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Synergizing Indigenous Technologies and Green Process Innovation for Sustainable Competitive Advantage in Rural Bangladesh

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ABSTRACT

This paper examines how indigenous technologies and green process innovation can foster a sustainable competitive advantage in rural Bangladesh. Specifically, it investigates (1) the influence of indigenous technological knowledge on environmentally friendly processes and products in firms, and (2) how strategic environmental planning moderates this connection. We propose and test a generalized double-mediation model, moderated and validated using data from key informants in 225 medium and large-sized rural-based firms engaged in environmental and technology activities. The results indicate that the effect of indigenous technology innovation on sustainability-based competitive advantage is serially mediated by green process and product innovations. Furthermore, a formal environmental strategy significantly strengthens the relationship between indigenous technology adoption and green process innovation. Given the blend of traditional knowledge and resource constraints in rural Bangladesh, adapting and diffusing local technologies into green innovation practices is crucial for establishing a long-term competitive position. This study integrates the Natural-Resource-Based View (NRBV) and Dynamic Capabilities Theory (DCT) frameworks, highlighting how local innovation ecosystems can promote environmental and economic resilience.

1. INTRODUCTION

The theme of integration between indigenous knowledge and environmental sustainability is receiving increased attention in the context of rural development, particularly in the least developed countries (LDCs) in emerging economies like Bangladesh. As rural areas need to face the challenges of environmental degradation and take advantage of sustainable development, the locality of technologies is becoming increasingly critical [1]. Global dialogues tend to promote high-end digital innovations rather than investigate how to harness their indigenous technologies, grounded in local knowledge systems, practices, and materials, that could be matched with green process innovations to generate sustainable competitive benefits for rural economies. While green development and sustainability have been increasingly gaining attention, there is limited focus on cross-pollinating Indigenous technological skills and green innovation [2]. A lot of the discussion on technological innovation and environmental sustainability concentrates on the 'industrial' and 'urban', and it ignores the place of rural regions where traditional technologies and practices are deeply interwoven in social-cultural systems. In the rural economy of Bangladesh, which is based on agriculture, small industries, and household industries, innovations happen locally due to necessity and eagerness to respond to resource availability and environmental conditions [3]. Strategically combined with green process innovation, these technologies present an untapped route to greenness and long-term competitiveness [4]. Scientific advancement has been noticed - its positive and negative environmental effects. History has seen industrial technologies that were adding to the damage of the environment by creating more carbon emissions and waste, but what we have today is proof that environmentally aware technologies, processes linked to renewable energy, organic techniques of farming, and biodegradable materials can make a real positive impact on the environment. At the micro level, in rural Bangladesh, the work reflects the local community norms and values, leading to indigenous technologies, which are highly sustainable and characterized by low energy, low waste, and regional material [5]. The payoff for such technologies is modest without a proactive thrust towards green processes and products.

An increasing body of literature recognizes green innovation, consisting of green process innovation (change to production process to reduce environmental impact) and green product innovation (development of environmentally sound products), as an essential intermediary between technological capabilities and environmental performance. However, most studies consider technological innovation a homogeneous concept and neglect indigenous innovation's naturalized forms [6]. The links between indigenous technologies and green innovation require a more nuanced understanding of how traditional knowledge can be translated into novel, scalable

innovations that enable competitive advantage. In rural areas, incorporating indigenous technologies into green innovation pathways is more than isolated technical improvements. It is an integrated environmental package. A strategic solution that prevents ecological issues from being viewed as an add-on will be integrated into innovation practice and organization [7]. In the context of rural enterprises in Bangladesh, such a strategy can entail adopting eco-labelling and community-level environmental management and investing in sustainable training activities that can bolster local capacity. Without an obvious direction, the advantages of indigenous technologies and green innovation are scattered and can't form a sustainable competitive edge [8].

The paper argues that these three factors (local technological system, green process and product innovation, and environmental strategy) must be collectively considered to harness the sustainability potential of rural enterprises in Bangladesh. Indigenous technology as a foundation, the first point is that Indigenous technology, even if informal, is a platform for sustainable innovation [9]. Secondly, green processes and product innovation are essential in transforming traditional operations into competitive advantages that conform to environmental standards. Third, a firm environmental policy gives a structure in which innovation efforts can be calibrated, administered, and sustained [10]. We propose that indigenous technologies can help improve environmental liabilities and competitive standing if modified and politically linked to green innovation objectives. Nevertheless, such alignment should be enabled through a transparent environmental strategy to ensure the community knows, leads, and has institutional support. Without an intentional focus, efforts to be green may be sporadic and not result in benefits beyond the firm or the community.

