin et al., 2022; Williams & Shepherd, 2016). Extant research has defined grand challenges as "specific significant barrier(s) and problems in society, [which] if addressed and scaled-up would likely deliver greater national and possible global impact" (see George et al., 2016, p. 4). Grand societal challenges such as extreme poverty, climate change, healthcare, migration, energy, and national security can have negative impacts on the global population (Voegtlin et al., 2022). This calls for the need to alleviate these challenges, especially in environments characterized by resource scarcity (Hossain et al., 2016; Nylund et al., 2021). Innovations that promote inclusion, creativity, and opportunities are crucial for addressing grand societal challenges (Khavul & Bruton, 2013; Voegtlin et al., 2022). For example, frugal innovation is an important panacea for reducing complexity and production costs (Dabić et al., 2022; Nylund et al., 2021). Frugal innovation reflects "a resource-scarce solution" devised and executed irrespective of the financial, economic, technological, or other resource limitations (Dabić et al., 2022; Hossain et al., 2016, p. 133; Levänen et al., 2022).

Given that poverty includes inadequate income, the deprivation of consumption, and lack of opportunities (Nakata & Weidner, 2012), innovation anchored in affordability is critical for emerging-market customers. Policymakers have identified innovations as vital mechanisms through which poverty in emerging and developing economies can be further alleviated (Hall et al., 2012; Hart, 2007), thereby bringing many impoverished people who have suffered social exclusion into the global economy (Behrman et al., 2003). Firms operating in resource-constrained environments are considered important agents of change (Aguilera et al., 2007). These firms are critical for developing innovations that can potentially alleviate poverty and inequality. Instructively, the orientation toward grand challenges has created innovation priorities for firms in alleviating poverty in emerging markets, making these economies a hotbed for the use and integration of technology in enhancing economic activities (Agarwal & Brem, 2012; Li & Kozhikode, 2009).

Frugal innovation offers various low-technology entrepreneurial opportunities and improvisation that meet the needs of local people (Radjou et al., 2012). Furthermore, several classifications have emerged in the frugal innovation literature such as "cost innovations," "affordable value innovation" (AVI), and "jugaad" (Christensen & Raynor, 2013; Zeschky et al., 2011). The consensus is that they all refer to the concept of frugality whereby the specific needs of consumers are developed from scratch to reduce cost.

However, the frugal innovation literature points to a fragmented picture where researchers have pursued a diverse set of objectives. In particular, recent studies have investigated knowledge sources (Dost et al., 2019); institutional context and resourcefulness (Cai et al., 2019); and bricolage, local embeddedness, and standardization as antecedents of frugal innovation (Ernst et al., 2015). Additionally, prior research has examined the effect of frugal innovation on sustainability (Iqbal et al., 2020), and firm performance (Cai et al., 2019). Though our understanding of the outcomes of frugal innovation (see Hossain et al., 2016) has improved, much effort is required to delineate the role of frugal innovation in domestic firms (Hossain, 2018). As such, recent studies have called for new research that tackles grand challenges through innovation (Grodal & O'Mahony, 2017; Howard-Grenville et al., 2014; Schroeder & Kaplan, 2019). This study was motivated by the limited scholarly insights into how small firms in emerging markets contribute to tackling grand challenges such as poverty via frugal innovation. This is crucial because the rise in societal grand challenges calls for a creative problem-solving approach such as innovation (cf. Arslan et al., 2020; Selsky & Parker, 2005). Thus, this study answers the following question: how do firms based in emerging markets address grand societal challenges?

Practitioner points

- Reverse engineering positively affects cost innovation and affordable value innovation (AVI) in emerging markets.
- The influence of reverse engineering on cost innovation is amplified when technological turbulence is high.
- Technological turbulence attenuates the impact of reverse engineering on AVI.
- Legal inefficiency in emerging markets strengthens the impact of reverse engineering on AVI.
- The effect of reverse engineering on frugal product-innovation performance is mediated by cost innovation and AVI.

This study contributes to the innovation and grand societal challenges literature in several ways. Firstly, this study broadens the scholarly scope of the antecedents of frugal innovation (i.e., cost innovation, and AVI) and how these impact on innovation performance of indigenous firms based in resource-constrained markets. In particular, extant frugal innovation studies in and for emerging economies have not explored how capability development (e.g., reverse engineering) by local firms could improve frugal innovation performance (Ernst et al., 2015; George et al., 2012). The essence of reverse engineering in emerging markets is that it makes new technology adoption and product development easier by shortening the time for acquiring such complex technologies. In addition, reverse engineering enables indigenous firms to promptly identify knowledge components for a product to serve customer needs and create customer value (cf. Malik & Kotabe, 2009).

Furthermore, given the growing number of firms in emerging markets adopting and implementing grand challenge-oriented practices such as poverty alleviation, gender inclusions, and environmental sustainability (Ferraro et al., 2015; Howard-Grenville, 2021), a more complete understanding is needed regarding the avenues for firms to address the grand societal challenges through innovation (Doh et al., 2019; Stilgoe et al., 2013). However, the current literature offers little insight into how indigenous firms in emerging economies can serve as agents of social change through innovation (Aguilera et al., 2007) in addressing societal grand challenges. Thus, our study shed new light on local small to medium-sized enterprises (SMEs) which are considered the engine of growth for emerging markets (see also Gherghina et al., 2020), and their role in contributing to addressing grand societal challenges.

In addition, we respond to calls for research that highlights conditions under which firm-level capability mechanisms can impact both costs and AVI (Cai et al., 2019; Ernst et al., 2015). This study highlights two such boundary conditions—technological turbulence and legal inefficiency—under which reverse engineering impacts the innovation performance of local small firms. The inclusion of these moderators is justified because prior studies suggest that the improvement in technology could impact the potency of firm innovation (Nakata & Weidner, 2012). Relatedly, extant research suggests that institutions are the background conditions for innovation infrastructure in developing countries (Peng et al., 2008).

Finally, we investigate cost innovation and AVI as the two key types of frugal innovations that mediate the link between reverse engineering, and product-innovation performance in emerging-market firms. Thus, we provide a clear picture of the distinctive mechanism through which capability development by small firms influences innovation performance (Alegre & Chiva, 2008; Prajogo & Ahmed, 2006).

2 | THEORETICAL BACKGROUND AND HYPOTHESES

2.1 | The strategy tripod perspective

Prior studies have adopted the strategy tripod view to explain the effect of firm capability, and innovation, on firm performance. Additionally, the extant literature has explored the moderating effect of institutional, and industry-level factors on the linkage between innovation, and firm performance (Bao et al., 2021; Su et al., 2016; Zhu et al., 2019). Our study follows these prior studies in addressing our key objectives. The strategy tripod view integrates three main perspectives to explain how industry, resources, and institutional factors impact firm performance. These key theoretical milieus are industry, resource, and institutional-based views (Bao et al., 2021; Lahiri et al., 2020; Peng et al., 2008, 2009). This theoretical perspective fills the gaps in the industry and resource-based perspectives. Factors related to the industry level are captured in the industry-based perspective which postulates that industry environment factors (e.g., technological turbulence, competitive intensity, and dynamism) explain variations in a firm's performance. It further suggests that firms can achieve a stronger competitive advantage by changing their industry position through competitive strategies (Boter & Holmquist, 1996; Porter, 1985). Given the heterogeneous, and idiosyncratic nature of resources, it has been suggested that the achievement of a stronger competitive position can be realized when a firm leverages its firm-specific, valuable, rare, and inimitable resources, and capabilities (Barney, 1991). However, this view has come under criticism as resources alone might not enable firms to develop a competitive advantage. Firms need capabilities to deploy resources effectively for value creation and improving its competitive position (cf. Teece, 2007; Teece et al., 1997).

While both perspectives highlight strategies for stronger competitive positioning, they ignore an important component of the business environment (i.e., institutional environment). The institutional perspective highlights the role of the institutional context on firm outcomes (Peng, 2017). The institutional perspective argues that the institutional context of a firm shapes its behavior and strategic choices (cf. Kim et al., 2010; Peng, 2003). Moreover, the institutional-based perspective suggests that firm outcomes reflect the constraints inherent in a particular institutional framework confronted by the firm (Peng et al., 2008). Although these three perspectives highlight important factors that may affect the firm, they focus on different levels of analysis. For example, the industry-based perspective considers external industry factors (e.g., technological turbulence) while the resource-based perspective identifies internal firm resources, and capabilities (e.g., reverse engineering). In addition, provided that the institutional-based perspective reflects the rules of the game that define socially acceptable behaviors highlights factors such as legal inefficiency and regulatory bodies (Dimaggio & Powell, 1983; North, 1990; Scott, 1995).

Given that each of the theoretical perspectives highlights different views on strategy, none can provide a complete picture of a firm's strategic choices, rather a combination of insights from all three perspectives provides a comprehensive view of the complex firm strategy and competitive advantage (Yamakawa et al., 2008). For instance, previous studies have criticized the resource-based view for not providing many insights into the role of contexts in the strategic decision-making of firms (Priem & Butler, 2001; Su et al., 2016). Thus, the strategy tripod perspective integrates the three key perspectives to form an overarching theoretical perspective to highlight the shortcomings of a single theory (Peng et al., 2009).

