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Lean production systems, social sustainability performance and green competitiveness: the mediating roles of green technology adoption and green product innovation

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Abstract

Purpose – This study aims to investigate the interrelationships between lean production, green technology adoption, green product innovation, social sustainability performance and green competitiveness. The study further investigates the mediation roles of green technology adoption and green product innovation between lean production systems, social sustainability performance and green competitiveness.

Design/methodology/approach – The quantitative research approach is used for the study. Data for the study is garnered from 197 managers of manufacturing firms in Ghana via a self-administered questionnaire. Structural equation modeling, specifically partial least square is applied as the methodological tool to test all hypotheses.

Findings – Results of the study suggest that lean production systems have a significant positive impact on green technology adoption, green product innovation and green competitiveness. However, lean production systems are found to have an insignificant impact on social performance. The results further confirm the mediation roles of both green technology adoption and green product innovation between lean production systems, social sustainability performance and green competitiveness; thus indicating that lean production systems create an efficient condition for firms to adopt green technologies and produce innovative green-based products to leverage superior social sustainability performance and green competitiveness.

Originality/value – This study proposes and develops a comprehensive research model that is supported by the natural resource-based view theory to investigate the link between lean production systems, green technology adoption, green product innovation, social sustainability performance and green competitiveness from an emergent country perspective.

Keywords Social sustainability performance, Green product innovation, Green competitiveness, Green technology adoption, Lean production systems

Paper type Research paper

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1. Introduction

Upsurge in climate change coupled with today's ever-changing business environment characterized by cut-throat competition and rigorous stakeholder activism on sustainability issues has challenged firms to look for operational efficiency techniques that protect the environment, compatible with social objectives (Caiado *et al.*, 2019; Afum *et al.*, 2020) and improve industrial green competitiveness. Apparently, one of the efficient operations management dogmas which has been popularized within several industrial domains is lean production systems (Rybski and Jochem, 2020; Agyabeng-Mensah *et al.*, 2020). Not only has lean production systems (LPS) become an industrial norm but it has also become one of the hotly discussed topics over the past three decades in the academic community (Sartal *et al.*, 2017).

LPS is deemed as a cluster of systematic manufacturing techniques deployed to relentlessly streamline a firm's production systems via the elimination of waste and reduction of non-value-added activities (Chavez *et al.*, 2020). The superiority of LPS is mirrored in its ability to enhance operational efficiencies, reduce negative environmental impacts and environmental risks, produce quality and innovative products (Solaimani *et al.*, 2019; Singh *et al.*, 2020), improve workplace safety and enhance corporate competitiveness (El-Khalil, 2020).

Although previous studies (Novais *et al.*, 2020; Belhadi *et al.*, 2018; Cheung *et al.*, 2017) have established that LPS can be implemented in isolation, contemporary evidence from academia and industry suggest that lean has the tendency to adequately provide tremendous outcomes when complemented with green technologies and other green-based paradigms (Sartal *et al.*, 2017; Kuo and Lin, 2020; Udokporo *et al.*, 2020). Green technology adoption (GTA), therefore, serves as a valuable resource to complement lean techniques. Integrating lean production and green technologies has been identified as one of the biggest prospects that are neglected across most manufacturing entities (Zokaei *et al.*, 2017). Given the approach of green technologies in reducing waste and energy, it is believed that together with lean techniques, firms should be able to identify innovative opportunities for eliminating waste (Sartal *et al.*, 2017), produce quality products and improve industrial green competitiveness (El-Kassar and Singh, 2019). Surprisingly, despite the promulgation of the lean-green theme in recent times, there is a dearth of studies when it comes to analyzing the interrelationships between LPS, GTA, green product innovation (GPI), social sustainability performance (SSP) and green competitiveness (GC).