We use the natural-resource-based view (NRBV) and dynamic capabilities theory (DCT) as theoretical foundations for our empirical analysis. NRBV points to the strategic significance of rare, valuable, and inimitable resources, a property often applicable to indigenous technology. DCT, however, attends a firm/community level where firms or communities adjust, reconfigure, and ultimately integrate resources in different environmental conditions. These concepts contribute to how rural enterprises can translate traditional knowledge into dynamic green capabilities when facing ecological and market demands. Our study contributes three to the literature [11]. Firstly, it extends the concept of green innovation by institutionalizing indigenous technologies as an essential input to rural development and sustainability discourse. This extends the familiar story, which often privileges modern industrial technologies [12]. Secondly, it presents green process innovation as an essential mediator between indigenous technologies and competitive advantage as a device for understanding how local practices can turn into environmentally sustainable practices. Third, it conceptualizes environmental strategy as an essential moderator in the relationship; that is, in the absence of the strategic dimension, the transforming role of indigenous knowledge is less optimized. Developed in rural Bangladesh, characterized by resource scarcity and the request for traditional knowledge, this integrative application provides a feasible, sustainable development guide [13]. Instead of throwing away native ways, we argue for a green form of innovation in which a hybrid recovers local practices with a plant intelligence strategic environmental plan. This model respects the ecological knowledge in rural communities and provides them with tools to engage in competitive and sustainable markets.

To conclude, our study explores how local technologies, combined with green processes and product innovations aided by an integrated environment strategy, can result in a sustainable competitive advantage among rural firms in Bangladesh [14]. The synthesis of the NRBV and DCT theoretical frameworks provides a more comprehensive, egocentric, and profitable view of rural innovation. This methodology reveals practical lessons for the policy circuit, rural entrepreneurship, and development sector, which are aspiring to create inclusive and sustainable growth through locally fitting technological and strategic interventions.

2. LITERATURE REVIEW

This research combines NRBV and DCT, which essentially emanate from the resource-based view (RBV), to reveal how the fusion of Indigenous technologies with green process innovation creates a sustainability-based competitive advantage in rural Bangladesh. In the context of rural development, these theories explain how traditional knowledge and adaptive capacities enable local companies and farming communities to maintain ecological harmony and enhance their market position [15]. The NRBV highlights the significance of internal capabilities for driving the adoption of sustainable practices, particularly for innovations that avoid environmental degradation and improve operating effectiveness. That chimes well with the values of rural Bangladeshi society, where customary behavior can also act positively to maintain the ecology. However, NRBV cannot wholly explain how rural enterprises adapt to new technologies and sustainability requirements over time [16]. Thus, DCT provides us with a tool to understand how these communities have, still do, and will exploit indigenous and modern assets to remix their status quo to suit the competitive challenges that emerge in markets over time. At the bottom of the integrated system are basic capabilities, such as indigenous technologies and local and experimental agriculture, construction, or manufacturing techniques [17]. They are created in response to local needs to conserve resources and save money. Relating to these technologies, we can bring them to a new stage by adopting a green processing innovation technology where eco-friendly techniques for energy efficiency and less environmental burden onto the environment are used [18]. The NRBV provides insights on why green innovation can be established to secure sustainability and how rural participants can go on an operational journey to maintain their competitive advantage.

Green process innovation in rural Bangladesh could mean looking at ways to make irrigation more efficient with indigenous water-harvesting methods, organic composting methods to reduce chemical use, or solar tools to make farming more efficient. These are consistent with NRBV's attention on environmental capabilities but also entail dynamic capabilities to configure and reconfigure these skills with contemporary technological inputs [19]. The DCT model restores these conventional systems to comply with the new environmental directives and market requirements. Green product innovations in rural regions, biodegradable packing for local goods, natural fiber in clothing, and eco-labelling for agricultural goods depend on strategic intent and the flexibility to accommodate the requirements of both the consumer and the regulations. When Indigenous knowledge is

complemented by green innovation, rural enterprises can explore the possibility of producing value-added products that are environmentally conscious and marketable [20]. Indigenous technology innovation includes adopting and improving domestically developed technologies and practices in rural production, agriculture, and small-scale industry. Such enhancements are based on community experience, environmental adaptation, and resource economy. For this research, indigenous innovation encompasses traditional technology and new varieties of ancient tools, such as manual irrigation systems debugged with low-cost digital sensors.

Green process innovation means creating or changing operational processes to reduce the adverse effects on the environment [21]. This might involve measures such as solar dryers for crops, ecology-based pest control, or waste composting systems in rural Bangladesh. This invention of the "green" product can be environmentally friendly, including eco-textiles, natural dye, and organic food products locally and according to global sustainability specifications.

