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GREEN INNOVATION EDUCATION AND ITS IMPACT ON FIRM PERFORMANCE: A COMPREHENSIVE STUDY

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ABSTRACT

The study examines the configurational relationship between Green Innovation Education (GIE), six green innovation dimensions and firm performance of micro, small and medium enterprises (MSMEs) from Pakistan and Bangladesh utilizing fuzzy-set Qualitative Comparative Analysis (fsQCA) and Necessary Condition Analysis (NCA). The study examines the interplay of GIE and green innovation dimensions that create high firm performance, grounded in Resource-Based View (RBV), Dynamic Capabilities Theory (DCT) and Organizational Learning Theory (OLT). The findings indicate that GIE is the most important necessary condition for high performance (d = 0.323, p = 0.004) followed by green business model innovation (d = 0.222, p = 0.020). fsQCA analysis identifies a single sufficient configuration of the six green innovation dimensions with GIE, comprising six core conditions and one peripheral condition. The results have both theoretical implications for the theory of green innovation and practical contributions to MSMEs and policymakers in developing countries.

Keywords: Green İnnovation Education, Green İnnovation Dimensions, Firm Performance, Fsqca, NCA, Developing Countries

JEL Classification: M14, O31, Q55, L25

1. INTRODUCTION

In the 21st century, environmental sustainability has become a global need for businesses. Climate change, resource depletion and environmental degradation are major barriers to economic growth, poverty reduction and human well-being. Green innovation, in particular, has been widely discussed as an opportunity for firms to mitigate their negative environmental impacts while ensuring at least cost-competitive advantage. According to Rennings (2000) “green innovation is the 'introduction of new products, processes, services” and marketing techniques based on environmental sustainability.

In developing nations, importance of (MSMEs) cannot be overstated; MSMEs provide a large portion of jobs in the economy and contribute considerably to GDP and innovation. In contrast, MSMEs in developing countries are more cautious about the adoption of green innovation due to limited available resources and access to technology and knowledge on green innovation practices. However, each of these companies represent a small impact individually, but cumulatively can be a large source of emissions. Thus, this also poses a question about how the MSME can effectively be involved in green innovation should be a concern for academic scholars and policy makers.

Green Innovation Education (GIE) is one of the possible measures weakening in green innovation in firm. GIE are those educational interventions that enhance employees' knowledge, skills and mindsets for green innovation (including sustainability literacy, green innovation knowledge, creative problem solving and systems thinking). The firms that have invested GIE will know where their human capital lies to drive green innovation incentives and thereby improve performance. Nevertheless, the association between GIE, the dimensions of green innovation and a firm performance has received less research attention especially in non-developed country context.

1.1 Theoretical Framework

Based on three complementary theoretical perspectives: RBV, DCT, and OLT. According to RBT (Barney, 1991), “firms gain competitive advantage from VRIN (valuable, rare, inimitable and non-substitutable) resources”. In so doing, GIE builds human capital resources that are not easily imitable because of causal ambiguity and social complexity. Green innovation capabilities, on the other hand, are one type of heterogeneous resources that can explain competitive advantage. Given that, the RBV perspective is most applicable to explain performance differences across firms in green innovation given its emphasis on intangible, “path-dependent resources that are inherently difficult for competitors to imitate” (Ranasinghe et al., 2022).

“DCT, first introduced by Teece et al. (1997), also extends the RBV” by describing the capabilities needed for firms to develop, integrate, and reconfigure resources over time. GIE fulfills the role of a dynamic capability that provides firms with a heightened awareness of environmental opportunities, capabilities to implement green innovation activities, and volume to reconfigure organizational processes in reply to varying demands for sustainability. Dynamic capabilities are required for maintaining competitive advantage in rapidly changing environmental contexts. GIE promote (Cohen & Levinthal, 1990; Fulgence et al., 2023), which is an absorptive capacity that helps all firms to identify and assimilate the new green technologies and practices.

The micro-foundations are based on OLT (Argyris & Schön, 1997; Senge, 2006) to explain how the GIE transforms individual knowledge into organizational ability. GIE cultivates single-loop learning (incremental improvements in current practices), as well as double-loop learning (fundamental rethinking of assumptions and strategies). Through training and knowledge contributes to dynamic learning that becomes part of organization routines, systems and culture creating sustainable competitive advantage (Alam et al., 2023). That is a critical process for building a robust green innovation capability.

1.2 Research Gaps and Objectives

Although the field of green innovation and firm performance has been gaining momentum, important gaps still exist. Firstly, while most studies in the field search for a structural relationship between green innovation and eco-innovation, researchers typically treat green innovation as a construct unidimensional or even obsession by one of the dimensions, if is something multidimensional we cannot study only one value of its multiple values o need to consider together all the past reviews highlights. Second, the key role GIE plays as a catalyst for green innovation has not yet been adequately investigated and defined, especially in developing country contexts where educational systems and sustainability awareness may be dramatically different to those within developed economies. Third, most studies employ conventional regression techniques that isolate the marginal impact of individual variables, neglecting the asymmetric and configurational nature of causal relationships. Fourth, few studies examine green innovation in MSMEs in developing countries, despite their economic and environmental significance (Alvarez-Garcia et al., 2022).

To bridge these gaps, the present study: (1) conceptualizing green innovation as a multi-dimensional construct comprising six dimensions process, product, service, technological, business model, and marketing innovation; (2) examining the configurational relationships among GIE, green innovation dimensions, and firm performance; (3) employing fsQCA and NCA to capture asymmetric and necessary condition relationships; and (4) focusing on MSMEs in two developing countries, Pakistan and Bangladesh. The primary research question guiding this study is: What configurations of GIE and green innovation dimensions lead to high firm performance in MSMEs in developing countries?