Previous research has utilized the tripod view to examine various phenomena (Cui et al., 2011; Yamakawa

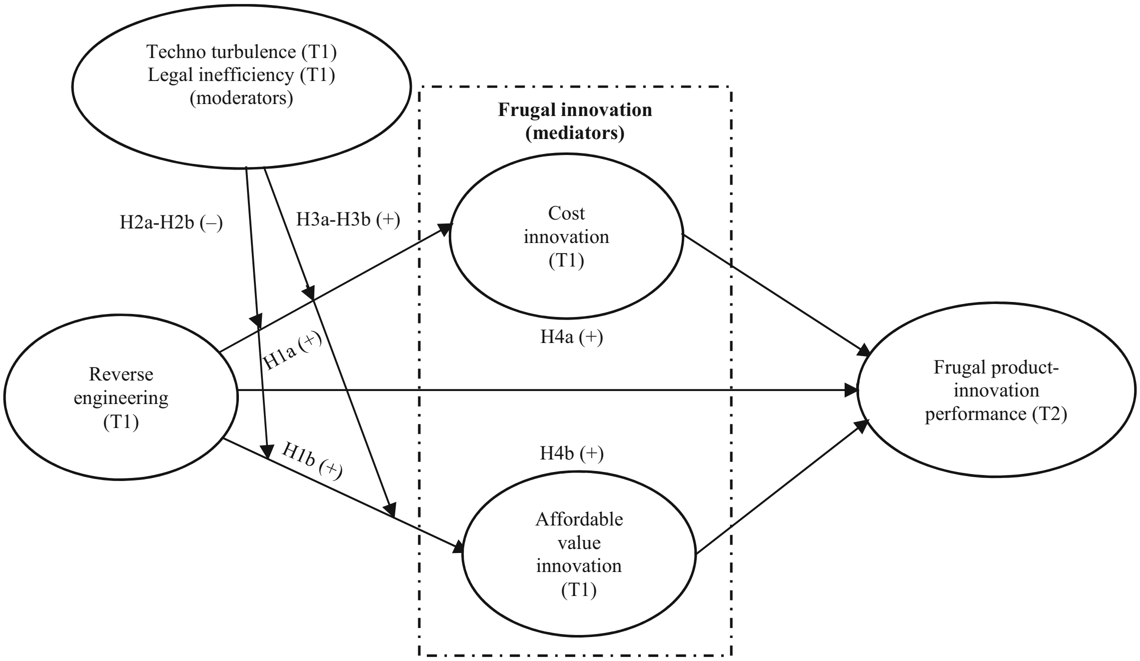

FIGURE 1 Research model.

et al., 2008; Zhu et al., 2019). While this body of research has explained the predictive nature of the strategy tripod view, they only accounted for the individual role of industry, resource, and institutional factors on firm outcomes (Su et al., 2016). In addition, highlights the interactive nature of the variables that constitute the strategy tripod perspective (Peng, 2017). Thus, by integrating these three perspectives, we generate more synergistic insights into their explanatory and predictive power in understanding how small firms based in emerging markets address grand challenges. Such perspectives also offer a clearer understanding of the processes and conditions that shed light on the mitigation or amplification of grand challenges (cf. Howard-Grenville, 2021). Grand challenges are often complex, and a reverse-engineering approach can help to scrutinize a complex system for inferring how the mechanism can work better and suit the desired environment (Faggini et al., 2021).

Our study considers technological turbulence as an industry condition (De Vaan, 2014; Song et al., 2005), legal inefficiency as an institutional factor (Lee & Tang, 2018; Zhu et al., 2019), reverse engineering (Adomako et al., 2022; Malik & Kotabe, 2009; Samuelson & Scotchmer, 2002), and frugal innovation as firm-level capabilities. The conceptual model in Figure 1 reflects one dynamic capability-development factor that is crucial for innovation performance in emerging-market SMEs. We integrate industry and institutional conditions as moderators of the linkage between reverse engineering. In addition, we consider frugal innovation as a firm-level capability. Accordingly, we suggest that the effect of reverse engineering on product-innovation performance is mediated by frugal innovation. Thus, we integrate the strategy tripod perspective into product-innovation performance in the hypothesis development section of this article. We argue that the utility of the strategy tripod perspective leads to improved innovation performance. In the sections that follow next, we align the model variables with the proposed hypotheses.

2.2 | Reverse engineering and frugal innovation

Emerging-market firms have limited resources, but they are trying harder to catch up with innovative firms from advanced markets (cf. Kumaraswamy et al., 2012; Liu et al., 2011; Malik & Kotabe, 2009). This reflects the important nature of capability building by emerging-market firms. For example, reverse engineering, a major capability-building strategy in emerging markets, provides important opportunities for firms to catch up quickly with technology by imitating the knowledge embedded in foreign technologies (Adomako et al., 2022; Kumaraswamy et al., 2012). Reverse engineering reflects the knowledge acquired by a firm through disassembling products and observing its technical units that allow the firm to imitate and enhance its product designs (Samuelson & Scotchmer, 2002). It is considered a firm-level dynamic capability in resource-constrained emerging-market firms derived from knowledge spillovers from competing products and ideas (Malik & Kotabe, 2009). Indeed, firms that can acquire and utilize valuable, rare, and inimitable are likely to improve their competitive position (Barney, 1991). Given the low R&D capabilities, product imitation strategy is considered a major mode of product development in emerging markets. Thus, firms focus on experiential methods of product development through improvisation, iteration, and frequent testing procedures to mitigate the uncertainty in new product introduction (Eng & Quaia, 2009; Kumaraswamy et al., 2012). One of the components of the strategy tripod view is the capability or resources of firms. Given that reverse engineering is a firm-level capability (Malik & Kotabe, 2009), firms can gain a sustainable competitive advantage by using their capabilities to utilize their resources efficiently (see Barney, 1991 for detailed analysis). Through reverse engineering, emerging-market firms gain follower advantages mimicking existing product attributes and it offers these firms an important route to catch up with advanced-market firms (e.g., Kumaraswamy et al., 2012).

In emerging markets, improvisation and iteration of new solutions using limited resources are considered a breakthrough in resource-constrained contexts (Halme et al., 2012). Provided that R&D activities in resource-constrained environments need to focus on cost and affordable value, reverse engineering is a critical capability to help firms achieve low-cost innovations and affordability which can be vital in addressing grand challenges in emerging markets. Firms that provide affordability in new products are likely to achieve success in these economies (Nakata & Weidner, 2012; Rogers, 2003). Through reverse engineering, firms in emerging markets can reduce costs and deliver value through alternative, unconventional, and iterative solutions (Ernst et al., 2015; Weiser et al., 2006). It has been suggested that frugal innovation translates into innovations in environments characterized by scarcity of affluence (Cunha et al., 2014). This type of innovation is different from bricolage which reflects when material and time resources are limited.

The frugal innovation literature suggests that the resource-constrained settings of emerging markets motivate firms to produce products that are affordable to meet the demands of customers who have limited financial resources (Agarwal et al., 2017; Hossain, 2018, 2020). Frugal innovation encompasses resource-scarce products or services targeted at underserved markets which are often cheaper relative to offers by competitors (Hossain et al., 2016, p. 133). Thus, frugal innovation is motivated by the demands of low-income consumers in emerging markets. This type of innovation is critical for poverty alleviation (Hossain, 2018, 2020; Lim & Fujimoto, 2019).

Reverse engineering is characterized by learning that tends to mimic the innovative activities of other firms. In addition, reverse engineering has the potential to offer products that target low-income customers. Thus, we consider reverse engineering as a firm-level capability (Malik & Kotabe, 2009) that contributes to the variations in frugal innovation in firms operating in emerging economies. As such, it has the potential to deliver inclusive growth and minimize inequality between developed and developing nations (Hossain, 2020). Given that reverse engineering is anchored in marshaling processes, mimicking the routines and technologies of existing firms and materials to develop low-cost products (Hossain et al., 2016; Lim & Fujimoto, 2019), it has the potential to help firms generate cost innovation and AVI that can be conducive to tackling grand challenges in emerging markets. Since emerging markets are away from the technology frontier, reverse engineering offers them the opportunity to design products that can provide solutions to customers who are unable to afford high-end products. These arguments lead us to suggest that:

Hypothesis 1a. Reverse engineering has a positive influence on cost innovation.

Hypothesis 1b. Reverse engineering has a positive influence on affordable cost innovation.

2.3 | The moderating role of technological turbulence

The strategy tripod view advocates investigating the interaction of resources, industry, and institutional factors to explain how the value of resources may vary with the industry and institutional forces (Lu et al., 2010; Su et al., 2016). In response to the strategy tripod view, we investigate the role played by technological factors such as turbulence on the link between reverse engineering and frugal innovation. Technological turbulence is an industry factor that refers to frequent flux and uncertainty relating to production or service technologies (Slater & Narver, 1994, p. 51). In other words, it indicates the extent of technological changes in an industry that results in uncertainty about future technological advancement. Typifying the contemporary emerging economies is a rapidly changing business environment that requires firms to make timely changes to stay in alignment with customers' needs and preferences (Bstieler, 2005; Zhang et al., 2022). Some of the changes are precipitated by technological turbulence, which requires firms to find creative ways to utilize the limited resources in their environment. When confronted with high technological uncertainty, firms in emerging markets are likely to utilize their existing capability to mimic the incumbent and resource-rich firms due to resource scarcity.