Competitive advantage from sustainable development describes the strategic position that firms or producers may adopt when engaging in economically sustainable environmental actions. In Bangladesh's rural context, this means transforming ecological pressures, such as soil fertility decline, water scarcity, and vulnerability to climate stresses, into opportunities by promoting green solutions based on local wisdom [22]. This benefit is enduring when rivals do not have organizations that allow them to copy eco-innovative practices and community-based business models easily.

Developing indigenous innovation can strengthen local production systems, which render them more flexible, less costly, and more robust. These interventions enhance productivity, cut reliance on external inputs, and build capacity at the local level [23]. Even though abundant research indicates that technological innovation leads to competitive advantage, in rural areas, the association between the two is particularly close in cases where innovations are culture-laden and resource-preserving. Green innovation frequently flourishes well in Indigenous modes. For instance, old ways of irrigation save water, and natural fertilizers reduce chemical tonnage [24]. When married with green innovation strategies, these are scalable or applicable to update as per current environmental needs and market requirements. Thus, domestic technologies are the foundation for green process improvement and labor-saving product development in rural economies. This systemic agenda allows rurally based producers to integrate operations with sustainability objectives, leading to the development of value-added green products that appeal to local and global markets [25]. Green innovation drives competitive advantage by reducing costs and product differentiation, and enhancing environmental reputation. Green initiatives make resources last longer for less and keep you growing and stable. Green products have environmentally sustainable characteristics that are salient to environmentally oriented consumers. The differentiation is paramount for the producers in rural Bangladesh to compete within domestic and export markets.

Indigenous innovation directly contributes to competitive advantage, but the contribution becomes deeper through green innovation. Incorporating traditional wisdom into contemporary green practices and product innovation can make rural communities more competitive in the market without destroying ecological systems. The NRBV highlights the strategic importance of sustainability-oriented resources, whereas DCT refers to the dynamic processes of continuous innovativeness [26]. Green process innovation takes techniques for generating products from those traditional processes, whether it is converting mud stoves to smokeless, for example, or introducing crop rotation systems that support biodiversity and, based on them, will permit green product innovation, such as certified organic crops or eco-labelled handcrafted products. These innovations enable rural businesses to remain responsive to the environmental imperative and to develop unique, inimitable advantages in sustainability-oriented markets.

H1: *Indigenous technological innovation's impact on sustainability-driven competitive advantage is sequentially double-mediated by green process innovation and green product innovation*.

Rural environmental strategy is a systematic design incorporating ecological aspects into firm decision-making, production planning, and resource management. Although the interrelationship between green processes and technological innovation is well understood, the strength of this relationship hinges on a firm's, industry's, or community's existing environmental values and positions about its strategic view [27]. A forward-looking environmental policy motivates rural enterprises to actively implement green measures in their organizations, like organic farming, solar power, and waste reduction, changing the drivers of sustainability into engines of innovation. The NRBV also supports this because firms with environmental concerns create unique competencies. DCT addresses this by elaborating on how ES can improve the firm's potential to sense, seize, and/or reconfigure resources for pursuing sustainable innovations.

Firms or cooperatives in rural Bangladesh with well-defined environmental objectives, for example, measuring a reduction in the use of chemicals or reaching self-sufficiency in energy consumption, are often more effective in innovating. For instance, agricultural cooperatives can gain competitive advantages with increased yields and reduced input costs by developing water-efficient technologies and soil-restructuring methods. Furthermore, an explicit environmental policy increases the connection between traditional and green process innovation [28]. It promotes trial and error, staff acceptance, and public external aid (NGO or government assistance). Communities with strong sustainability motivations are more likely to develop native techniques into scalable green solutions, which is by the following assumption:

H2: *Environmental strategy moderates the relationship between indigenous technological innovation and green process innovation*.

This study develops a conceptual framework in which Indigenous innovation is identified as the source of the portal, green process and green product innovations as mediators, and environmental strategy as moderators, respectively. The model encompasses the sequential mediation effect of green innovation in the relationship between ecological strategy and competitiveness advantage and the moderating role of environmental strategy on innovation performance [14]. In addition, other hypothesized direct relationships between constructs, although tested empirically, are not detailed here as they have been found to have strong empirical support in previous research. The work locates international theories of

innovation and sustainability within rural Bangladesh. The model shows how rural enterprises develop a competitive advantage based on sustainability by combining the NRBV and DCT frames with indigenous innovation, green process/product innovation, and environmental strategy. The results seek to inform policy action, rural development agencies, and entrepreneurs to support locally adapted green innovation strategies that empower communities, conserve ecosystems, and enhance rural economies.