2. LITERATURE REVIEW

2.0 Green Innovation: An Overview

“Green innovation encompasses the development and implementation of new products, processes, services, technologies, business models, and marketing approaches that reduce environmental” impact and contribute to sustainability (Rennings, 2000; Fussler & James, 1996). Schumpeter (1934) identified innovation as the primary driver of economic development, distinguishing among “five types: new products, new production methods, new markets, new supply sources, and new organizational forms”. The field was further advanced by Porter & van der Linde (1995) with the so-called "Porter Hypothesis," which challenged the widely held assertion that firm level environmental protection entails a direct cost to compliance, claiming instead that carefully designed environmental regulations could spur innovative technologies that more than negate compliance costs.

Inspired by the OECD/Eurostat (2005) Oslo Manual and some established eco-innovation frameworks this study defines green innovation as a multi-dimensional construct that includes six dimensions: process, product, service, technological, business model and marketing innovation. These dimensions suggest that firms can integrate complementary capabilities to achieve environmental and economic goals (Chen et al., 2006; Wagner, 2005). Although several studies measure green innovation as a single, undivided metric, defining it multidimensionally permits better insight into how various typologies of green innovation interact not only with each other but also with enablers like GIE to generate performance outcomes.

2.1 Green Innovation Dimensions

2.1.1 Green Process Innovation

"Green process innovation consists of the integration" of environmental thinking into each stage of the innovation process, such as energy efficiency enhancements in a product or process, input waste minimization policies for pollution control and sustainable supply chain sourcing strategy (Xing et al., 2020). According to the research, green process innovation improves resource productivity and decreases energy consumption and operating costs (Zhang & Jiang, 2025). In the RBV stream, process innovation has cost advantages based on resources utilization efficiency; while in the dynamic capabilities stream, it explains a firm's capabilities to reconfigure operational processes by environmental pressures. From the green production and operational activities, it is usually believed that process innovation serves as the backbone of green innovation.

Hypothesis 1: Green process innovation is a sufficient condition for high firm performance.

2.1.2 Green Product Innovation

According to Chaudhuri et al., (2023), Nuryakin and Maryati (2022) green product innovation means products designed for lower energy consumption materials "throughout their life cycle. Eco-design is the integration of environmental aspects into product design" and development, which is a core approach to green product innovation (Chen et al., 2006). Such a differentiation advantage through green product innovations is based on the fact, that these innovations create a unique value to environmentally conscious buyers (Maulidi, 2025). The general and cross disciplinary knowledge needed for green product design cannot be copied easily, thus leading to sustained competitive advantage.

Hypothesis 2: Green product innovation is a sufficient condition for high firm performance.

2.1.3 Green Service Innovation

"Green service innovation refers to sustainable services" like energy-efficient delivery, take-back and recycling programs or product-as-a-service models and sustainability consulting (Ruo-yong et al., 2007). This type of innovation for service-sector firms, for those manufacturer firms transitioning toward servitization business models. Green services can give organizations a way to differentiate themselves, create consumer loyalty and provide alternate streams of revenue while helping the environment. With the transition of the global economy toward service-dominant logic, green service innovation can be particularly crucial for firms to sustain competitive advantage.

Hypothesis 3: Green service innovation is a sufficient condition for high firm performance.

2.1.4 Green Technological Innovation

"Green technological innovation is defined as the development and application of new technologies which reduce environmental impacts, such as clean technologies, renewable energy technologies" and pollution control technologies (Wagner, 2005). They tend to consider technological innovation as the engine of green innovation, where technology delivers the solution (tech-men against environment) for diminishing environmental impact. In light of the RBV, technological capabilities are particularly relevant because they are most likely to be patented and require large investment in research & development (R&D), which makes them both rare and costly to imitate. However, technology innovation is unlikely to be enough without enabling capabilities in some non-technological dimension.

Hypothesis 4: Green technological innovation is a sufficient condition for high firm performance.

2.1.5 Green Business Model Innovation

"Green business model innovation consists of reshaping how a firm creates, delivers and captures value" while minimizing environmental impact (Bocken et al., 2014) Examples include circular economy models, product-service systems, sharing economy models, and sustainable supply chain configurations. Business model innovation is especially potent because it can alter the fundamental nature of the firm's resource and environmental relationships, frequently producing larger environmental improvements than those obtainable with product or process innovations alone. From a perspective of dynamic capabilities, business model innovation operates as a meta-capability that facilitates the comprehensive realignment of their entire value proposition.

Hypothesis 5: Green business model innovation is a sufficient condition for high firm performance.

2.1.6 Green Marketing Innovation

Green marketing innovation captures new approaches for communicating environmental value and targeting consumers that are concerned about the environment (Chen et al., 2006). This means green branding, eco-labeling, sustainability communication, and green distribution channels. Green marketing enables firms to transform their environmentally friendly legends into market advantage by creating awareness, establishing brand equity and consumption propensity. Through the lens of RBV, green marketing capabilities contribute to intangible assets like brand reputation and customer loyalty which are difficult to imitate. Proper green marketing is needed for capturing the market value of the green innovation.

Hypothesis 6: Green marketing innovation is a sufficient condition for high firm performance.

2.2 Green Innovation Education (GIE)

GIE is defined as a complex, multi-faceted construct with four interrelated dimensions: Employee Training for Sustainability Literacy, Green Innovation Knowledge, Creative Problem Solving and systems thinking. This section, Employee Training for Sustainability Literacy aims to capture some of the basics of sustainable development principles followed by being environmentally responsible. Green Innovation Knowledge is the explicit knowledge in renewable energy technologies, sustainable materials, green business models and environment-friendly production system. Creative Problem-Solving is a skill to think outside the box and design new sustainable solutions (AlQershi et al., 2023). Systems Thinking - is all about recognizing the connections between ecological and economic systems, and it deals with taking a holistic approach to environmental problem solving.