SMEs in emerging markets tend to adopt a reverse-engineering strategy in a technologically turbulent environment because such an environment requires that firms invest in R&D to improve their existing R&D capabilities. Such an effort helps these firms in facilitating change, reconfiguring resources, and allowing them to improve their market position (Nelson & Winter, 1982; Suarez & Lanzolla, 2007). Inspired by the aim of meeting the unmet needs in emerging markets, SMEs with stronger reverse-engineering capability tend to mimic successful incumbent products to come out with low-cost and affordable innovative products that are conducive to addressing grand challenges. However, uncertainty from a turbulent environment could escalate the cost of innovation in emerging markets. This is because uncertainty adds additional costs and risks for firms to innovate (Ragatz et al., 2002) and, given that emerging-market firms lag behind the technological frontier, this external environmental uncertainty may generate extra pressure on these firms to design products that can achieve more value and in turn meet the requirements of low-income customers of emerging markets. Thus, in turbulent environments, SMEs with stronger reverse-innovation capability are likely to be burdened by the high costs of innovation in highly uncertain markets which in turn could reduce profits. Thus, we propose that:

Hypothesis 2a. The positive influence of reverse engineering on cost innovation is attenuated when technological turbulence is high.

Hypothesis 2b. The positive influence of reverse engineering on AVI is attenuated when technological turbulence is high.

2.4 | The moderating role of legal inefficiency

We argue that firms in institutionally dysfunctional environments (e.g., legal inefficiencies, government red tape, and lack of access to financial credit) do not necessarily consider this precarious environment as a barrier to investments and growth (Amankwah-Amoah et al., 2022), but rather it motivates them to explore creative solutions such as reverse engineering to produce frugal innovations that help to attenuate the institutional voids. Thus, in addition to examining an industry-level moderator, we followed the strategy tripod view by investigating an institutional-level factor (i.e., legal inefficiency) on the linkage between reverse engineering, and frugal innovation. The institutional-based view suggests that firm outcomes such as innovation in part reflect the challenges of institutional factors confronting firms (Peng, 2017; Peng et al., 2008). We consider legal inefficiency which reflects the degree to which firms' competitive behaviors are considered unfair, opportunistic, and illegal (Li & Atuahene-Gima, 2001, p. 1125) as an institutional factor that confronts firms in emerging markets. This suggests that legal inefficiency is a condition where the legal system, laws, and regulations are decoupled from their enforcement (Wei et al., 2017; Zhou & Poppo, 2010). Given the poor nature of the legal framework in emerging markets, firms tend to engage in opportunistic, unfair, and illegal behaviors by producing counterfeit products that violate contract rights (Sheng et al., 2011). For example, emerging-market environments are characterized by copyright violations, broken contracts, and unfair competitive practices (Zhu et al., 2019), and firms operating in emerging markets face significant challenges in protecting their intellectual property. This suggests that in the absence of strong legal support and strong intellectual property-right regimes, firms can use their capability to copy and imitate the intellectual property rights of innovative products, making both tangible and intangible assets prone to unfair and unlawful competitive actions.

Unlike developed economies where formal institutions such as regulations and laws operating in tandem with effective law-enforcement systems and procedures in the business environment (North, 1990), emerging economies often lack these key ingredients that lead to dysfunctional market competition and legal inefficiency, which can increase the cost of protecting key knowledge. The resource-constrained environment of emerging economies (Lim & Fujimoto, 2019), coupled with institutional impediments such as limited access to credit, legal inefficiency, poor government support, and weak enforcement of the principles of the rule of law, forces them to use their existing capabilities to explore ingenious, affordable solutions and mechanisms in designing products and redesigning existing products (Radjou et al., 2012). Since legal inefficiency prompts emerging-market firms to follow opportunistic behaviors, this institutional factor affords SMEs' improvisational behavior through mimicking new solutions from competitors using limited resources to minimize product-development costs and bringing affordable products to market through reverse engineering (Gurca & Ravishankar, 2016; Lim & Fujimoto, 2019). Thus, we suggest that:

Hypothesis 3a. The positive relationship between reverse engineering and cost innovation is amplified when legal inefficiency is high.

Hypothesis 3b. The positive relationship between reverse engineering and AVI is amplified when legal inefficiency is high.

2.5 | The mediating role of frugal innovation

Although prior research has argued that reverse engineering is an important predictor of firm performance (Kumaraswamy et al., 2012; Malik & Kotabe, 2009), the mechanisms by which reverse engineering affects innovation performance remain under-explored. This study fills this knowledge gap by highlighting the mediating role of frugal innovation. Frugal innovation manifests under conditions of resource scarcity to develop functionality-focused and affordable products/services tailored to underserved markets (Lei et al., 2021). Such innovations are vital in addressing grand societal challenges due to their affordability to the base-of-the-pyramid customers. By instilling processes that allow firms to minimize material and financial resource utilization, firms become better equipped to bring those products to market that are cheaper relative to alternatives (Hossain, 2020; Lei et al., 2021). As demonstrated by Weyrauch and Herstatt (2016), frugal innovation is typified by crafting solutions that are inherently rooted in delivering new products at substantially lower costs relative to standard products. By concentrating on core functionalities as pivotal features of the product-development processes, emerging-market SMEs can conserve resources and utilize limited materials (Santos et al., 2020) which allows them to achieve cost-efficient innovations.

As cost innovation focuses on the lower cost that meets the expectations of resource-constrained consumers, it is likely to help emerging-market SMEs achieve higher profitability. In addition, the pursuit of AVI is aimed at new functions and features of a product that can be sold at the lowest cost possible to resource-constrained consumers. This has the potential to help SMEs in emerging markets to gain greater performance outcomes and much-needed legitimacy for diverse stakeholders. Moreover, innovations require R&D capability and investments, yet emerging-market firms lack these capabilities (Kumaraswamy et al., 2012; Malik & Kotabe, 2009; Samuelson & Scotchmer, 2002). For example, emerging-market SMEs often lack the resources for ground-breaking innovations. As such, SMEs tend to acquaint themselves with the local market to develop capabilities that are used for reverse engineering. These capabilities allow emerging-market SMEs to develop innovations that meet the needs of consumers who are less resourced to buy expensive products. These arguments suggest that both cost and affordable innovations may mediate the effect of reverse engineering on PIP. The preceding discussion leads us to suggest that:

Hypothesis 4a. Cost innovation mediates the effect of reverse engineering on frugal product-innovation performance.

Hypothesis 4b. AVI mediates the effect of reverse engineering on frugal product-innovation performance.

3 | RESEARCH METHOD

3.1 | Context of the study

Our empirical setting involves manufacturing SMEs in Ghana. Similar to other emerging markets, Ghana is facing significant grand challenges. This makes the role of for-profit SMEs important in addressing grand challenges in such markets (Amankwah-Amoah et al., 2022). Firms could address the grand challenges by developing innovations that are conducive to the needs of local customers. In addition, affordability is critical for new product development, given that large segments of customers in emerging markets are unable to afford luxury products with a high level of functionality. Data were collected from SMEs in Ghana for several reasons. First, as a low-income country, Ghana has attracted several foreign direct investments (FDI) because of its democratic tradition. The country is also considered a destination for doing business due to its fast economic-growth rates and regulatory reforms. For instance, the World Bank (2019) revealed that Ghana's growth rate was 8%. Indeed, this growth rate is due to the country's focus on manufacturing activities. However, the income distribution in Ghana can be considered to exhibit the characteristics of emerging countries. Second, the extreme complexity and dynamism in emerging-country contexts suggest that firms could potentially face challenges posed by dysfunctional competition, technological turbulence, and weak capabilities (De Luca & Atuahene-Gima, 2007). For this reason, reverse-engineering capabilities for frugal innovation is crucial for firms in such markets to sustain frugal innovation performance. Third, the importance of manufacturing SMEs in emerging economies (Adomako & Nguyen, 2020; Tybout, 2000) calls for studies to investigate how the manufacturing SMEs' capabilities are conditioned by exogenous factors to influence frugal innovation activities and ultimately innovation performance. Additionally, it is also noted that SMEs account for 90% of registered businesses, contributing to 70% of Ghana's GDP, and constituting about 85% of manufacturing sector jobs (Multisoft Solutions, 2017).

Thus, we consider Ghana an interesting emerging market on which to test our research model.

3.2 | Sample and data collection

We collected the data in two waves utilizing a face-to-face and multi-informant survey approach. The data were collected such that all independent, mediating, moderating, and control variables were captured in phase 1 (i.e., May to August 2019), whereas we measured the dependent variable 6 months later in phase 2 (February to May 2020). We embarked on an extensive literature review to identify measures of interest. Subsequently, we conducted a pilot survey with 15 CEOs, and finance managers of SMEs (not included in the main survey) to obtain feedback on the clarity of the measures. The feedback obtained from the pilot survey was used to refine the measures and readability of the questionnaire. We followed a comprehensive three-step procedure to refine the measures used in this study: (1) literature review; (2) pilot testing; and (3) statistical processes during our measurement and structural models.

In the main survey, a random sample of 1000 manufacturing SMEs was drawn from the National Board of Small-Scale Industries' (NBSSI) database. This database contained the current information on small to medium-sized firms in Ghana. A sample of manufacturing SMEs was used due to the Government of Ghana's focus on turning the economy around through manufacturing. In addition, the use of manufacturing SMEs is justified because the Ghanaian government's approach to innovation and, employment generation to tackle grand challenges is mainly focused on SMEs' development (World Bank, 2019). We utilized the following sampling criteria in selecting our sample: (1) firms employing not more than 250 employees; (2) firms with CEO contact information; and (3) firms with no direct or indirect affiliation with any company group. We targeted firms employing not more than 250 full-time workers to meet the selection criteria for SMEs (Ghana Statistical Service, 2000).

The survey took place in two phases with a 6-month interval, targeting 1000 SMEs. In phase 1, we approached the CEO of the selected SMEs and gave the survey instrument to them. This phase of the survey captured data on reverse engineering, frugal innovation, legal inefficiency, technological turbulence, and the control variables. Phase 1 obtained 269 responses out of which 19 were not usable due to missing values, yielding 250 usable questionnaires.