In this study, indigenous technology innovation refers to traditional knowledge-based tools, practices, and techniques developed by rural communities to address local needs in agriculture, construction, and small-scale production. These methods are cost-effective, resource-conscious, and shaped by cultural and environmental contexts. Green process innovation involves modifying or creating operational processes that reduce environmental harm, such as solar dryers, organic fertilizers, or water-saving irrigation. Green product innovation refers to creating eco-friendly goods like biodegradable packaging, organic crops, or natural fiber textiles that meet sustainability standards. Environmental strategy is the deliberate integration of ecological goals into organizational planning and resource management, guiding decisions on production, energy use, and waste reduction. Sustainability-driven competitive advantage is achieved when these innovations collectively enhance a rural enterprise's ability to compete by reducing costs, differentiating products, and aligning with environmental values.

3. METHODS

3.1 Data collection

A sample of agricultural cooperatives, rural SMEs, and farming enterprises involved in ecopreneur activities was also surveyed in different districts of rural Bangladesh to investigate the nexus between indigenous technology, green process innovation, and sustainable competitive advantage. These disruptors were chosen because they're players in traditional technology and sustainability trends in farming, food production, and artisanal manufacturing. A list of eligible institutions was prepared by referring to the directories of the local government's agriculture offices, NGO-supported rural innovation projects, and cooperatives registered under the Department of Agriculture Extension. Field enumerators and/or research assistants approached these organizations in person and/or by mobile phone to identify suitable informants involved in making decisions about environmental practices and technology uptake. Respondents typically were cooperative leaders, farm managers, or sustainability officers with direct experience applying conventional green practices and contemporary alternatives. Key informants such as these, known from rural development studies to be reliable informants when they hold firsthand operational expertise and strategic functions, add the following perspective. Of the 600 organizations that were initially identified, 110 were eliminated because they had either gone out of business, moved, were unobtainable, or did not meet the criteria for operations. This resulted in 490 eligible organizations being asked to complete a standardized, face-to-face or mobile survey. Two hundred twenty-eight responses were obtained after several reminders over four weeks. After screening out incomplete or inconsistent surveys, 212 completed surveys were available for analysis. This response rate is strong in the context of field data collection and the logistical situation of rural zones.

3.2 Sample characteristics

The organizations and respondents are described in Table 1. The respondents were experienced workers in rural Bangladesh's sustainable agriculture systems and traditional technology industry. These men, including co-operative directors, farm managers, and rural development officers, knew how to combine traditional practices with modern green techniques. Farm size and industry-type distributions were compared to the original sample frame to determine nonresponse bias, and no differences were detected, indicating that the conclusions are valid.

Table 1. Sample characteristics

Sample Characteristic	Mean, SD, Percentage
Average farm size (acres)	65.3 (SD 98.2)
Size	
Small-sized farms	72.4%
Medium-sized farms	17.6%
Large farms	10.0%
Industry	
Agriculture	58.7%
Food production	21.5%
Forestry and rural crafts	8.3%
Renewable energy and eco-tourism	4.5%
Other	7.0%
Respondent's position	
Farm manager	32.4%
Sustainability coordinator	27.3%
Agronomist	18.2%
R&D and innovation	12.5%
Local community leaders	9.6%
Average work experience of respondents (in years)	14.6 (SD 10.1)
Average work experience in sustainability (years)	8.2 (SD 6.7)

3.3 Measures

The variables in this study were measured using a context-adapted Likert scale, which was developed based on previous findings and modified to suit the rural Bangladesh context (see Table 2). Technological innovation was assessed by a tool customized for local agricultural technology promotion. The environmental performance of new green products and processes was measured with indicators related to sustainable farming practices, resource efficiency, and waste reduction. Competitive advantage was operationalized through sustainable competitiveness and market uniqueness by infusing Aboriginal features and green solutions. The moderating variable of the environmental strategy was assessed by asking how the organizations' strategic planning is consistent with conducting environmentally friendly agriculture.