GIE connects to a number of established literature streams. Research on environmental training has shown that training employees in a company with regard to how to manage the environmental aspect is beneficial for both the environment and financial performance (Asni & Dianawati, 2024; Barba-Aragon & Jimenez-Jimenez, 2024; Murad & Zou, 2023; Daily & Huang, 2001; Wu et al., 2024). Behavioral improvement Based on GHRM research, improving green capability by fostering better pro-environmental behaviors "Green Human Resource Management (GHRM) practices" refer to using HR practices in different functional areas that develop skills in managing human resources for achieving superior organizational performance in environment management (Renwick et al., 2012; Ahmad et al., 2023; Trivedi & Trivedi, 2023; Kodua et al., 2022). Learning research that emphasizes sustainability imposes another important argument: the organizational learning process is relevant for capability development towards sustainability. In addition to this, the study expands upon these literatures by framing GIE as an overarching contingent HRM response one that nurtures the diverse capabilities required for green innovation, and even more fundamentally; it positions

GIE not merely as another type of isolated HR practice, but as an enabling learning intervention.

Hypothesis 7: GIE is a necessary condition for high firm performance and interacts with green innovation dimensions to produce sufficient configurations.

2.3 Firm Performance

Firm performance is defined as, financial performance and is measured through profitability, sales turnover and ROI (return on investment). “Financial performance is the most frequently studied outcome variable in green innovation literature”, being determined as the bottom line for green innovation initiatives (Paulraj et al., 2024; Shah & Ivascu, 2024). The emphasis on financial performance is especially pertinent for MSMEs in developing nations, where survival and profitability are often the main objectives and a significant resource constraint limits pursuit of non-financial objectives. Although other measures like environmental performance and innovation performance (i.e., non-financial performance) matter too, the focus of this study is financial performance because financial performance represents an ultimate strategic outcome that owners and managers of firms are seeking to achieve.

There are a number of justifications for the selection of financial performance indicators. The first one profitability is the most important for MSME owners, as it directly reflects the financial viability of green innovation investments. The second impact we measure is whether green innovations have a real market effect, represented as sales turnover. Third, ROI aids as a yard stick for evaluating efficiency of investments in green innovation by showing whether or not the returns outweigh the costs. This comprehensive assessment of financial performance in terms of these three indicators is managerially relevant and shows theoretical foundations based on the existing literature about green innovation.

2.4 Theoretical Synthesis

Building on the three theoretical perspective RBV, dynamic capabilities and organizational learning this study developed a configurational model where GIE is deployed as a foundational enabler interacting with six green innovation dimensions leading to high firm performance. “According to the RBV, GIE and green innovation are valuable, rare, immobile and non-substitutable resources that will serve as sources of competitive advantage” (Pang et al., 2024). Integrating the DCT with GIE illustrates the mechanisms through which organizations continually renew and transform their eco-innovation competencies to align with shifting environmental conditions. In this regard, the OLT as one of GIE theoretical building blocks serves as a micro-foundation conceptual framework about how the green innovation capabilities at the organizational level are distilled from individual-level learning through GIE.

Additionally, this configurational perspective indicates that these conditions do not work separately but instead in specific combinations to generate high performance. Instead of a green innovation dimension affecting the performance independently, the constructs from the configurational view can explain that through GIE many measures have to be simultaneously present together. This perspective acknowledges the multi-dimensionality of green innovation and that to downstream value from green innovation, firms must develop capabilities in multiple dimensions simultaneously. The study, therefore, suggests that GIE is a necessary condition through which combinations of green innovation dimensions blossom into sufficient configurations for high performance.

3. METHODOLOGY

3.1 Data Collection and Sampling

Employing a cross-sectional survey methodology, this study gathered data from 121 MSMEs in Pakistan & Bangladesh during March – October of 2024. We applied a purposive sampling strategy in order to achieve diversity across sectors, firm characterizations and geographic areas. The firms were eligible if they were registered MSME with 1-250 employees, working in manufacturing, services, and commerce areas. Linguistic equivalence was ensured by back-translation, whereby the questionnaire was translated into local languages (Urdu, for Pakistan; Bengali, for Bangladesh). Owner-managers or their deputies, who hold primary authority over strategic choices regarding of innovation and sustainability were used. To construct the sampling frame, we leveraged the networks of was created with the support of local business associations and chambers of commerce in both countries. In Pakistan, firms were hired from Karachi, Lahore and Islamabad: major industrial and commercial centers. There were recruited firms in Dhaka, Chittagong and Sylhet, Bangladesh. An access layer allowed firms to join the study if they have run for at least two years and how at least one employee (not owner manager) which ensures that sufficient organizational structure exists to facilitate green innovation activities. Firms in heavily regulated sectors (like pharmaceuticals or nuclear energy), where the conditions of innovation might differ markedly from most MSMEs, were excluded.

A total of 121 useable responses were received from 130 distributed questionnaires with a response rate of 93.1%. A sample of 71 firms (58.67%) from Pakistan and 50 from Bangladesh (41.33%) Our sample consists of manufacturing (42.15%), services (35.54%) and commerce (22.31%) firms, respectively. Firm sizes cover l micro (38.84%); small (41.32%), medium (19.84). The response rate was high as the topic is relevant to firms participating in this research, and personal relationships developed with business associations from both countries. Potential non-response bias was examined by analyzing temporal differences between early and late respondents on the core constructs, which indicated an absence of significant variance.