Six months later, in phase 2, heads of the finance division of the 250 SMEs were issued with a questionnaire utilizing the same approach as in phase 1. The main focus of the phase 2 survey was to capture frugal innovation performance. We eliminated seven questionnaires after discounting missing values, yielding 243 usable questionnaires. This represents a 24.30% effective response rate (243/100 × 1000).

Table 1 contains the descriptive statistics of the demographic variables. The mean age of the sampled SMEs was 10.54 (s.d. = 7.54) years, whereas the mean size was 12.56 (s.d. = 15.71) full-time employees. In addition, 67.9% of the firms were high-technology firms, whereas 32.1% were low-technology firms. The average managerial experience of the CEO was 5.00 years. To test for nonresponse bias, respondents and nonrespondents were compared in terms of firm age, size, and industry. Since the results of *t*-tests yielded no substantial differences, we concluded that nonresponse bias did not influence our findings (Meitinger & Johnson, 2020).

3.3 | Measures

All the measures were derived from previously validated scales. These scales were captured on a seven-point Likert scale (1 = "strongly disagree," 7 = "strongly agree"). Appendix presents the measure, validity, and reliability assessment.

3.3.1 | Reverse engineering

Use the four-item scale developed by Malik and Kotabe (2009) to measure reverse engineering The scale captured whether firms disassembled competing products intending to gain knowledge to support the development of new products (Malik & Kotabe, 2009). The items also measured the extent to which the new products are designed and grounded in the approaches used by rival products (Adomako et al., 2022).

3.3.2 | Frugal innovation

We measured frugal innovation with two constructs (i.e., cost innovation and AVI). First, we used three items from previous studies (Cai et al., 2019; Zeschky et al., 2014) to capture cost innovation. This scale contains three items. Second, we used two items from Ernst et al. (2015) to measure AVI.

TABLE 1 Demographic and venture characteristics of the sample distribution.

Variables	Subcategory	Frequency	%
CEO gender	Male	144	59.3%
	Female	99	40.7%
CEO age	25–30 years	9	3.7%
	31–40 years	86	35.4%
	41–50 years	88	36.2%
	51–60 years	52	21.4%
	>61 years	8	3.3%
Industry	High-tech	165	67.9%
	Low-tech	78	32.1%
Firm age	1–5 years	89	36.6%
	6–10 years	44	18.1%
	11–15 years	54	22.3%
	16–20 years	36	14.8%
	>20 years	20	8.2%
Firm size	0–9 employees	141	58.0%
	10–20 employees	60	24.7%
	21–30 employees	24	9.9%
	>30 employees	18	7.4%
CEO managerial experience	<1 year	66	27.2%
	1–5 years	170	70.0%
	6–10 years	5	2.0%
	>10 years	2	0.8%

Note: $n = 243$. The industry is a dummy variable.

3.3.3 | Technological turbulence

We used Jaworski and Kohli's (1993) four-item scale to measure the degree of technological turbulence. The scale captured the degree to which industry technological changes were rampant and uncertain.

3.3.4 | Legal inefficiency

Li and Atuahene-Gima's (2001) four-item scale was used to measure legal inefficiency. The items captured the extent to which managers perceived illegal and unlawful activities related to competition in the business context.

3.3.5 | Frugal innovation product performance

Atuahene-Gima et al.'s (2005) five-item scale was used to capture frugal product-innovation performance. We asked finance managers or heads of the finance division of each firm to rate the degree to which their firms' frugal product objectives have been met in the last 3 years.

3.3.6 | Control variables

The control variables used in this study were gender, industry, CEO age, firm age, firm size, and CEO managerial experience. We measured gender by asking the CEO to choose "0" if female or "1" if male. The industry was measured following previous studies (see Karami & Tang, 2019). Accordingly, we coded industry type as follows: 0 = for "high-technology" industry and 1 = "low-technology industry." We used the CEO's actual age to capture his/her age. Firm age was measured utilizing a natural logarithm transformation of the original value. Firm size was also a logarithm transformed from the original value. Finally, the CEO's managerial experience was measured as the logarithm transformation of the CEO's professional experience in the number of years. These variables were controlled because previous research has argued that they could potentially affect the decision-making processes of managers (Papadakis & Barwise, 2002).

4 | ANALYSES AND RESULTS

4.1 | Assessment of common method bias

The CFA approach was utilized to test the likelihood of CMB. We calculated three distinct CFA models, including method-only, trait-only, and method-plus-trait models, after Carson (2007) and Cote and Buckley (1987). In the first model, that is the method-only model, by allowing the indicants to load onto a single common factor the following results were obtained: $\chi^2 = 1967.969$; df = 230; RMSEA = 0.177; SRMR = 0.128; TLI = 0.447; and CFI = 0.498. With each indicator loading onto its corresponding theoretic factor, the trait-only model was estimated, and the following results were obtained: $\chi^2 = 336.712$; df = 215; RMSEA = 0.048; SRMR = 0.049; TLI = 0.943; and CFI = 0.951. In the third and final model, we estimated simultaneously the method-and-trait model and obtained the following result: $\chi^2 = 264.601$; df = 186; RMSEA = 0.1423; SRMR = 0.043; TLI = 0.951; and CFI = 0.964. We observed that Models 2 and 3 were superior to Model 1 when we compared the three models. However, Model 3 was not significantly superior to Model 2 indicating that CMB did not present a threat to the results of our research.

4.2 | Validity and reliability tests

We employed LISREL 8.92 for Windows (Joreskog & Sorbom, 2014) with the maximum likelihood estimator and covariance matrix to perform a CFA analysis. As shown in Appendix, our hypothesized CFA model produced an acceptable fit to our data and therefore resulted in the following heuristic fit statistics: χ^2/df (336.712/215) = 1.57; RMSEA = 0.05; CFI = 0.95; TLI = 0.94; and SRMR = 0.05. Therefore, the results obtained for our hypothesized six-factor model were within the acceptable scope (Bagozzi & Yi, 2012; Williams et al., 2009). To evaluate the validity and reliability of our multi-item measures, we then retrieved the AVE and CR from our proposed six-factor model. The results, which are presented in Appendix, indicate that the CR, AVE, and α values for all the multi-item constructs were higher than the specified threshold scores of 0.60, 0.50, and 0.70 respectively (Bagozzi & Yi, 2012; Hair et al., 2019; Nunnally & Bernstein, 1994). Furthermore, all our standardized factor loadings were significant at 0.05, which further confirms the convergent validity and robustness of our multi-item measures (Hair et al., 2019). The lowest SMC value was 0.36, suggesting that our items explained a minimum of 36% of the variance in our model. In addition, all the VIF scores were below the specified value of 10 (Field, 2017; Tabachnick & Fidell, 2013). Finally, we applied the Fornell and Larcker (1981) criterion to compare the AVEs of our latent constructs with the squared correlation between pairs of the primary constructs to evaluate the discriminant validity of our latent constructs. As shown in both Tables 2 and 3, all the AVEs were above the square of the correlation among every pair of the latent constructs that supports the discriminant validity. The averages, standard deviations, and correlations are presented in Table 2.

4.3 | Structural model estimation

We tested our hypotheses using the covariance-based SEM anchored in LISREL 8.92. We used the maximum likelihood estimator and covariance matrix. Following Ping (1995), and Jöreskog et al. (2016), we computed the averages for the constructs used in the multiplication interaction while allowing the full information details of the outcome variables. This approach helps to minimize the potential for multicollinearity and model underspecification (Hair et al., 2019). In addition, based on established protocols, we estimated seven hierarchical nested models. This approach is important because it helped to observe changes in R-square (ΔR^2) and normed chi-square ($\Delta\chi^2/\Delta$df) as latent constructs were gradually added in the subsequent model estimation. Accordingly, we estimated our structural models based on the equations as reported in Table 3. This enabled us to determine the direct, interaction, and mediation paths as illustrated in our research model presented earlier in Figure 1.

Additionally, we estimated seven models, with the two dimensions of the frugal innovation as outcomes for the direct effect of reverse engineering in Models 1 and 3, and results of the interaction effect of reverse engineering and the moderators (technological turbulence, and legal inefficiency) in Models 2 and 4. Further, we also estimated three models (Models 5–7) to test the indirect effect of reverse engineering on frugal product-innovation performance via cost innovation and AVI. We estimated our structural models based on the equations shown in Table 3. Results of the estimated structural models, their significant levels, and heuristic fit statistics are shown in Table 4. The results in Model 1 show that reverse engineering is correlated with cost innovation ($\delta = 0.30$, $p < 0.01$). Similarly, reverse engineering is strongly related to AVI ($\delta = 0.15$, $p < 0.05$). These outcomes, therefore, support H1a and H1b. Again, we contend in H2a and H2b that the reverse engineering and technological turbulence product term is negatively related to cost innovation and AVI (Models 2 and 4 of Table 4). However, we found support for H2a because the interaction between REV and TET (i.e., REV × TET) on cost innovation was positive and strongly related ($\delta = -0.19$, $p < 0.05$). Accordingly, high technological turbulence minimizes cost innovation. In addition, we argue in both H3a and H3b that the interaction between reverse engineering and legal inefficiency is strongly related to cost innovation and AVI. As indicated in Model 4, we found support for H3b which posits that the interaction between reverse engineering and legal inefficiency (i.e., REV × LEG) is strongly related to AVI ($\delta = 0.15$, $p < 0.05$). Therefore, a high level of legal inefficiency implies superior AVI.