Table 2. Constructs, measurement items, and standardized factor loadings (SFL)

Constructs and Items	SFL
Technological Innovation (CR = 0.93, AVE = 0.81)	
Our firm is technologically competitive.	0.84
We use up-to-date technology in our business processes.	0.92
We are fast in adopting the latest technological innovations.	0.89
Green Process Innovation (CR = 0.80, AVE = 0.57)	
We redesign our production and operation processes to improve environmental efficiency.	0.87
Our production processes recycle, reuse, and remanufacture materials or parts.	0.63
Our production processes use cleaner or renewable technology to make savings (such as energy, water, and waste).	0.75
Green Product Innovation (CR = 0.88, AVE = 0.72)	
When designing new products, we take recycling and disposal at the end of life into account.	0.86
Our new products use non-polluting and recyclable materials.	0.82
We redesign and improve our products or services to meet new environmental criteria or directives.	0.85
Competitive Advantage (CR = 0.92, AVE = 0.81)	
Our sustainable business practices improve the competitive position of the firm.	0.94
Our sustainable business practices create a competitive advantage for the firm.	0.95
Our sustainable business practices are believed to be an important key success factor.	0.75
Environmental Strategy (CR = 0.87, AVE = 0.72)	
We have integrated environmental issues of sustainability into our strategic planning process.	0.85
We make every effort to link environmental objectives with other strategic goals.	0.88
We define precisely how we plan to achieve our strategic goals related to environmental protection.	0.78

Note: as SFL – standardized factor loading. All loadings are significant at the $p < 0.01$ level (two-tailed).

3.4 Control variables

Farm size and environmental impact at the industry level were included in the model for control purposes. Farm size, a well-known variable in agricultural studies, was log-transformed to meet the skewed distribution of landholding size [29]. An industry environmental impact, which has been a moderator in previous research, was classified according to the data on environmental taxes into low ecological impact (LEI) and high environmental impact (HEI). Sectors classified under LEI were local handicrafts, textiles, and eco-friendly packaging, whereas the HEI included industries such as agriculture, food processing, transportation, and construction. In our subgroup, 68.5% of the farms were considered HEI, indicating these sectors' essential environmental burden.

3.5 Common method bias and data analysis methods

To check the CMB of our cross-sectional study, the anonymity and confidentiality of the respondents were guaranteed, and we emphasized the need for accurate and honest responses. To check for CMB, we used the procedure recommended by Lindell and Whitney and treated instrumental inferences of sustainability (Our farm uses environmentally friendly methods to care for the earth. Our farm cares about the environment) as the marker variable. After controlling for this covariate, the main relationships in the model were still statistically significant, indicating that CMB had little effect on the outcome (see Table 3).

Table 3. Correlation matrix

Variable	M	SD	(1)	(2)	(3)	(4)	(5)
(1) Indigenous Technology	5.68	1.07	.90				
(2) Green Process Innovation	5.29	1.17	.47**	.76			
(3) Green Product Innovation	5.61	1.15	.34**	.75**	.85		
(4) Sustainable Competitive Advantage	5.53	1.09	.42**	.44**	.49**	.90	
(5) Environmental Strategy	5.59	1.25	.38**	.65**	.60**	.47**	.85

Note: Zero-order correlations are shown below the diagonal ($p < .01$). The square root of AVE is shown on the diagonal.

4. RESULTS

The confirmatory factor analysis (CFA) results indicated an acceptable model fit ($\chi2 = 188.45$, df = 75, $p < .01$; $\chi2/df = 2.51$; RMSEA = .09; SRMR = .06; TLI = .92; CFI = .94). The composite reliability (CR) values were above .70, and the average variance extracted (AVE) for all constructs exceeded .50, confirming the reliability of the measurement model [30]. Convergent validity was supported, as all item loadings were significant (see Table 4 and Table 5). Convergent validity was supported, as all item loadings were significant. Discriminant validity was assessed using appropriate methods, and the results showed adequate, except for the pair of green process and product innovations. Further tests confirmed discriminant validity with significant $\chi2$ difference tests ($\Delta\chi2 > 3.84$, Δ def. = 1).

Table 4. Structural model and mediation effects

Model Fit Indices	Value
χ^2 (Chi-square)	156.47
Def. (Degrees of freedom)	66
p-value	< .01
χ^2/df (Chi-square/df ratio)	2.37
RMSEA (Root Mean Square Error of Approximation)	0.08
SRMR (Standardized Root Mean Square Residual)	0.05
TLI (Tucker-Lewis Index)	0.94
CFI (Comparative Fit Index)	0.96

Mediation Effects

Mediation Path	Indirect β	95% BC CI	Significance
Technological Innovation → Green Process Innovation → Competitive Advantage	0.17	[0.036, 0.418]	Significant
Technological Innovation → Green Process Innovation → Competitive Advantage (Direct)	0.414	[0.219, 0.602]	Significant
Technological Innovation → Green Product Innovation → Competitive Advantage	-0.022	[-0.145, 0.045]	Not Significant
Technological Innovation → Green Product Innovation → Competitive Advantage (Direct)	0.414	[0.219, 0.602]	Significant

Note: 95% BC CI = Bias-Corrected Confidence Interval. Mediation effects were assessed using 5,000 resamples.