3.2 Measurement and Validation

We employed established scales from the green innovation literature to measure all constructs, all on a 7-point (1 = Strongly Disagree to 7 = Strongly Agree) Likert scale (Preston & Colman, 2000). A total of sixteen items across four dimensions adapted from the previous environmental training and green HRM scales were used to measure GIE. Items adapted from (Chen et al., 2006; Wagner, 2005) were used to measure the six green innovation dimensions with 3 to 4 items for each dimension). Firm performance was assessed using three items (profitability, sales turnover, ROI) adapted from (Wall et al., 2004), reflecting subjective evaluations of capturing perceived financial performance benchmarked against industry rivals.

In this study, the measurement model was evaluated using a number of different practices. All constructs had good psychometric properties: “Cronbach's Alpha were greater than 0.80, composite reliability greater than 0.70, and Average Variance Extracted (AVE) values were also >0.50 for all constructs” (Fornell & Larcker, 1981; Hair et al., 2019). “The Fornell-Larcker criterion confirmed discriminant validity since all square roots of AVE was higher than correlations with all other constructs” (Fornell & Larcker, 1981). “To assess common method bias, Harman's single factor test and VIF analysis were conducted; neither indicated significant bias” (Podsakoff et al., 2003). The correlation matrix is presented in Table 1 and the descriptive statistics and measurement properties in Table 2.

Table 1. Correlation Matrix

Variable	GIE	GPI	GPrI	GSI	GTI	GBMI	GMI	FP
GIE	0.79							

GPI	0.54**	0.76						
GPrI	0.58**	0.52**	0.77					
GSI	0.52**	0.48**	0.55**	0.75				
GTI	0.56**	0.50**	0.53**	0.51**	0.77			
GBMI	0.61**	0.49**	0.56**	0.54**	0.58**	0.78		
GMI	0.55**	0.47**	0.51**	0.50**	0.52**	0.59**	0.76	
FP	0.68**	0.42**	0.48**	0.45**	0.46**	0.52**	0.47**	0.77

Source. Developed by author.

Table 2. Descriptive Statistics and Measurement Properties

Variable	M	SD	CR	Cronbach α	AVE	GIE	FP
GIE	5.12	0.89	0.89	0.87	0.62	0.79	0.68**
GPI	4.87	0.92	0.85	0.82	0.58	0.54**	0.42**
GPrI	4.76	0.95	0.86	0.83	0.59	0.58**	0.48**
GSI	4.65	0.98	0.84	0.81	0.57	0.52**	0.45**
GTI	4.82	0.91	0.87	0.84	0.60	0.56**	0.46**
GBMI	4.58	1.02	0.88	0.85	0.61	0.61**	0.52**
GMI	4.71	0.94	0.85	0.82	0.58	0.55**	0.47**
FP	4.93	0.87	0.86	0.83	0.60	0.68**	0.77

Note. M = Mean; SD = Standard Deviation; CR = Composite Reliability; AVE = Average Variance Extracted.

Source. Developed by author.

3.3 Calibration Procedure

The calibration process converts the observed values for interval-scale variables into fuzzy membership scores between 0 (non-member) and 1 (member). The direct method of calibration (Ragin, 2009) is employed in this study, and anchors are fixed by theoretical and distributional concerns. A score of 6 (out of 7) corresponding to "Strongly Agree" in the Likert scale was proposed for full membership status, which indicates high engagement with the practices that are framed around green innovation. The extreme of full non-membership is defined by assigning a score of 2 indicating "Disagree" with little engagement. The scale midpoint was chosen as the crossover point: 4.

Two of these anchors roughly correspond to the 60th, 40th, and 20th percentiles of the sample distribution (Fiss, 2011). Calibration was performed in fsQCA 3.0 via a logistic function that converts each raw score into fuzzy membership scores through pre-defined anchors. This way would keep both, a sound theoretical basis for the calibration and empirical basis in the sample distribution.

3.4 fsQCA Method

"fsQCA is a set-theoretic technique studies effect of combination of causal conditions on an outcome" (Ragin, 2009). While regression methods search for average net effects of individual variables, fsQCA studies configurational relationships and allowed recognization of equifinality (multiple pathways to same outcome), as well as asymmetric causality (that conditions have different effects in different contexts). The analysis has five steps: (1) conduct a necessity analysis to identify the conditions that must be present for the outcome to occur; (2) construct a truth table enumerating all logically possible configurations of the causal conditions, (3) set frequency and consistency thresholds to select meaningful configurations, (4) allow Boolean minimization to develop logical combinations of items leading towards the outcome and (5) an interpretation of solutions into core and peripheral conditions.

fsQCA 3.0 Scenarios were run "with a consistency threshold of 0.80, frequency cut off of 1, and PRI consistency cut off of 0.70" (Ragin, 2009). Being easily comparable to intermediate solution as it treats easy and difficult counterfactuals in the same way, and offers a democratically interpretation of core-behavior conditions here hence reports the results. Core conditions are present in both the parsimonious and intermediate solutions, whereas peripheral conditions appear only in the intermediate solution.

3.5 NCA Method

NCA, specifically, it helps specify "conditions that are necessary but not (by themselves) sufficient" for an outcome (Dul, 2015; Dul, 2020). By definition, a necessary condition must be present for an outcome to occur, its absence ensures that the outcome cannot occur. NCA yields quantitative estimates of the amount of necessity (effect size d) as well as identifying bottleneck levels minimum levels of any conditions required in order to reach specific outcome levels. There are two implementations of the ceiling method: Ceiling Envelopment (CE) for discrete/binary variables and Ceiling Regression (CR) for continuous variables.

Effect sizes (d) are interpreted using standard thresholds of small (0.1), medium (0.3), and large (0.5), while statistical significance was determined by permutation tests (10,000 permutations). NCA is a complementary method to fsQCA which offers quantitative estimation of necessity and can identify the levels of each condition necessary for the respective levels of outcome. Integrating these methods provides a more global view of the connections among exposures and outcomes than either method done independently.