We employed the Johnson–Neyman (JN) method to examine the interaction effect (Carden et al., 2017; Spiller et al., 2013). This strategy helps to avoid the drawbacks associated with the pick-a-point method (Aiken & West, 1981). As illustrated in Figure 2, when the level of technological turbulence is high (above the JN value of 3.40), the 95% CI for the effect of reverse engineering on cost innovation contains zero. This finding indicates that reverse engineering has no significant effect on cost innovation under high levels of technological turbulence. However, when technological turbulence is not intense (JN $\leq$ 3.40), the 95% CI of this effect is above zero, indicating that reverse engineering exerts a significant positive influence on cost innovation. This finding implies that technological turbulence moderates the impact of reverse engineering on cost innovation, with the effect

TABLE 2 Means, standard deviations, and zero-order inter-construct correlations.

Variable	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12
1. Reverse engineering	5.79	1.00	1.000											
2. Cost innovation	5.24	1.04	0.237***	1.000										
3. Affordable value innovation	4.70	1.64	0.149*	0.333***	1.000									
4. Technological turbulence	5.63	1.01	0.598***	0.297***	0.299***	1.000								
5. Legal inefficiency	5.38	0.96	0.250***	0.204**	0.151*	0.382***	1.000							
6. Product-innovation performance	5.62	1.00	0.297***	0.239***	0.223***	0.410***	0.347***	1.000						
7. CEO gender[a]	–	–	−0.087	−0.114	0.013	−0.132*	−0.128*	−0.079	1.000					
8. Industry[a]	–	–	−0.041	−0.039	0.025	−0.036	−0.167**	−0.019	0.086	1.000				
9. CEO age	43.53	8.78	0.045	0.036	0.043	0.004	0.041	−0.010	−0.001	−0.098	1.000			
10. Firm age (log)	2.07	0.81	0.010	0.168**	0.048	−0.017	0.002	0.029	−0.064	−0.100	−0.051	1.000		
11. Firm size (log)	2.01	1.02	0.056	0.020	0.132*	0.101	0.023	0.048	−0.127*	−0.261***	0.087	0.511***	1.000	
12. CEO managerial experience (log)	0.45	0.57	0.032	0.002	−0.025	−0.016	−0.057	0.065	−0.078	−0.014	−0.041	0.362***	0.230***	1.000

Note: $n = 243$.
Abbreviation: s.d., standard deviation.
[a]Dummy variable.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 3 Model equations.

Model	Equation
Direct path	
Model 1	*Cost innovation* $= \delta_{000} + \delta_{100} * \text{FAG} + \delta_{200} * \text{FSIZ} + \delta_{300} * \text{IND} + \delta_{400} * \text{REV} + \varepsilon_t$
Model 3	*Affordable value innovation* $= \delta_{00} + \delta_{100} * \text{FAG} + \delta_{200} * \text{FSIZ} + \delta_{300} * \text{IND} + \delta_{400} * \text{REV} + \varepsilon_t$
Interaction path	
Model 2	*Cost innovation* $= \delta_{000} + \delta_{100} * \text{FAG} + \delta_{200} * \text{FSIZ} + \delta_{300} * \text{IND} + \delta_{400} * \text{REV} + \delta_{500} * \text{LEG} + \delta_{600} * \text{TET} + \delta_{700} * \text{REV} \times \text{LEG} + \delta_{800} * \text{REV} \times \text{TET} + \varepsilon_t$
Model 4	*Affordable value innovation* $= \delta_{000} + \delta_{100} * \text{FAG} + \delta_{200} * \text{FSIZ} + \delta_{300} * \text{IND} + \delta_{400} * \text{REV} + \delta_{500} * \text{LEG} + \delta_{600} * \text{TET} + \delta_{700} * \text{REV} \times \text{LEG} + \delta_{800} * \text{REV} \times \text{TET} + \varepsilon_t$
Indirect path	
Models 5–7	*Frugal product-innov. perform.* $= \delta_{000} + \delta_{100} * \text{FAG} + \delta_{200} * \text{FSIZ} + \delta_{300} * \text{IND} + \delta_{400} * \text{REV} + \delta_{500} * \text{COI} + \delta_{600} * \text{AVI} + \varepsilon_t$

Abbreviations: AVI, affordable value innovation; COI, cost innovation; FAG, firm age; FSIZ, firm size; IND, industry; LEG, legal inefficiency; REV, reverse engineering; TET, technological turbulence; δ_{000}, intercept; $\delta_{100} \rightarrow \delta_{800}$, coefficients of the main constructs; ε_t, error term.

being larger under low uncertainty than under high uncertainty. This finding supports Hypothesis 2a.

Furthermore, as depicted in Figure 3, reverse engineering has a positive effect on AVI when legal inefficiency is high (JN $\geq$ 5.67). Yet, reverse engineering has an adverse effect on AVI under low legal inefficiency (JN $\leq$ 2.51). Thus, results from the JN floodlight analysis support Hypothesis 3b. Taken together, these results substantiate the boundary condition of both technological turbulence and legal inefficiency in the reverse engineering and frugal innovation association.

To examine the indirect effect of reverse engineering on frugal product-innovation performance via cost innovation (H4a) and AVI (H4b), we employed Hayes' (2013) PROCESS macro with a 95% BCCI based on 5000 resamples (Preacher & Hayes, 2008). We utilized Model 4 to estimate our indirect effect hypotheses. As shown at the bottom of Table 4, our indirect hypothesis through cost innovation was found to be positively significant (standardized $\beta = 0.043$, SE $= 0.023$) and the bias-corrected CI ranged from 0.008 to 0.097, and also did not contain zero. Moreover, the indirect effect of reverse engineering through AVI to frugal product-innovation performance was positive and significant (standardized $\beta = 0.027$, SE $= 0.016$). Further analysis also revealed that the bias-corrected CI ranged from 0.002 to 0.065 and contained nonzero. This provides support for Hypotheses 4a and 4b.

In addition, we complement Hayes' (2013) process macro results with the SEM results in Models 5 and 6 which revealed similar normed chi-square (χ^2) tests. For instance, we observe in Table 4 that the normed chi-square (χ^2) for Model 5 (χ^2/df $= 1.54$) and Model 6 (χ^2/df $= 1.54$) were slightly lower than Model 7 (χ^2/df $= 1.57$). In addition, Model 5 and Model 6 explained 15.6% and 15.1% of the variation in the frugal product-innovation performance. Comparatively, the Tucker–Lewis index for Model 5 (TLI $= 0.95$) and Model 6 (TLI $= 0.95$) were slightly better than Model 7 (TLI $= 0.93$). Accordingly, we used Model 5 and Model 6 rather than Model 7 to test our mediation hypotheses. Hypothesis 4a posits that cost innovation mediates the link between reverse engineering and frugal product-innovation performance. As illustrated in Table 4, H4a is supported because the structural path from the reverse engineering → frugal product-innovation performance is positively significant ($\delta = 0.29$, $p < 0.01$), and cost innovation → frugal product-innovation performance is positive and significant ($\delta = 0.20$, $p < 0.01$). This finding further provides empirical evidence to substantiate our claim that cost innovation partially mediates the reverse engineering and frugal product-innovation performance association. In addition, H4b posits that AVI partially mediates the reverse engineering and frugal product-innovation performance association. Model 3 of Table 4 shows that the structural path from reverse engineering → AVI was positively significant ($\delta = 0.15$, $p < 0.05$) and AVI → frugal product-innovation performance ($\delta = 0.18$, $p < 0.01$) was positively significant. Thus, this finding lends support to H4b. Taken together the results from Hayes' (2013) PROCESS and the SEM show that frugal innovation is a mediating mechanism through which reverse engineering channels its effect on frugal product-innovation performance.

To establish the robustness of our mediation results and cross-validate our findings, we carried out additional mediation analysis. We estimated three different regression equations using Kenny and Baron's (1986) mediation method, as shown in Table 5. In H4a, cost innovation was regressed on reverse engineering. The relationship was both positive and significant with reverse engineering accounting for 5.6% of the variance in cost innovation. In equation two, frugal product-innovation performance was regressed on reverse engineering and the latter accounted for 8.8% of the variation in the former. In equation three, we regressed frugal product-innovation performance simultaneously on reverse engineering and cost innovation with both relationships being significant and explaining

TABLE 4 Structural model estimation.