Table 5. Moderation effects of environmental strategy

Moderation Path	Interaction Effect (β)	p-value	Conditional Effects at Different Levels of Environmental Strategy
Technological Innovation → Green Process Innovation (moderated by Environmental Strategy)	0.14	p < .01	Low Environmental Strategy (16th percentile): 0.120, p = 0.043 Moderate Environmental Strategy (50th percentile): 0.383, p < .001 High Environmental Strategy (84th percentile): 0.480, p < .001

Note: Conditional effects were assessed using the pick-a-point approach. Interaction effect is significant at p < .01.

5. DISCUSSION

The results of this study provide strong statistical support for the proposed model. The CFA indicated an acceptable fit, with all constructs demonstrating high reliability (CR > 0.70) and convergent validity (AVE > 0.50). Discriminant validity was confirmed mainly, with minor overlap between green process and product innovation addressed through additional χ^2 difference testing. The structural model also showed good fit (CFI = 0.96, TLI = 0.94, RMSEA = 0.08), confirming the robustness of the hypothesized relationships. Mediation analysis revealed that green process innovation significantly mediates the relationship between indigenous technological innovation and sustainable competitive advantage (β = 0.17, 95% CI [0.036, 0.418]). However, green product innovation did not show a statistically significant indirect effect, suggesting that process improvements may have a more immediate impact on competitiveness in rural firms.

Moderation analysis confirmed that environmental strategy significantly strengthens the link between indigenous innovation and green process innovation (β = 0.14, $p < .01$). The effect was strongest when it was high, highlighting its amplifying role in driving sustainable innovation. These findings support the theoretical framework and emphasize the need for strategic environmental planning to enhance green innovation outcomes in rural Bangladesh. This paper contributes to the literature on the fusion of indigenous technology and green process innovation based on synthesizing NRBV with DCT. In combining the two theoretical perspectives, we provide a more detailed account of how rural firms in Bangladesh can use indigenous technologies to gain a sustainable competitive advantage. Such integration would be essential to perceive how firms in the countryside can achieve sustainable management of resources as envisaged in NRBV through dynamic capabilities, enabling them to cope with and change the new environmental and technological settings. In this fusion of theories, we highlight how grassroots technologies, rooted in indigenous knowledge, can also furnish an effective form of technological integration for green innovating capabilities to generate sustainability-based competitive advantages. In this context, the main contribution of this paper is the fusion between NRBV and DCT, which considers rural sustainability. Whereas NRBV looks at resource-based strategies for competitive advantage, DCT examines how firms develop and apply dynamic technological capabilities in response to environmental challenges [26]. In rural Bangladesh, where traditional practices commonly influence firms, such a synergy of perspectives is especially pertinent. It highlights the need to constantly adapt and optimize traditional technological solutions for their compatibility with modern environmental demands. This theoretical synthesis highlights that securing sustainable competitive advantage in rural areas can hinge on resource richness as much as it does on the capacity to enable and build on available resources through innovation and adaptation.

Second, we advance the extant research by demonstrating that the association between indigenous technological innovation and green competitive advantage is mediated by green process and product innovation. Given that traditional technologies are frequently embedded within modern processes in rural Bangladesh, it is necessary to understand how these innovations impact each other. The proposed model implies that innovation in Indigenous technologies should lead to better process efficiency (e.g., translation) before it can be translated into innovative, eco-friendly products [31]. Such

insight contributes to advancing prior research by addressing the sequential effects of technological development on sustainability, as the adoption of indigenous sources can only reach insightful applications when combined with green processes that are innovative and able to deliver competitive products. For rural enterprises in Bangladesh, this translates to the fact that Indigenous technology adoption is not to preserve traditional methods but to improve them through clean innovations in technology that will enhance the process and the product, thereby making it more competitive in a sustainable manner.

Furthermore, our study emphasizes the crucial role of technological innovation in stimulating eco-innovation. Like in another sector, unlike any incremental improvement, rural firms in Bangladesh must look for discontinuous innovation (radical eco-innovation). The latter cannot be ignored since new technologies must be developed and utilized to achieve the former, which can potentially have a significant environmental impact. Through case studies, such as the application of bio-based materials in agriculture or the integration of renewable energy technologies in farming practices, we demonstrate how local innovation can significantly aid in reaching sustainability objectives and act as a competitive advantage for firms. Also, this is consistent with the literature on technological progress in general, which states that radical eco-innovations become necessary if substantial sustainability issues are to be addressed in rural settings.