Moreover, under the lean theme, previous studies (Singh *et al.*, 2020; Khalfallah and Lakhal, 2021; Dieste *et al.*, 2020) have overly focused on how lean techniques are compatible with either economic performance or environmental performance or a blend of the two; however, studies linking lean-to social outcomes is still sparse. The relatively few studies that have attempted to link lean-to-SSP have provided divergent results. For instance, whereas a number of empirical studies (Chavez *et al.*, 2020; Sajan *et al.*, 2017; Nath and Agrawal, 2020) have disclosed that lean production systems tend to be a significant precursor of SSP in terms of reducing worker stress and improve general well-being, other studies (Brown and O'Rourke, 2007; Nordin and Belal, 2017) have unveiled a negative effect of lean on social outcomes (e.g. negative work climate and poor worker health and safety). Besides, recent systematic literature reviews (Henao *et al.*, 2019; Sony *et al.*, 2020) have bewailed the paucity of research regarding the linkage between lean methodologies and social sustainability performance, especially in emerging countries; hence call for more studies from such geographical contexts. Based on the submission of some scholars (Soundararajan and Brammer, 2018; Choi and Luo, 2019), investigating the linkages between lean and social performance in industries from emerging markets is relevant and needed because such countries are characterized by weak institutions and legal systems. More specifically, the work of Agyabeng-Mensah *et al.* (2020) stresses the need for more lean-based research in the Ghanaian manufacturing sector, which happens to be our study context.

Furthermore, contemporary firms (including those in Ghana) are under incessant pressure to be innovative in terms of deploying lean methods, adopting green technologies and offering green-based products to enhance their competitiveness (Oduro and Nyarku, 2018; Shashi *et al.*, 2019; Zameer *et al.*, 2020). From an empirical perspective, an insight on how the application of lean production systems leads to green product innovation has not been given the needed attention. Likewise, there is skepticism from some industry players in relation to whether the adoption of green technologies and green product innovation actually lead to the achievement of anticipated social impact or outcome (Ramani *et al.*, 2017). This study, therefore, seeks to address the gaps explicated above by principally investigating the mediation roles of green technology adoption and green product innovation between lean production systems, social sustainability performance and green competitiveness. Specifically, the study tries to answer the following germane research questions:

RQ1. Is there any significant interrelationships between LPS, GTA, GPI, SSP and GC?

RQ2. Do GTA and GPI play mediation roles between LPS, SSP and GC?

In responding to the research questions above, data is cautiously garnered from 197 manufacturing firms in Ghana, an emergent country in Africa where the lean-green bandwagon happens to be in a budding stage. The study makes significant contributions to both theory and practice to existing literature. The study applies and confirms the robustness of the NRBV to empirically explain the connections between the underlying constructs. From the practitioners' perspective, the outcome of the study informs managers (especially those from emergent countries) about the need to complement investment in lean techniques with the adoption of green technologies that guarantee the production of green innovative products so as to drive their green competitiveness and social targets.

The paper is structured as follows. Section 2 captures the theoretical background and explanation of the thematic constructs leading to the development of the research model and hypothesized relationships. Afterward, the research methods adopted for the study are described in Section 3. This is followed by the results and a detailed discussion of the results in Section 4. The conclusion, implications of the study to theory and practice, limitations and directions for future studies are detailed in Section 5.

2. Theoretical background

2.1 Natural resource-based view theory

The natural resource-based view (NRBV) theory is an extension of the resource-based view (RBV) theory. As a theoretical lens, the RBV theory provides a framework that explicates how firms can gain competitive advantage via bundles of internally unique capabilities and resources (Barney, 1986). Despite the relevance of RBV in understanding how firms gain competitive advantage, the theory predominantly stressed internal resources and failed to capture external natural resources. In addressing this limitation, the NRBV theory was propounded (Hart, 1995). The NRBV framework works on the premise that a firm's competitive advantage is fundamentally contingent on the relationship it has with the natural environment (Hart, 1995). As a theoretical framework, the NRBV identifies how firms can gain competitive advantage via integrating internal and external natural resources.

The NRBV theory, according to Hart (1995), is rooted in three interconnected capabilities: pollution prevention (PP), product stewardship (PS) and sustainable development (SD). PP strategies and competencies ensure that waste and emissions are curtailed. Through PP competencies, firms are able to significantly optimize their operational processes, increase productivity, enjoy greater efficiency and cost savings. On the other hand, PS strategies ensure that firms address the environmental concerns of stakeholders in their operational value chain and product designs. PS helps firms to enjoy a competitive advantage through product innovation (modifying existing products or developing new products) in such a way that the life cycle cost of products is minimized. SD strategies concentrate on removing the negative environmental outcomes of firms that come as a result of their growth and development. SD strategies require heavy investments and usually have long-term performance outcomes.