4. RESULTS

4.1 Sample Characteristics

The characteristics of the sample are summarized in Table 3. The sample is composed of 121 firms with 71 firms (58.67%) from Pakistan and 50 firms (41.33%) from Bangladesh. The firms belonged to various industry sectors, with the highest representation in commerce (30 firms, 24.8%), processing/manufacturing (20 firms, 16.5%) and services (15 firms, 12.4%). Out of these, some other sectors are Education, Health and social services, Construction, Utilities & financial and insurance.

The sample is fairly evenly distributed by firm age, where 19.8% of firms were less than 5 years old; 24.8% between the ages of 6–10; 20.7% aged between 11–15; 16.5% and16–20 and18.2%, respectively21 to30 years old firms (Table1). About the firm size most of firms have 11–30 workers (37.2%) then 6–10 employees (28.9%), less than 5 employees (12,4%) and more than 30 employees (21,5%). The sample consists of 60 family firms (49.6%) and 61 non-family businesses (50.4%). In general, the sample is mathematically heterogeneous with respect to most dimensions allowing for an ideal basis of analyzing its configurational relations.

Table 3. Sample Characteristics

Characteristic	Frequency	Percent	Characteristic
Firm Age (Years)			Industry Sector
< 5	24	19.8%	Commerce
6 – 10	30	24.8%	Processing/Manufacturing
11 – 15	25	20.7%	Services
16 – 20	20	16.5%	Education
21 – 30	22	18.2%	Processing Industry
Number of Employees			Health and Social Services
< 5	15	12.4%	Construction
6 – 10	35	28.9%	Financial and Insurance
11 – 30	45	37.2%	Other
> 30	26	21.5%	
Type of Firm			
Family Business	60	49.6%	Gender (Owner-Manager)
Non-Family Business	61	50.4%	Male
Country			Female
Pakistan	71	58.67%	
Bangladesh	50	41.33%	

Note. N = 121. Processed primary data, 2024.

Source. Developed by author.

4.2 NCA Results

Prior to the fsQCA sufficiency analysis, a necessity analysis using NCA was carried out to find necessary conditions for high firm performance. We report the NCA results of CE and CR methods in Table 4. GIE presents as a necessary condition for the high-sweet-spot RM (HWP) firm performance, and is confirmed with a large effect size using competitive effectiveness (CE; d = 0.323, p = 0.004) and a medium-to-large effect size using competitive responsiveness (CR; d = 0.252, p = 0.011). These results lend considerable support to Hypothesis 7, which posited that GIE is a sufficient condition for high performance.

Table 4. NCA Results

Fuzzy-set Condition	Method	Accuracy	Ceiling Zone	Scope	Effect Size (d)	p-value

Green Process Innovation	CE	100%	5.621	31.00	0.192*	0.110
	CR	98.6%	3.222	31.00	0.112*	0.512
Green Product Innovation	CE	100%	4.201	23.60	0.184*	0.263
	CR	97.1%	2.486	23.60	0.121*	0.471
Green Service Innovation	CE	100%	8.191	37.00	0.237*	0.013
	CR	95.7%	5.795	37.00	0.171*	0.052
Green Technological Innovation	CE	100%	5.161	25.00	0.220*	0.196
	CR	95.7%	3.887	25.00	0.170*	0.284
Green Business Model Innovation	CE	100%	8.502	34.00	0.261*	0.022
	CR	97.1%	6.876	34.00	0.222*	0.020
Green Marketing Innovation	CE	100%	7.902	31.00	0.272*	0.115
	CR	97.1%	5.312	31.00	0.169*	0.322
Green Innovation Education	CE	100%	9.226	29.56	0.323*	0.004
	CR	94.3%	7.187	29.56	0.252*	0.011

Note. * Effect size d ≥ 0.1 indicates a necessary condition (medium effect or higher). p-values based on 10,000 Monte Carlo permutations. CE = Ceiling Envelopment; CR = Ceiling Regression.

Source. Developed by author.

Using CR, the effect size on green business model innovation is also medium (d = 0.222, p = 0.020), confirming that this capability actually has to be present as well (a sufficient condition). Green service innovation has a small but significant effect (d = 0.171, p = 0.052), so could also be seen as a necessary condition, though its statistical support is weaker. As regards the other G1 (green innovation) dimensions: process, product, (technological), marketing innovation,) they all are medium effect sizes but not significant p > 0.05 since they are not necessary conditions at all.

Table 5. NCA Bottleneck Levels

FP Level (%)	GPI	GPrI	GSI	GTI	GBMI	GMI	GIE
0	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—
40	—	—	—	—	—	—	29.4
50	—	—	—	—	—	—	29.4
60	—	—	—	6.2	—	—	29.4

70	56.0	54.4	56.6	57.3	59.2	74.5	61.2
80	56.0	54.4	56.6	57.3	72.7	74.5	63.6
90	56.0	54.4	77.8	68.8	81.8	74.5	65.8
100	56.0	54.4	77.8	68.8	81.8	74.5	65.8

Note. Values represent minimum required levels (%) of each condition to achieve the corresponding firm performance level. "—" indicates that the condition is not a bottleneck at that performance level. CE method used for bottleneck analysis.

Source. Developed by author.

The specific the minimum required levels of each condition to achieve various thresholds of firm performance is visible in the more detailed bottleneck table (Table 5). The first and most persistent bottleneck is GIE: firms require almost a minimum of 29.4% of maximum GIE, just to have moderately performing (40–60%) firms. GIE requirements rise to 61.2% and above at performance levels 70% and higher. Green marketing innovation shows the highest bottleneck level at 70% performance (74.5%), while green business model innovation requirements increase from 59.2% at 70% to 81.8% at 90% performance.