	Dependent variables						
	Frugal innovation				Frugal product-innovation performance		
	Cost innovation		Affordable value innovation				
Independent variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Control paths							
CEO gender	−0.11 (−1.58)	−0.10 (−1.50)	0.05 (0.71)	0.04 (0.67)	−0.03 (−0.48)	−0.06 (−0.88)	−0.04 (−0.62)
Industry	0.02 (0.25)	−0.02 (−0.29)	−0.01 (−0.08)	0.02 (0.31)	−0.00 (−0.04)	−0.00 (−0.06)	−0.00 (−0.00)
CEO age	0.02 (0.28)	0.01 (0.22)	0.01 (0.14)	0.02 (0.34)	−0.03 (−0.48)	−0.02 (−0.39)	−0.03 (−0.49)
Firm age (log)	0.27 (3.12)**	0.29 (3.49)**	0.01 (0.03)	0.01 (0.10)	−0.06 (−0.81)	−0.01 (−0.18)	−0.05 (−0.67)
Firm size (log)	−0.15 (−1.80)	−0.18 (−2.31)*	0.15 (1.95)	0.11 (1.46)	0.03 (0.41)	−0.02 (−0.22)	0.01 (0.11)
CEO managerial experience (log)	−0.08 (−1.12)	−0.07 (−1.02)	−0.06 (−0.84)	−0.05 (−0.75)	0.06 (0.93)	0.06 (0.86)	0.07 (1.00)
Direct effect paths							
Reverse engineering (REV)	0.30 (4.09)**	0.06 (0.70)	0.15 (2.27)*	−0.09 (−1.14)	0.29 (4.29)**	0.31 (4.63)**	0.28 (4.18)**
Cost innovation					0.20 (2.95)**		0.16 (2.21)*
Affordable value innovation						0.18 (2.71)**	0.13 (1.89)
Technological turbulence (TET)		0.23 (2.50)*		0.25 (2.82)**			
Legal inefficiency (LEG)		0.13 (1.70)		0.12 (1.63)			
Two-way interaction paths							
RENG × TET		−0.19 (−2.45)*		−0.14 (−1.91)			
RENG × LEG		0.03 (0.39)		0.15 (2.37)*			
Goodness-of-fit indices							
R^2	0.152	0.244	0.046	0.153	0.156	0.151	0.170
ΔR^2	–	0.092	–	0.107	–	–	0.014/0.019
χ^2/df	23.073/14	27.999/22	3.785/6	5.007/10	56.906/37	57.019/37	64.448/41
RMSEA	0.052	0.031	0.000	0.000	0.047	0.047	0.049
SRMR	0.028	0.023	0.009	0.006	0.029	0.029	0.029
TLI	0.903	0.955	1.000	1.058	0.946	0.946	0.934
CFI	0.970	0.989	0.706	1.000	0.974	0.974	0.970
p-value	0.059	0.203		0.887	0.021	0.019	0.011

(Continues)

TABLE 4 (Continued)

Bootstrap results for the indirect effect of reverse engineering on frugal product-innovation performance through cost and affordable value innovation				
Hypothesized indirect path	Stand. estimate	Boot SE	LL 95% CI	UL 95% CI
Bootstrap results for the indirect effect of reverse engineering on frugal product-innovation performance through cost and affordable value innovation				
Hypothesized indirect path	Stand. estimate	Boot SE	LL 95% CI	UL 95% CI
REV → COI → FPIP	0.043	0.023	0.008	0.097
REV → AVI → FPIP	0.027	0.016	0.002	0.065

Note: $n = 243$. Critical values of the t-distribution for $\alpha = 0.05$ and $\alpha = 0.01$ (two-tailed test) are * = 1.96 and ** = 2.58, respectively (t-values reported in parentheses).
Abbreviations: AVI, affordable value innovation; COI, cost innovation; FPIP, frugal product-innovation performance; REV, reverse engineering.

11.8% of the variation. However, the results show that the beta coefficient ($\beta = 0.255$) in equation 3 was less than the beta coefficient ($\beta = 0.297$) in equation 2. These observations are in line with Kenny and Baron's (1986) fourth condition for mediation. Thus, we conclude that cost innovation partially mediates the connection between reverse engineering and frugal product-innovation performance.

Similar results were found for the H4b, which stated that AVI mediates the association between reverse engineering and frugal product-innovation performance. In the first equation, we regressed AVI on reverse engineering and found a significant and positive relationship with the latter explaining 2.2% of the changes in the former. In the second equation, we regressed the effectiveness of frugal product-innovation performance on reverse engineering in the second equation and discovered a favorable and significant association between the two constructs. In the third equation, frugal product-innovation performance regressed simultaneously on reverse engineering and AVI, and found both relationships positive and significant. The two predictors accounted for 12.1% of the variance in the outcome. However, adhering to Kenny and Baron's (1986) fourth condition for the establishment of mediation, we scrutinized the beta coefficients of the REV → FPIP in equation 2 ($\beta = 0.297$) and equation 3 ($\beta = 0.270$), and noted that the beta coefficient value in equation 3 was less than that of equation 2. These findings lend credence to H4b, indicating that AVI partially explains the relationship between reverse engineering and frugal product innovation.

5 | DISCUSSION AND IMPLICATIONS

Our study builds on the strategy tripod perspective advanced by Peng et al. (2008, 2009) to explore how reverse engineering influences product innovation performance through the mediating mechanism of frugal innovation (i.e., cost innovation, and AVI). Emerging markets face significant grand challenges such as inequality, and rising levels of extreme poverty that require firms to address such challenges by launching products that are affordable to low-income consumers. Thus, the first finding of the study (i.e., reverse engineering fosters cost innovation and AVI) highlights the previously neglected role of firm capabilities such as reverse engineering in identifying frugal innovation types in emerging-market firms. Emerging-market firms aim to catch up with advanced markets, but due to the weak resource base they often rely on imitating foreign firms' products and process innovation to develop their capabilities and move toward the technology frontiers (Kumaraswamy et al., 2012). Therefore, reverse

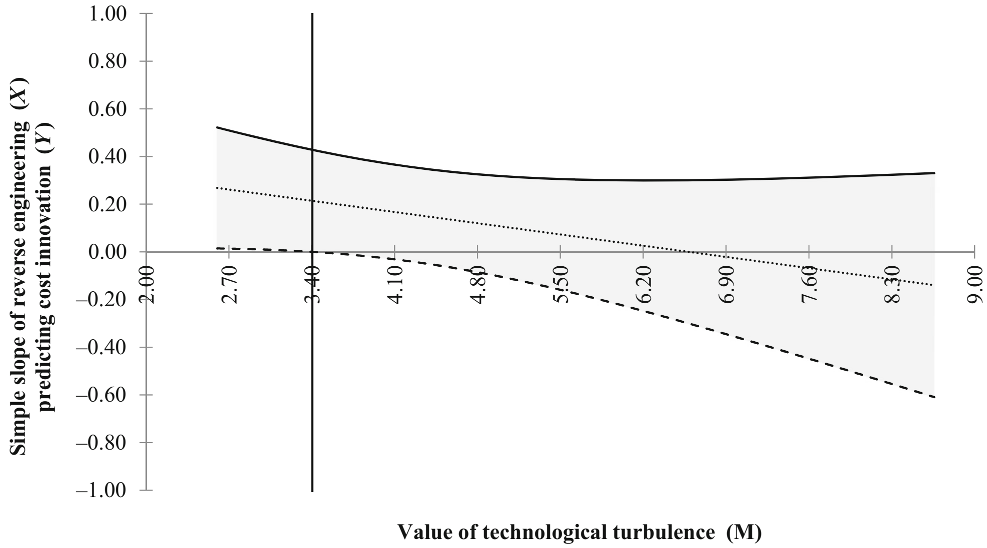

FIGURE 2 Johnson–Neyman plot of the region of significance for the effect of reverse engineering on cost innovation across the range of technological turbulence.

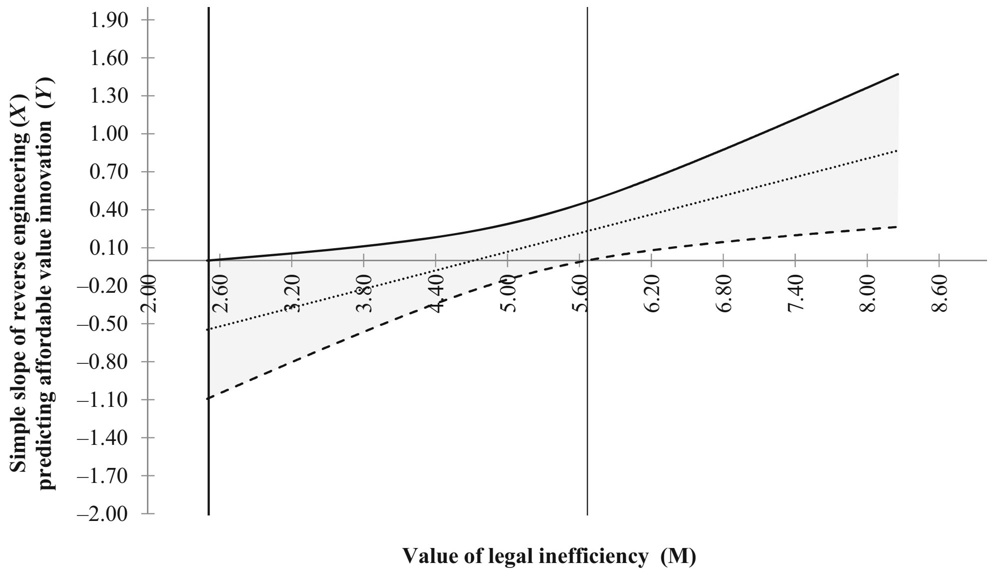

FIGURE 3 Results of the Johnson–Neyman floodlight analysis. *At a 95% confidence level, the effect of reverse engineering on AVI is significant when legal inefficiency is ≤ 2.508 and legal inefficiency ≥ 2.92.

engineering offers these firms the opportunity to close the capability gap and develop products that are conducive to local and foreign markets. We also observed an indirect influence of reverse engineering on frugal innovation performance. Our first finding is consistent with previous research that found that reverse engineering positively influences firm performance (Adomako et al., 2022; Malik & Kotabe, 2009) and innovation output (G. Zhang & Zhou, 2016). We also found that technological turbulence moderates the effect of reverse engineering on cost innovation, such that the effect is attenuated when technological turbulence is high. However, our findings did not support the moderating effect of technological turbulence on the linkage between reverse engineering and AVI.

In addition, the moderating role of legal inefficiency on the relationship between reverse engineering and cost innovation did not receive empirical support. On the other hand, we found support for the moderating effect of legal inefficiency on the relationship between reverse engineering and AVI. Our findings show that the positive effect of reverse engineering on AVI is amplified when legal inefficiency is high. Finally, we find that cost innovation and AVI mediate between reverse engineering and product-

TABLE 5 The mediating role of frugal innovation in the link between reverse engineering and frugal product-innovation performance.