In connection with this study, it is argued that the implementation of lean techniques supports the NRBV theory, such that, firms can use LPS to drive continuous improvement and eliminate all forms of waste (King and Lenox, 2002; Huo *et al.*, 2019), deploy green technologies, produce eco-innovative products so as to achieve social targets and enhance its green competitiveness. Implementing LPS through the NRBV lens can serve as a unique resource to the firm and can be used as leverage to enhance its green competitiveness via the use of eco-technologies and the production of eco-friendly products.

2.2 Research model and hypotheses development

2.2.1 Lean production systems, social sustainability performance and green competitiveness. Studies linking LPS to SSP are still in their early stages, with the relatively few ones providing mixed results. By collecting data from some selected manufacturing firms in Chile, Chavez *et al.* (2020) disclosed that the nexus between lean methods and social performance is positive and significant. Likewise, through an international survey, Mousavi *et al.* (2020) disclosed that the application of lean practices has a significant impact on task characteristics, workforce characteristics and the working environment. Moreover, Tenera *et al.* (2019) established through a case study approach that lean systems tend to improve workers' welfare and conditions, thereby leading to superior social performance. Furthermore, by using Nike corporation as a case study, Distelhorst *et al.* (2017) strengthened the notion that lean practices' serve as a significant catalyst to the improvement of social sustainability performance in two important ways: lean practices increase workers' involvement at the work and positively influences labor relations and lean ensure that workers comply with workplace standards. Meanwhile, some scholars (Martínez-Jurado and Moyano-Fuentes, 2014; Nordin and Belal, 2017) have provided reports suggesting that applying lean principles may lead to negative work outcomes like workforce stress. This notwithstanding, it is imperative to accentuate that the implementation of lean methods may yield either positive or negative outcomes on workforce health and safety (e.g. workforce stress) conditional on how the methods are implemented (Longoni *et al.*, 2013). By juxtaposing the empirical discussions above, this study proposes that:

H1a. LPS has a positive impact on SSP.

Although theoretically acknowledged, the empirical discourse between LPS and GC is still evolving. The implementation of lean techniques tends to improve a firm's green competitiveness via improved energy efficiency and reduce the emission of harmful substances (Zhu *et al.*, 2018). In many industries, firms that deploy lean methods tend to enjoy long-term competitive superiority via reducing the environmental cost of products and the overall achievements in green benefits (Belhadi *et al.*, 2018). As a result of the applicability of LPS, firms are able to conserve energy, save energy and combat global warming (Chugani *et al.*, 2017), thereby leading to the achievement of superior green competitiveness. Based on the dynamic capabilities theory, the application of lean methodologies helps firms to generate competencies for achieving greener outcomes, thus serving as a source of GC (Hansen and Møller, 2016). Firms are able to achieve their green targets via the application of LPS, thus helping them to enhance social and green reputation (Zhu and Lin, 2017) and significantly boost their green competitiveness (Udokporo *et al.*, 2020). Besides, firms with lean credentials are capable of producing green products at a faster rate and later create new market opportunities for such unique eco-friendly products, thus enriching their green competitive advantage (Cheung *et al.*, 2017). Following the empirical studies discussed above, this study hypothesizes that:

H1b. LPS has a positive impact on GC.