4.3 fsQCA Configuration Results

Following the NCA necessity analysis, fsQCA was used to identify configurations of conditions that are sufficient for high firm performance (Ragin, 2009; Fiss, 2011). The analysis was conducted using fsQCA 3.0 software, with a consistency threshold of 0.80, a frequency threshold of 1, and PRI consistency threshold of 0.70 (Ragin, 2009; Fiss, 2011). The truth table analysis revealed that of the 128 possible configurations (2^7), 43 had at least one case. Of these, 12 configurations met the consistency and PRI thresholds of 0.80 and 0.70, respectively. These 12 configurations were subjected to Boolean minimization to identify the simplest combinations of conditions that produce high firm performance.

Table 6. Configuration Analysis for High Firm Performance

Condition	Configuration 1
Green Process Innovation (GPI)	○
Green Product Innovation (GPrI)	●
Green Service Innovation (GSI)	●
Green Technological Innovation (GTI)	●
Green Business Model Innovation (GBMI)	●
Green Marketing Innovation (GMI)	●
Green Innovation Education (GIE)	●
Consistency	0.998
Raw Coverage	0.992
Unique Coverage	0.992

Solution Consistency	0.998
Solution Coverage	0.992

Note. ● = core condition (present in both parsimonious and intermediate solutions); ○ = peripheral condition (present only in intermediate solution). Solution term: GPI*GPrI*GSI*GTI*GBMI*GMI*GIE.

Source. Developed by author.

The analysis yielded one solution configuration that is sufficient for high firm performance. This configuration combines all six green innovation dimensions with GIE. Six conditions green product innovation, green service innovation, green technological innovation, green business model innovation, green marketing innovation, and GIE emerge as core conditions. Green process innovation emerges as a peripheral condition. The solution is highly consistent (0.998) and highly coverage (0.992) showing that very few cases cannot be considered as this configuration, and that almost all high-performing cases can be accounted for with the same.

Finally, the absence of equifinality only one sufficient configuration is found indicates that only a full engagement (all green innovation dimensions) with GIE will lead to superb performance. This result could reflect the developing country context where resource restraints limit the availability of other green innovation routes and a combined approach is needed to overcome institutional and resources constraints.

4.4 Hypothesis Assessment

The hypothesis testing is presented in Table 6. H1 (green process innovation as sufficient) is partially supported it enters a peripheral role for the sufficient configuration but it is not sufficient alone. H2-H6 Attained only partial support (goodness-of-fit perspective), with product, service, technology, business model and marketing innovation being core conditions in the sufficient configuration yet individually each is insufficient. Strong support for H7 (GIE as necessary and interacting with green innovation dimensions, NCA confirms GIE as a necessary condition while it emerges as core in the sufficient configuration).

4.5 Robustness Checks

The robustness of the empirical findings was assessed through three distinct procedures: (1) sensitivity analysis of calibration where anchors were adjusted up and down by ±5% and ±10%; (2) variations from 0.80 to 0.85 in the cut-off threshold for consistency; and, (3) consideration of PRI consistency. The robustness test with adjusted calibration is shown in Table 7.

Table 7. Robustness Test: Adjusted Calibration Anchors

Condition	Configuration (Adjusted Calibration)
Green Process Innovation (GPI)	○
Green Product Innovation (GPrI)	●
Green Service Innovation (GSI)	●
Green Technological Innovation (GTI)	●
Green Business Model Innovation (GBMI)	●
Green Marketing Innovation (GMI)	●

Green Innovation Education (GIE)	●
Consistency	0.995
Raw Coverage	0.987
Unique Coverage	0.987
Solution Consistency	0.995
Solution Coverage	0.987

Note. ● = core condition; ○ = peripheral condition. Results shown for ±5% calibration adjustment as representative. Solution term: GPI*GPrI*GSI*GTI*GBMI*GMI*GIE.

Source. Developed by author.

The same single configuration is found irrespective of the robustness condition, with coverage and consistency values higher than 0.95. Core and peripheral condition designations remain stable. These results confirm that the identified configuration is robust to plausible variations in analytical parameters; thus, endorsing the plausibility of the configuration identified.

5. DISCUSSION

5.1 Interpretation of Findings

In this study, some main findings describe the relationships between GIE, green innovation dimensions and firm performance in MSMEs located in developing countries. In the first instance, GIE evidences the largest necessary condition for high firm performance disposition with a large and significant effect. These results imply that excessive investment in any particular dimension of innovation will not translate into effective green innovation performance without sufficient education and training for workers on how to deal with the green innovations. This highlights the importance of human capital and knowledge in making green innovation successful. GIE has a relatively large effect size than other conditions indicating GIE plays a unique and irreplaceable role as one intrinsic green innovation bottleneck.

Second, green business model innovation likewise emerges as a statistically significant necessary condition signifying that business model reconfiguration is critical for the success of green innovation. This means, in our view, that firms need to reconceptualize their value creation and delivery mechanisms, as well as how they capture the benefits from green innovation. Business model innovation plays a pivotal role as it brings about aggregate effect with new value propositions and revenue streams. The fact that business model innovation is required also points to the systematic characteristics of green innovation which often calls for a more fundamental change in the operating mechanism and goes beyond merely incremental adjustments to existing cycles.

Third, all six dimensions of green innovation were found to be configurations leading to high performance, and solely the combination with GIE itself tended to act as the configuration for this type of dual-pathway relationship (at levels lower than perfect = green innovation combination efficiency), indicating that a high performing level of each multiple dimensionality leads involved simultaneously in directly crossing the connected two things: practically complementary multi-dimensionality orientation required combinations on dynamic Process44. The core condition that six of seven conditions is the main one shows how crucial it is to take green innovation as holistic in resource-based environment context. This

pattern indicates that firms in developing country contexts cannot pursue fragmented or partial green innovation strategies leading to high performance but rather must develop a full range of capabilities across the entire domain of green innovation activities.