Equation	Dependent variable	Independent variable	β	*t*-value	R^2	*F*-statistic
1.	COI	REV	0.237	3.780***	0.056	14.288***
2.	FPIP	REV	0.297	4.829***	0.088	23.315***
3.	FPIP	REV	0.255	4.085***	0.118	16.086***
		COI	0.178	2.857**		
1.	AVI	REV	0.149	2.341*	0.022	5.479*
2.	FPIP	REV	0.297	4.829***	0.088	23.315***
3.	FPIP	REV	0.270	4.406***	0.121	16.525***
		AVI	0.183	2.994**		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.Abbreviations: AVI, affordable value innovation; COI, cost innovation; FPIP, frugal product-innovation performance; REV, reverse engineering.

innovation performance. Collectively, several theoretical, and practical implications are derived from our findings.

5.1 | Theoretical implications

Our study makes several contributions to frugal product innovation and grand societal challenges literature. First, findings from the study show that frugal innovation activities in emerging markets are fostered by firm-level capabilities (i.e., reverse engineering). This finding highlights the importance of reverse engineering as an alternative product-innovation strategy in contexts characterized by weak R&D intensity (Kumaraswamy et al., 2012; Wang & Kafouros, 2009; G. Zhang & Zhou, 2016). This helps emerging-market firms to absorb foreign technologies to enhance the innovation that is conducive to addressing grand challenges. Our findings extend the frugal innovation literature (Dabić et al., 2022; Levänen et al., 2022) by exploring how an emerging-market firm context, and specific dynamic capability mechanism foster low-cost and AVI. This extension is important because previous research has mainly focused on poor R&D capability as a major characteristic of firms found in emerging markets (Kumar & Aggarwal, 2005; Wells, 1983); our findings reveal that dynamic capability plays a central role in frugal innovation. More importantly, fostering reverse engineering in emerging-market SMEs contributes to increased frugal innovation as these firms are aiming to close the capability gap.

Second, this study enhances our understanding of the conditions under which reverse engineering is more or less an effective driver of frugal innovation performance. In doing so, we explain when reverse engineering predicts frugal innovation. In particular, we demonstrate that technological turbulence, and legal inefficiency are boundary conditions of reverse engineering. These findings expand the scope of arguments in the reverse-engineering literature (Adomako et al., 2022; G. Zhang & Zhou, 2016) by highlighting the institutional and industry conditions that convert firm-level capability into frugal innovation. These findings indicate that addressing grand challenges requires understanding the prevailing institutional and industry contexts as firms' strategies and actions aimed at finding solutions for grand challenges depend not only on their internal resource base but also on the external environments in which firms operate. These findings highlight the relevance of institutional, and industry factors as conditions for improving the role of reverse engineering in frugal innovation performance in emerging markets.

However, it is important to note that our empirical test of the moderating role of technological turbulence on the association between reverse engineering and affordable innovation was not supported. The rationale behind the insignificant moderating influence is attributed to the growing phenomenon in emerging economies. Due to increasing growth in these economies, firms with greater reverse-engineering capability face the threat of technological turbulence for introducing affordable value products. This indicates that a firm's level capability to embark on reverse engineering is incompatible with the technological changes occurring in the market for developing AVIs. In addition, the finding that institutional context (i.e., legal inefficiency) did not moderate the influence of reverse engineering on cost innovation suggests that, in the absence of strong legal protection that legitimizes business activities, a firm's innovation efforts may be jeopardized by rival firms' unlawful and unfair activities such as imitation (Sheng et al., 2011). In addition, our finding that technological turbulence moderates the relationship between reverse engineering and cost innovation, such that the relationship is attenuated when technological turbulence is high, is surprising. For example, technological turbulence may offer SMEs in emerging markets more opportunities to reverse engineer. Thus, the uncertainty surrounding technological turbulence may not be pronounced as SMEs are not directly competing with frontier firms on innovation, per se. Instead, technological turbulence may drive more new products to come to market, which enhances reverse engineering opportunities.

Also, the finding that the influence of reverse engineering on AVI is moderated by high degrees of legal inefficiency contradicts previous findings in the innovation literature (Du et al., 2016; H. Li & Atuahene-Gima, 2001; Nee, 1992). In contrast with previous studies (Y. Liu et al., 2018; Senyard et al., 2014), our findings show that legal inefficiency impels SMEs to develop affordable value products. Thus, our study challenges the dominant logic that argues that institutional support plays a major role in converting firm capability into innovation, thus opening up a new promising domain for future research.

Further, this study clarifies why frugal innovation matters in improving product-innovation performance by its mediating role. The results show that reverse engineering affects frugal product performance through frugal product innovations (i.e., cost innovation, and AVI). This new insight suggests that by failing to acknowledge the mediating role of frugal innovations, prior studies may have provided limited insights into how the underlying mechanisms shape the impact of reverse engineering on product-innovation performance in emerging markets (Malik & Kotabe, 2009). Our findings show that frugal innovation plays an important role in product-innovation performance (PIP) through its mediating role. Thus, the indirect, positive effect of reverse engineering on product-innovation performance underscores the need for frugal innovation in product-innovation theory. As Howard-Grenville (2021, p. 257) indicates, it is important to examine "the process and relationships that drive and connect articulation, actions, and outcomes and give rise to specific trajectories that either mitigate or amplify grand challenges." Thus, by integrating important moderating and mediating variables, we shed light on the roles of reverse engineering and frugal innovation in the context of SMEs of emerging markets that aim to mitigate grand challenges.

Finally, since our sample comes from emerging-market SMEs, the findings contribute to the frugal innovation literature by showing that frugal innovation has been traditionally focused on innovations by MNEs from advanced markets (Ernst et al., 2015). The existing literature on the drivers and consequences of frugal innovation is quite limited. Our study suggests that reverse engineering predicts both cost innovation and AVI in the context of local SMEs in emerging markets. In this way, we contribute to the recent research on innovation activities that suggests that emerging markets are a hotbed for innovation (Cai et al., 2019; Ernst et al., 2015; Subramaniam et al., 2014).

5.2 | Practical implications

Our study has two important implications for managers. First, the finding that reverse engineering boosts frugal innovation performance through cost innovation and AVI highlights the importance of firm capabilities in driving innovation outcomes in emerging markets. To managers, the finding suggests that by utilizing reverse-engineering capability, they can enhance the firm's frugal innovation activities in these markets. In doing so, firms operating in these markets can find ways to outperform their competitors by investing in reverse-engineering activities. By this finding, firms are encouraged to build on new approaches to design business models that capture frugal innovation activities to serve consumers in emerging markets. For example, instead of investing in new technologies that are too costly to obtain, emerging-market SMEs could rather learn from competitors' product technologies (Patel & Pavitt, 1995). SMEs from emerging markets could build this capability by enhancing their informal exchanges with production engineers to learn about process technologies.

Second, the findings from this study show that institutional and industry conditions influence the effect of reverse engineering on frugal innovation. The implication is that managers should consider the external business environment when committing resources to reverse-engineering activities in emerging markets. The varying influences of the external environment on the effect of reverse engineering on types of frugal innovations suggest that managers should take into consideration the institutional and industry environments when investing in firm capabilities in emerging markets. In terms of the industry conditions, this study suggests that managers should direct more investment to reverse-engineering activities in contexts where technological turbulence is low. When the market is characterized by a high rate of technological change (Jaworski & Kohli, 1993), it may impose risks on firms to engage in R&D activities and not reverse engineering. Moreover, the finding that legal inefficiency enhances the effect of reverse engineering on AVI suggests that managers should be cognizant of the institutional contexts that have high legal inefficiency. This is the case because when the environment is characterized by inefficient legal enforcement, there is potential for unfair competitive actions that could boost reverse-engineering activities. We encourage SME managers to pay attention to the legal frameworks in emerging markets when investing in reverse engineering. This is because, in contexts where legal regimes are weak, firms tend to adopt imitation strategies, which is a major characteristic of reverse engineering. Given that grand challenges necessitate creative problem-solving approaches (Selsky & Parker, 2005), the focus on frugal innovations provides an opportunity to innovate with fewer resources. The findings about frugal innovation suggest that there are economic gains for resource-poor developing nations to direct resources to incentivize firms to adopt such creative solutions.

6 | LIMITATIONS AND FUTURE RESEARCH

The findings from the study have contributed theoretically and practically to extending the firm capability and frugal innovation literature regarding how and when reverse engineering influences SMEs' frugal innovation performance in emerging markets. However, despite the important contributions, our study is prone to some limitations that open avenues for future research trajectories. First, while our study focuses on performance outcomes of reverse engineering, we did not investigate the factors that drive reverse engineering, a major firm's capability. We recommend that future research should consider this limitation. This is an important research agenda because insights into the antecedents of reverse engineering may extend our knowledge about factors driving experiential approaches to frugal product development based on improvisation (Malik & Kotabe, 2009). This investigation holds promise for the reduction of technological uncertainty in emerging economies in addressing grand challenges. This is the case because reverse engineering of successful competing products can allow emerging-market small firms to gain late follower advantages through the development of products that focus on affordability (Nakata & Weidner, 2012). Future research could also explore the role of diverse stakeholders and how they coordinate and collaborate for mitigating grand challenges through sustainable business models. There is scope for future studies to focus on the underlying causes of grand societal challenges and how firm-based resource-constrained environments develop new sets of capabilities and leverage resources to address these challenges. Furthermore, there is a value in examining the role of cross-sector partnerships in resource-constrained contexts and how these partnerships enable the development of frugal innovation and sustainable business models to address grand challenges (cf. Arslan et al., 2020). Such studies could draw upon from the ecosystems and network perspectives (cf. Adner, 2017; Shipilov & Gawer, 2020) and examine how different network partners involving both small and large firms based in resource-constrained contexts contribute resources and capabilities to address grand challenges.