2.2.2 Lean production systems, green technology adoption and green product innovation. Owing to the fact that both lean methodologies and green technologies targets the elimination of wastes, some scholars (Tortorella and Fettermann, 2018; Rossini *et al.*, 2019) have suggested that lean techniques facilitate the adoption of green technologies. By undertaking a quantitative study among companies (machinery and automotive and industries and research institutes) from Germany, Gerhard *et al.* (2012) unveiled that the application of lean methodologies tends to create constructive impacts on technology development. In another study conducted via the sampling of 763 manufacturing plants from five European countries, Sartal *et al.* (2017) established that lean management creates efficient and well-organized conditions within the organization for the development of possible technology-driven capabilities, thus leading to the implementation of new and ecologically sound technologies. Firms with lean thinking create an organizational climate where workers are expected to look for effective approaches and embrace innovative technologies to address specific operational deficiencies (Bittencourt *et al.*, 2020). Without designing robust continuous improvement methodologies, firms may be less prepared to embrace innovative technologies (Rossini *et al.*, 2019). This is an indication that firms that implement LPS in pursuit of achieving operational efficiencies stand a better chance of using the most potent innovative technologies (Moyano-Fuentes *et al.*, 2012). Given the above discussion, it is logical to suggest that firms that use lean systems are likely to pull or adopt the right green-based technologies to enhance operational efficiencies; therefore, the study proposes that:

H2a. LPS has a positive impact on GTA.

Relatively few studies have provided evidence to support the claim that the execution of lean techniques leads to the production of innovative products. For instance, after cautiously gathering data from 374 manufacturing firms from India, Shashi *et al.* (2019) empirically found leanness to have a positive effect on product innovation. Also, Johansson and Sundin (2014) undertook a systematic literature review and emphasized that the implementation of lean methodologies ensures that firms produce greener products. It is seemingly logical to assert that, as lean management emphasizes customer-centric thinking, firms with lean methodologies are likely to modify existing products or produce new products aimed at satisfying customer's green-sensitive demands (Nath and Agrawal, 2020). With the implementation of lean systems, firms are able to detect the deficiencies in their operations, thus leading to a decrease in wastes and consequently the creation of value-added products or products with superior quality (Nicoletti, 2015). Owing to the deployment of lean approaches, firms are able to receive timely feedback from customers, rejuvenate their innovative capabilities and enhance operational methods to develop new products or transform already existing products (Solaimani *et al.*, 2019). Considering the above discussion, this study hypothesizes that:

H2b LPS has a positive impact on GPI.

2.2.3 Green technology adoption, green product innovation, social sustainability performance and green competitiveness. There is a literature dearth regarding the observable interrelationships between GTA, GPI, SSP and GC. In a study carried out in Malaysia, Min *et al.* (2016) found technological innovation as an antecedent of product innovation. In a similar study conducted among Korean manufacturing SMEs, Lee *et al.* (2016) revealed that technology exploration has a substantial impact on the extent to which product innovativeness is achieved. Also, Shi *et al.* (2018) empirically disclosed that the adoption and subsequent implementation of new technologies lead to significant changes or improvement in product quality among Chinese firms. GTA shows its distinctive pro-environmental physiognomies in product design and development (Schiederig *et al.*, 2012). Firms that invest in new eco-oriented technologies tend to reduce the variable costs related to the product designing and development stage and this helps in manufacturing products with the highest quality (Matt *et al.*, 2015).

In applying the NRBV theory as a theoretical lens, Forés *et al.* (2020) sampled 426 Spanish firms in the tourism sector and found the implementation of green technologies as a significant antecedent of improved SSP. Thus, it is logical to suggest that green technologies help firms to achieve their social targets in terms of social progress in workers' welfare and upgrading of working conditions in terms of security and health. Firms may achieve their social targets to a larger extent when they successfully install new technologies and improve their technological capabilities (Hostettler, 2016). Worker injuries and fatalities are likely to be curtailed when firms adopt green-based innovative technologies (Nnaji *et al.*, 2018). Nowadays, innovation in the form of technological advancement is not only just a means to enhancing a firm's competitiveness but also an essential requirement for affirming social legitimacy (Li *et al.*, 2017) and guaranteeing societal well-being (Shahzad *et al.*, 2020).

It is suggested that firms implement green technologies to directly or indirectly attain their social benefits and green competitive targets (Ainin *et al.*, 2016). The use of novel technological tools has been credited with providing lasting environmental solutions through curtailing the impact of pollutants (Xie *et al.*, 2019) while achieving superior green competitiveness (Zhang *et al.*, 2020). GTA is expected to improve the green competitive position of firms via reducing the environmental cost of products, reduction in cost compliance regarding environmental legislation and enjoyment of first-mover advantages (Horbach, 2008; Cillo *et al.*, 2019).