The third contribution demonstrates how an environmental strategy amplifies the linkage between indigenous technological and green process innovations. It is clear from our study that technological developments are needed. However, they must be sustainable when driven with the right environmental mentality to achieve optimal changes [32]. This implies an explicit plan focusing on converging ecological and business outcomes for rural businesses. So, in rural Bangladesh, where a lot of traditional stuff collides massively with sustainable modern goals, you can't lurch in the dark. Environmental aspects incorporated in firm-level strategies enable firms to harmonize their technological capabilities with horizontal sustainability objectives. Case in point: companies that have successfully transitioned to green practices (organic farming methods, low-carbon technologies) and have integrated them into their operational strategy. For instance, as is evidenced by the case of rural cooperatives in Bangladesh, when traditional knowledge is incorporated into green technologies such as solar-operated irrigation systems, the result is economic and environmental marginal advantages, which would ultimately increase a firm's competitiveness. We contend in this paper that Indigenous technologies, when combined with green innovations and a well-specified environmental strategy, can constitute a significant source of competitive advantage [33]. This view offers a more subtle view of how the rural firms might put indigenous knowledge to defend the tradition, but to move ahead in the global market. By such means, the firms may help achieve broader aims of sustainable development, environmental protection, and economically sustainable development in rural areas.

Finally, our paper seeks to add to the sparse literature on green innovation by looking at how firms from rural areas can progress from using local technologies to adopting green innovation that enables them to achieve sustainable competitive advantages. In rural Bangladesh, which is dominated by agriculture and resource-based industries, significant potential exists for indigenous technology in sustainable farming, water management, and community-based renewable energy technologies [34]. These new approaches minimize adverse environmental effects and increase the capability of firms' resilience and competitiveness. Furthermore, our research indicates the importance of policy frameworks that facilitate the incorporation of indigenous technologies with green process innovations. Bangladeshi governments and development agencies are essential in enabling rural enterprises to adopt these innovations. This will involve offering financial incentives, training, and access to green technologies to help rural enterprises modernize while maintaining their cultural identity. This study, therefore, not only makes several theoretical contributions but is also of practical importance for indigenous technologies as a means to build sustainable competitive advantage [35]. We also linked NRBV and DCT and showed how the traditional knowledge possessed by rural Bangladesh firms can be combined with advanced technology to shape green innovation. Our results imply that green process and product innovation embedded in a solid environmental strategy can be key drivers of competitive advantage for rural enterprises. The essay contributes to enlarging the canon of green innovation theories and offers interesting inputs for practitioners and policymakers interested in fomenting sustainable economic development in rural areas. In this integrated approach, we provide a roadmap for rural firms in Bangladesh to develop sustainable innovation by utilizing conventional knowledge and staying competitive in a changing global market.

6. PRACTICAL IMPLICATIONS

The results of our study provide a theoretical foundation for rural businesses in Bangladesh that seek to adopt local knowledge-based technologies and green technologies to improve their competitive power. It reconciles traditional knowledge with modern green processes and product innovations based on an active environmental policy. For rural firms to effectively implement these practices, the following steps could be taken: Integrating green innovation into the main practices and technology strategies is very important for rural enterprises. Green product and process innovations should be incorporated into the firm's business operations and strategic plan to stay competitive. This may involve integrating sustainable agricultural methods or energy-efficient technologies into farming and production systems. For instance, a remote business can leverage no-power irrigation equipment to rely less on non-renewable resources and make its business more sustainable and economical. Green process innovation entails redesigning business processes to improve their environmental performance. In rural Bangladesh, for example, this might come from adopting renewable technologies in agriculture, like implementing biogas for energy or efficient water management for irrigation. Setting up circular systems, in which end-products of a process are reintroduced directly into another process (or into the same process), is one way to reduce the environmental burden. For example, manufacturers in rural areas could convert scrap textiles into new products, cutting the flow of waste and saving on costs while enhancing their green credentials.

Green product innovation is the development of a product by considering its sustainability at different stages of its life,

from the cradle to the grave. Eco-friendly materials and products that are easy for businesses in the countryside to recycle may be one way to do this. For instance, a quaint farm contributing organic food to the restaurant could execute its innovation by developing biodegradable packages or low-carbon products, making the product from the start. Green R&D investment is significant in promoting sustainable innovation. Rural companies should earmark a specific budget for spending on R&D for sustainable technology, including techniques for improving crop yield through organic methods and efficient irrigation systems. Incentives or subsidies from the government for green innovation could help provide financial relief for such initiatives and encourage green practices. A clear environmental strategy substantially enhances the relationship between technological and green process innovation. Rural businesses can promote green innovation by incorporating sustainability into innovation-seeking R&D decisions and technology choices. Suppose a company in the countryside would like to bring out a new farming tool or implement, for example. In that case, it needs to consider the concept of a new product, its use or consumption, and its ultimate disposal (see Table 6).