Third, although our investigation specifically addresses the extent to which firms from emerging markets provide solutions to grand societal challenges, we did not highlight the role played by specific technologies. We suggest that future studies examine the impact of specific technological adoption such as artificial intelligence, 3D printing, and the internet of things (IoT) in facilitating frugal innovation in these economies.

Fourth, our sample is from firms operating in an emerging market, which limits the generalizability of the findings. Although Ghana sheds some semblance of characteristics of most emerging markets, Ghana is a small sub-Saharan African market. Therefore, extending this study to other emerging markets such as Indonesia, India, Turkey, South Africa, and Vietnam may provide strong external validity to the findings. More importantly, future research may examine frugal innovations in emerging-market firms and foreign multinationals as a way of comparing the results.

Finally, despite collecting data at different times from multiple respondents, our study could still be considered cross-sectional. As with cross-sectional research, we are unable to make causal claims about the relationships explored in this study. Thus, we recommend that future research should collect data longitudinally or use experimental techniques to be able to attenuate potential endogeneity problems (Cooper et al., 2020; Zaefarian et al., 2017). Moreover, given that firms' capabilities and innovation activities could change during the economic transition (Cai et al., 2019), we encourage future studies to use longitudinal data sets to examine the relationships explored in this study.

7 | CONCLUSION

Despite the preceding limitations, our study from a sample of 243 SMEs in Ghana found support for the role of reverse engineering on frugal PIP through the mediating mechanism of frugal innovation. In addition, the findings show the contingent roles of technological turbulence and legal inefficiency in the association between reverse engineering and categories of frugal innovation (i.e., cost innovation, and AVI). Collectively, the findings from this study contribute to the product-innovation literature in many aspects. In the main, our study extends product-innovation theory development by offering a clearer picture of how and when the influence of reverse engineering and frugal innovation enhance the product-innovation performance of SMEs based in resource-constrained emerging markets.

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ORCID

Samuel Adomako https://orcid.org/0000-0002-7139-0988
Michael Asiedu Gyensare https://orcid.org/0000-0001-7150-3594
Joseph Amankwah-Amoah https://orcid.org/0000-0003-0383-5831
Pervaiz Akhtar https://orcid.org/0000-0002-7896-4438

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APPENDIX

RELIABILITY AND VALIDITY TEST

Constructs, details of measures, and results reliability and validity test	Mean	s.d.	λ	*t*-value	SMC	VIF
Reverse engineering (Malik & Kotabe, 2009): CR = 0.860; AVE = 0.578; α = 0.857						
We look toward our foreign competitors for ideas to develop new products	5.69	1.26	0.69	Fixed	0.47	2.04
Our engineers have often bought competing products and disassembled them in order to understand the technologies and manufacturing practices underpinning these products	5.81	1.22	0.79	10.82	0.62	2.43
Some of our new product ideas have come from foreign customers	5.81	1.16	0.86	11.56	0.74	2.72
We have developed new products based upon the design and technology of competing for foreign products	5.85	1.14	0.78	10.71	0.60	2.31
Cost innovation (Cai et al., 2019; Zeschky et al., 2014): CR = 0.760; AVE = 0.518; α = 0.753						
The innovation product offers similar functionalities compared to the mainstream products in the market	5.24	1.32	0.61	Fixed	0.38	1.59
The innovation product has a drastically lower price compared to the mainstream products in the market	5.20	1.29	0.68	7.96	0.46	1.73
The innovation product is at lower costs for resource-constrained customers	5.28	1.21	0.85	8.19	0.72	2.19
Affordable value innovation (Ernst et al., 2015): CR = 0.923; AVE = 0.858; α = 0.921						
The innovation product provides new value to low-income customers	4.73	1.70	0.88	Fixed	0.77	4.08
The innovation product is affordable for the low-income population	4.67	1.72	0.97	10.63	0.94	4.31
Legal inefficiency (H. Li & Atuahene-Gima, 2001): CR = 0.805; AVE = 0.508; α = 0.804						
Unlawful competitive practices such as illegal copying of new products	5.56	1.16	0.69	Fixed	0.48	1.77
Counterfeiting of your firm's own products by other firms	5.38	1.26	0.75	9.46	0.56	2.12
Ineffective market competitive laws to protect your firm's intellectual property	5.30	1.20	0.71	9.16	0.51	1.93
Increased unfair competitive practices by other firms in the industry	5.27	1.22	0.70	9.00	0.49	1.79
Technological turbulence (Jaworski & Kohli, 1993); CR = 0.886; AVE = 0.610; α = 0.882						
Technologies in our industry are changing rapidly	5.46	1.22	0.65	Fixed	0.42	1.94
It is very difficult to forecast technology developments in our industry	5.62	1.24	0.82	10.69	0.67	2.75

(Continues)

Constructs, details of measures, and results reliability and validity test	Mean	s.d.	λ	*t*-value	SMC	VIF
Newly developed technologies in our industry can easily become out of date	5.66	1.22	0.85	11.00	0.72	3.22
Technological changes provide big opportunities in our industry	5.76	1.20	0.83	10.85	0.69	3.11
Several new product ideas have been made possible through technological breakthroughs in our industry	5.64	1.25	0.74	9.91	0.55	2.28
Frugal product innovation performance (Atuahene-Gima et al., 2005); CR = 0.878; AVE = 0.592; $\alpha = 0.875$						
Rate the extent to which your firm has achieved the following frugal product development objectives						
Market shares relative to the firm's stated objectives	5.67	1.14	0.77	Fixed	0.59	2.48
Sales relative to stated objectives	5.30	1.30	0.60	9.31	0.36	1.81
Return on assets relative to stated objectives	5.77	1.22	0.87	13.90	0.75	3.17
Return on investment related to stated objectives	5.72	1.22	0.82	13.16	0.68	2.77
Profitability relative to stated objectives	5.63	1.16	0.76	12.07	0.58	2.36

Note: *Fit statistics:* χ^2(df) = 336.712***(215); *p*-value = 0.000; χ^2/df = 1.566; RMSEA = 0.048; SRMR = 0.049; TLI = 0.943; CFI = 0.951.
Abbreviations: AVE, average variance extracted; CR, composite reliability; s.d., stand. deviation; SMC, squared multiple correlation; VIF, variance inflation factor; α, Cronbach's alpha; λ, stand. factor loadings.

AUTHOR BIOGRAPHIES

Samuel Adomako, PhD is an Associate Professor of Strategy and Innovation at the University of Birmingham. His research examines the nexus of strategy and innovation. His research has appeared in leading journals including British Journal of Management, International Small Business Journal, International Business Review, R&D Management Journal, International Journal of Entrepreneurial Behavior and Research, Business Strategy and the Environment, Management International Review, Journal of Institutional Economics, Journal of Business Research, Journal of International Management, and many others. He earned his PhD from the University of Warwick. He is a Fellow of the Higher Education Academy, UK.

Michael Asiedu Gyensare is completing his PhD in Management at Edith Cowan University, Australia. His research straddles the divide between strategic HRM/OB and Entrepreneurship. Michael's research has been appeared in leading journals such as Journal of Business Research, Leadership and Organisation Development Journal, Cogent Business and Management, and Sustainability. He is currently an editorial board member of Industrial and Commercial Training Journal.

Joseph Amankwah-Amoah is a Professor of International Business at the University of Kent, UK. Joseph has consistently published in many journals of international repute, including Journal of International Business Studies, Journal of World Business, British Journal of Management, Industrial and Corporate Change, Business History, Management International Review, and International Business Review. In all, he has published over 150 articles in leading journals. Joseph was included in Stanford University's prestigious list of the World Top 2% scientists for citation impact during the single calendar year.

Pervaiz Akhtar is currently the Director of MBA Programmes and Chair (Full Professor) in Business Analytics, Big Data, and Supply Chains at the University of Aberdeen, United Kingdom. His achievements have set records and he became the Youngest Professor from his country of origin with three-consecutive promotions in the same university, a historical record in the University along with a professorship offer from a top-10 U.K. university. This also placed him among just over 150 academics across all disciplines in the United Kingdom who earned their Professorship under age 35 as per HESA records. He is associated with Imperial College London for his philosophy of continuous learning. Capitalizing on over 20 years of academic and industrial experiences from leading public, private, and non-profit-making organizations, he has published in top-tiered international journals such as the International Journal of Operations & Production Management, British Journal of Management, Journal of Product Innovation Management, International Journal of Production Economics, Business Ethics, Technological Forecasting and Social Change, IEEE Transactions on Engineering Management, among others. Professor Akhtar is a Senior Associate Editor for the International Journal of Physical Distribution & Logistics Management and is affiliated with the editorial boards of the British Journal of Management and Journal of Knowledge Management.

Nazim Hussain is a tenured Associate Professor of Sustainability Accounting at the Faculty of Economics and Business of the University of Groningen, The Netherlands. His research interests lie in the areas of Corporate Sustainability Performance and Disclosure analysis, Corporate Greenwashing, Corporate Governance, and Environmental Innovation. His research has appeared in many journals, such as the British Journal of Management, Journal of Business Ethics, British Accounting Review, Journal of International Money and Finance, Business & Society, Business Strategy and the Environment, International Financial Markets, Institutions & Money, and Energy Economics among others.