Environmentally-friendly products are developed to decrease the use of energy and inputs and have the potential to lessen pollution emissions (El-Kassar and Singh, 2019). As firms produce eco-oriented products, their green image is likely to increase, leading to a superior competitive edge over competing firms (Chan *et al.*, 2016). This is an indication that firms can use the development of eco-products as an important organizational resource to boost their green performance, enhance their reputational standing and significantly gain a competitive advantage (Singh *et al.*, 2020). Besides, firms are likely to enjoy superior social benefits from producing innovative products (Padgett and Moura-Leite, 2012). It is imperative to indicate that firms can view the production of green products as a business solution to achieve their social responsibility targets (Zhang *et al.*, 2020). While this assertion seems logical, a study by Sezen and Çankaya (2013) disclosed that eco-product innovation has no significant impact on social performance. Based on the discussion above, the following hypotheses are proposed:

H3a. GTA has a positive impact on GPI.

H3b. GTA has a positive impact on SSP.

H3c. GTA has a positive impact on GC.

H3d. GPI has a positive impact on SSP.

H3e. GPI has a positive impact on GC.

2.3 Mediating roles of green technology adoption and green product innovation

Existing literature (Rossini *et al.*, 2019; Bittencourt *et al.*, 2020) suggests that lean-thinking provides the opportunity for firms to embrace novel technologies. As firms embrace eco-oriented technologies due to the application of lean methodologies, they are likely to produce products that have the potential to mitigate environmental challenges (El-Kassar and Singh, 2019). Hence, it can be proposed that GTA serves as an indirect mechanism through which the effect of lean production on green product innovation can be explained. Indeed, the implementation of lean methodologies increases the desire of firms to improve their production processes via the installation of new technologies (Tortorella and Fettermann, 2018). With the use of innovative eco-friendly technologies, firms may not only be able to manufacture green products but are further likely to achieve their social targets (Hostettler, 2016). Thus, the adoption of supportive eco-friendly technology can help protect the social well-being of employees (Jilcha and Kitaw, 2017; Shahzad *et al.*, 2020). This study, therefore, posits that GTA works as an explanatory link between LPS and SSP. Organizations that invest in green technologies can enjoy environmental benefits and have the ability to create market opportunities and improve their competitiveness (Li *et al.*, 2019). With lean methodologies helping firms to improve their competitiveness (Bevilacqua *et al.*, 2016) and green technologies serving as the cradle for firms' green competitive advantage (Küçükoğlu and Pınar, 2015), it is, therefore, necessary to explore the indirect effect of GTA between LPS and GC.

When firms opt for lean methodologies, they tend to create an organization that is capable of producing less costly, value-added, safer and quality products that have less damage to the environment (Kumar and Rodrigues, 2020). Producing eco-friendly products via the adoption of lean techniques may not only help firms abide by environmental regulations but will help them fulfill their social responsibility (Zameer *et al.*, 2020), thereby improving social performance. In effect, it is presumed that LPS may provide firms with the ability to manufacture green products, which can further impact social performance, thus, suggesting that GPI plays a mediation role between LPS and SSP. Besides, it can be argued that when firms deploy lean production systems (LPS), it creates opportunities for green product innovation (GPI), which can boost their green competitiveness (GC). Considering the discussion above, the following mediation hypotheses are proposed and tested (Figure 1):

H4a. GTA mediates the link between LPS and GPI.

H4b. GTA mediates the link between LPS and SSP.

H4c. GTA mediates the link between LPS and GC.

H4d. GPI mediates the link between LPS and SSP.

H4e. GPI mediates the link between LPS and GC.