Of note is the nonexistant equifinality: only one configuration yields high performance. This contrasts with some fsQCA studies conducted in developed country contexts that reveal multiple routes to high performance. The one-size configuration could represent the situation of developing countries, in which alternative type of green innovation strategies are not feasible because of resource constraints and a holistic framework is necessary to overcome institutional barriers or resource constraints. In contexts in which firms are more resource-constrained and experience lower institutional support for green innovation, the only way to secure high performance may reside in a holistic approach capable of achieving the necessary economic critical mass towards greening innovation capabilities.

Importantly, the finding that green process innovation was identified as a peripheral rather than core condition is also significant. Although process innovation is included in the sufficient configuration, it appears to be a less central contributor to performance than the two dimensions above. Since process innovation is less innovative and easy to adopt, this could result in it being less of a distinguishing factor or because having the green practice itself as they are more frequent. Or it may reflect that process innovation is not enough without parallel capabilities in product, service, technology business model and marketing innovation that are required to convert process gains into market success.

5.2 Theoretical Implications

This study first advances GIE theory by proposing that GIE serves not as a green innovation dimension, but as a foundational enabler. Reference to the RBV indicate that GIE is a human capital resources which constitutes with valuable, rare, imperfectly imitable and without substitutable ownership. GIE, viewed as a higher-order capability in the dynamic capabilities frame, allows firms to effectively sense opportunities in their environments and deploy dynamically lower-order operational capabilities. NCA results empirically confirm GIE being the main necessary condition and add to environmental training and GHRM literatures.

Second, the research donates to theory of green innovation by processing that the drivers of innovation dimensions collaborate rather than work as independent drivers. A unique, overall sufficient configuration contradicts the notion that forms must specialize in certain kinds of innovations in order to outperform others. It is rather a holistic approach. Additionally, the lack of equifinality underscores contextuality in viable pathways for innovation since they are fewer alternatives available in resource-poor developing environments.

Third, research makes several meaningful contributions to the extant literature on developing countries by using the examples of MSMEs in Pakistan and Bangladesh. This demonstrates that green innovation has distinctive characteristics, particularly on educational and knowledge barriers, and contributes to thinning the literature bias towards large firms.

Finally, methodological contributions: the study is important for showing how fsQCA and NCA can be combined. NCA estimates the requirements of bottlenecks and fsQCA elucidates conjunctural causation patterns; together, they provide a full roadmap for future configurational inquiries.

5.3 Practical Implications

The findings underline to MSME owner-managers that GIE is an essential pre-condition not a discretionary investment. Managers in every corner of the organization must provide training in sustainability literacy, green knowledge, creative problem solving and systems

thinking. Investments in specific technological or process innovations may fail to perform without this foundation. In addition, firms should pursue green innovation strategies that are comprehensive (i.e., they consider all six dimensions) rather than piecemeal initiatives. The widespread bottleneck analyses that are considered in the study not only allow taking a vital perspective to determine which investments managers should make and when.

The findings thus suggest that, for policymakers, supporting GIE via capacity building and educational partnerships is more reinforcing than single technological solutions. Policymakers should integrate financial, technical assistance, and education policy packages. Such holistic programs should target specific downstream and upstream institutional and resource barriers for MSMEs, aimed at guiding firms in overcoming the pressures restricting alternative green innovation options.

The study calls for educators and training providers to create practical, applied GIE programs across all four dimensions of education. These should be designed specifically for the operational realities and resource constraints of MSMEs in developing countries, so that they can go beyond a theoretical understanding to practical skills that employees can immediately deploy in their work.

6. CONCLUSION

6.1 Summary of Key Findings

This study examined the configurational relationships among GIE, six green innovation dimensions, and firm performance using fsQCA and NCA on a sample of 121 MSMEs from Pakistan and Bangladesh. The results confirm GIE as the strongest necessary condition for high performance ($d = 0.323$, $p = 0.004$), with green business model innovation also identified as a statistically significant necessary condition ($d = 0.222$, $p = 0.020$). The fsQCA analysis identifies a single sufficient configuration combining all six green innovation dimensions with GIE, with six core conditions and one peripheral condition. These findings highlight the importance of a comprehensive, multi-dimensional approach to green innovation, enabled by GIE, for achieving high firm performance in developing country MSMEs.

6.2 Limitations

This research is subject to certain limitations are needed to establish causal relationships and examine how GIE and green innovation capabilities evolve over time. Second, the sample size of 121 firms from two countries limits generalizability larger and more diverse samples would strengthen external validity and allow for more fine-grained configurational analysis. Third, the focus on financial performance excludes other important outcomes such as environmental performance and innovation performance, which may be relevant for understanding the full impact of green innovation. Fourth, the use of single-source perceptual data carries the potential risk of common method variance, though Harman's test and VIF analysis suggest this is not a significant concern. Fifth, calibration in fsQCA involves some subjectivity, though robustness tests confirm the stability of results across reasonable parameter variations.

Sixth, the study focuses on MSMEs in two South Asian countries, and the findings may not generalize to other regions or to larger firms with different resource endowments and organizational structures. Seventh, the study examines only seven conditions (six green innovation dimensions plus GIE), and there may be other important factors such as institutional environment, regulatory pressure, and stakeholder influence that could affect green innovation and performance. Future research could incorporate additional conditions to provide a more comprehensive understanding of the configurational pathways to high performance.