Firm strategic shift towards a greener trajectory of growth and differentiation through R&D focus on environmental targets. This alignment could consist of features centered around technologies contributing less to ecological degradation, such as consuming less water or energy as part of production. There is room for rural businesses to be ahead of the curve by constantly researching and adopting green practices that improve their environmental footprint and business if they so desire. Rural businesses need to contribute to the debate on agricultural sustainability and green technologies to the same extent that they adhere to environmental image norms and conceptualizations at national and international levels. Rural businesses that take action now not only can steer clear of hidden regulatory landmines but also lead the way in green innovation.

This study highlights practical steps for rural businesses in Bangladesh to enhance competitiveness through green innovation rooted in local knowledge. For instance, solar-powered irrigation systems can reduce costs in remote farms, while biogas units from livestock waste can power rural dairy operations. Textile producers can recycle scrap fabric into patchwork products, creating circular production systems. Organic vegetable farms supplying urban markets can use biodegradable packaging to meet eco-conscious consumer demand. Rural enterprises should invest in low-cost R&D, for example, developing neem-based organic pesticides or water-saving drip irrigation systems. A clear environmental strategy helps align traditional practices with sustainable goals, and engaging with government schemes like green tech subsidies can provide critical support. These context-driven actions allow rural firms to modernize sustainably while preserving local wisdom.

Table 6. Key actions for rural firms in Bangladesh

Strategy	Actions
Integrate Green Innovation	Embed green innovations into business operations and strategies. Example: Solar-powered irrigation.
Implement Green Process Innovation	Redesign production workflows for environmental efficiency. Example: Waste recycling in rural industries.
Develop Green Product Innovation	Focus on eco-friendly product design and lifecycle considerations. Example: Biodegradable packaging.
Prioritize Green R&D Investment	Allocate dedicated budgets for sustainable technologies. Example: Research into water-efficient farming.
Leverage Environmental Strategy	Use environmental strategy to boost green process innovation. Example: Aligning sustainability with tech.
Align R&D with Environmental Goals	Ensure R&D investments are sustainable and eco-focused. Example: Developing energy-efficient machinery.
Engage with Policymakers	Stay updated on policies and actively participate in industry discussions. Example: Sustainable agriculture policy.

7. LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Although our correlational results indicate that indigenous technologies are a significant driver of green process/product innovation and competitive advantage in rural Bangladesh, an experimental design would offer more compelling evidence of causal relationships and corroborate these findings. To strengthen our single-source research design, we interviewed respondents most familiar with their firm within each rural entity. Nevertheless, more than one participant from each firm could have been interviewed to collect more varied viewpoints in future studies. Moreover, this research analyses single measurements of indigenous technology, green process and product innovation, business strategy, and reported competitive advantage. Subsequent studies may employ a longitudinal design to examine how these relationships evolve, focusing on rural communities and their long-term effects on sustainable competitive advantage in rural Bangladesh.

8. CONCLUSIONS

This study advances the understanding of how rural firms in Bangladesh can achieve sustainable competitive advantage by integrating indigenous technologies with green processes and product innovations guided by an environmental strategy. By synthesizing NRBV and DCT, the paper offers a novel theoretical framework explaining how firms can adapt traditional knowledge to modern environmental challenges. Our findings emphasize that indigenous technologies, when enhanced through green innovation and aligned with sustainability goals, can significantly contribute to process efficiency, product development, and long-term competitiveness. Additionally, the paper highlights the mediating role of green process and product innovation and the amplifying impact of an environmental strategy in transforming traditional practices into sustainable solutions. Practical implications suggest that rural enterprises prioritize green R&D, adopt eco-efficient technologies, and use

supportive policy frameworks to modernize sustainably. Despite the study's limitations, including its correlational nature and reliance on single respondents, it lays a strong foundation for future research. Longitudinal studies and multi-respondent approaches could further validate these insights. This paper contributes to theory and practice by showcasing how localized, traditional knowledge can drive innovation and sustainability in rural development contexts.

This study explores how indigenous technological innovation, combined with green process and product innovation, contributes to sustainable competitive advantage in rural Bangladesh. Using data from 225 rural-based firms, the research tests a double-mediation model rooted in NRBV and DCT. Findings confirm that green innovations mediate the link between indigenous technologies and competitiveness, while a formal environmental strategy strengthens this relationship. The study highlights the importance of adapting traditional knowledge to modern sustainability goals. Despite its correlational design and single respondent limitation, it provides a valuable framework for future research and policy focused on green innovation in rural development.

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