6.3 Future Research Directions

Future research could pursue several directions. First, longitudinal studies could examine how GIE and green innovation capabilities evolve over time and their causal effects on performance, addressing the limitations of cross-sectional designs. Second, sector-specific studies could explore whether different configurations are effective in different industries, providing more targeted insights for specific sectors. Third, qualitative in-depth qualitative investigations would be well-positioned to elucidate the underlying processes by which GIE enables green innovation, complementing the quantitative configurational analysis with richer process understanding. Fourth, future research could examine how contextual factors such as institutional environment, industry characteristics, and firm size moderate the relationships between GIE, green innovation, and performance. Fifth, methodological research could develop more objective calibration approaches for fsQCA, reducing the subjectivity involved in this critical step.

EXTENDED ABSTRACT

This study examines how Green Innovation Education (GIE), various green innovations interact with each other to influence firm performance. These interactions are investigated where GIE, six dimensions of green innovation and firm performance variables examined using a sample of 121 MSMEs from Pakistan and Bangladesh. Using fsQCA analyzed with NCA, the study fills an important gap by investigating the combination of multi-dimensional green innovation strategies and GIE for high firm performance outcomes in a developing context. Considering the major environmental challenges facing these economies and the importance of MSMEs, both for theory and practice it will be interesting to understand how green innovation is promoted.

The study has been designed from three complementary theoretical viewpoints. The work builds upon well-established literature rooted in the RBV, which suggest that by virtue of being rare, valuable, inimitable and non-substitutable (VRIN) resources, GIE and green innovation capabilities may act as sources of competitive advantage. DCT elaborates on how firms assimilate and reconstitute these capabilities over time, GIE is proposed to be a dynamic capability through which firms sense opportunities in their environment, seize them, and reorganize organizational processes. Drawing on OLT, GIE offers micro-foundations explaining how the individual knowledge generated through single- and double-loop learning transforms into organizational routines. These theories together position GIE as a critical determinant of green innovation and performance.

Green innovation is defined as a multidimensional construct, which consists of six specific dimensions (green process, product, service, technological, business model and marketing innovation). This is complementary capabilities that firms integrate or combine to accomplish mixed environmental and economic-oriented objectives. Four interconnected dimensions form GIE and these are Employee Training for Sustainability Literacy, Green Innovation Knowledge, Creative Problem-Solving and Systems Thinking. These dimensions provide employees with the holistic capabilities needed to help in the efforts towards green initiatives. The business case for green investments, especially for resource-scarce MSMEs in developing countries where survival is paramount, affects the ultimate firm performance outcome measured through profitability as defined by three financial indicators/proxy sales turnover and return on investment (ROI).

A cross-sectional survey design using data from N:121 MSMEs collected between March and October 2024 was used in the study. A purposive sampling method was used to include firms from different sectors, sizes and geographical locations in Pakistan and Bangladesh. In this case, firms were required to have been in business for a minimum of two years and had at least one employee who was not an owner (to ensure adequate organizational structure). Following established literature, all constructs were measured using 7-point Likert

scales and reliability and validity were confirmed using standard psychometric tests with no common method bias found.

There are two complementary methods for analyzing the research question. Instead, fsQCA, on the one hand, finds configurational relationships and asymmetric causality, emphasizing how combinations of conditions generate outcomes (e.g., high performance) rather than each condition viewed independently; therefore, meaning that it is well suited to analyze multi-dimensional phenomena. NCA: Necessary Condition Analysis (also identifies the type of condition and computes its effect size: has, be bottleneck conditions are necessary to be present "for" an outcome to occur) We used the direct method for calibration and conducted the analysis using fsQCA 3.0 software with standard consistency and frequency thresholds.

According to the NCA results, GIE is the most substantial necessary condition for high firm performance; this shows that the effect size is quite large (CE: d = 0.323, p= 0.004; CR: d = 0.252, p = 0.011). Thus, establishing GIE as a necessary supporter of successful green innovation. It turns out that green business model innovation also emerges as a statistically significant necessary condition (d = 0.222, p = 0.020), indicating the need to reconfigure value creation mechanisms. Among the three factors, bottleneck analysis indicates that GIE is the most early-stage and stage-restricted limiting factor; 29.4% of GIE at maximum is necessary in order to yield moderate performance (40–60%), while optimum performance (70% or above) can only be achieved with GIE reaching over 61.2%.

The fsQCA identifies only one sufficient configuration the combination of all six green innovation dimensions with GIE. Apart from GIE, six conditions emerge as the core conditions common to both parsimonious and intermediate solutions namely green product innovation (GPI), green service innovation (GSI), green technological innovation (GTI), green firm-level business model innovation (GFMBMI) and marketing process-oriented innovative business model for sustainability. Green process innovation works as an outer circumstance This solution has very high consistency (0.998) and coverage (0.992). In particular, the lack of equifinality denotes that high performance is only met with a combination of multi-dimensional approaches. It speaks to the experience in developing contexts, which suffer from a lack of resource buffers and institutional compromise, where firms do not have more specialized alternative pathways open to them nor are they part of universal solutions that dominant logic would envision hence needing broader capabilities to escape systemic constraints. Stability of these findings across a range of calibration anchors and thresholds is confirmed through robustness tests.

The results provide both theoretical and practical implications. Conceptually, the research extends GIE literature by conceptualizing it not just as an isolated HR practice, but as a higher-order dynamic capability at grass-roots of green innovation. In this way, it contributes to configurational theory by showing that pathways towards high performance are limited in resource-constrained settings and thus need to be considered from a holistic rather than specialized perspective. Theoretically, the research presents a framework for understanding how and why investments in green technologies or processes will perform poorly unless they are supported by intense GIE initiatives. This bottleneck analysis indicates the minimum capability scores that need to be achieved at different performance levels and helps in managing your resources strategically. The implications for policymakers the results highlight the importance of coupling educational with financial or technical incentives capacity-building programs along with money if a sustainable development path is to be attained in developing economies.

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