3. Research methods

3.1 Sample and data collection

In this study, the quantitative research approach was used. Data from Ghanaian firms within the manufacturing sector was used for the study. As an emergent country, Ghana's

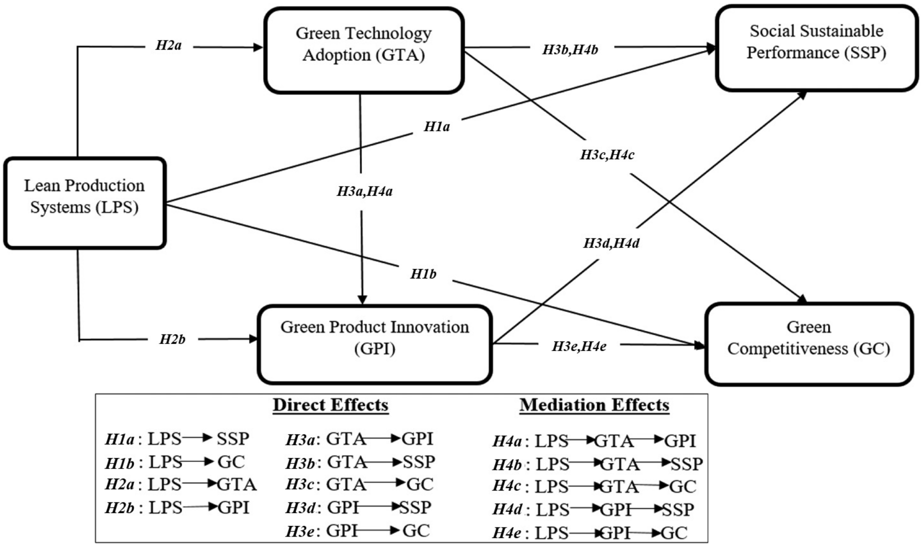

Figure 1.
Research model with hypothesized relationships anchored on the NRBV theory

manufacturing sector provides significant contributions to its economic growth. In total, 542 manufacturing firms that have been practicing lean production systems and have benefitted from such practices for more than five years were originally contacted for the study. However, 388 of the contacted firms agreed to participate in the study. A cover letter describing the nature and purpose of the study was presented to these firms. Additionally, questionnaires were sent to the chosen firms between July 2019 and October 2019. The self-administered questionnaires were distributed to the manufacturing firms with the help of hired and trained research assistants. During the data collection period, constant follow-ups were made through email reminders and telephone calls. At the end of the data collection process, 197 of the questionnaires were eventually received, signifying an effective response rate of 50.7%. Data was mainly collected from managers in higher hierarchical positions of their respective firms. There are two predominant reasons for the selection of managers in higher hierarchical positions. First, managers were contacted because of their requisite knowledge in lean operations; hence it was anticipated that they (managers) could provide informed opinions to help make concrete extrapolations. Second, relying on managers helped to minimize the potential threat of common method bias. Table 1 presents the summary of the sample demographics of the respondents.

3.2 Measurement description

As mentioned earlier, a questionnaire was the main data collection instrument. A three-step approach was followed in the development of the questionnaire. First, the measurement scales for the questionnaire development were identified through an extensive literature review, taking into consideration the thematic areas of the study. Next, the list of items obtained was skimmed and subjected to thorough scrutiny with the help of a panel of experienced industry practitioners and academic professionals. Results of this step allowed to drop redundant items, reduce the number of items and improve the semantic comprehensibility and clarity of the questions. Second, 35 manufacturing firms were chosen as a random sample for the pre-test to evaluate the appropriateness of the questionnaire as

Category	Frequency	Percentage (%)
Chemicals	28	14.2
Food products and beverage	51	25.9
Textile and apparel	43	21.8
Metals and roofing sheets	36	18.3
Plastic and rubber	24	12.2
Wood, lumber products and processing	15	7.6
Qualification		
General manager	43	21.8
Operations manager	51	25.9
Logistics manager	13	6.5
Procurement manager	20	10.2
Quality control manager	46	23.4
Industrial waste manager	24	12.2
Number of employees		
0–50	23	11.7
51–100	96	48.7
101–500	47	23.9
>500	31	15.7

Note: NB: *n = 197

Table 1. Summary of sample demographics

an instrument of measurement. Results of this step were minor changes in the wording of sentences to improve the readability and clarity of the questions. Third, the questionnaire was reviewed and finalized by the authors before it was administered to the respondents with help of hired and trained research assistants. The valid items for measuring all the five constructs (LPS, GTA, GPI, SSP and GC) were in harmony with the proposed hypotheses of the study. All respondents were entreated to indicate the extent to which they agreed or disagreed with each statement on a five-point Likert scale. The questionnaire was divided into two parts. While the first part captured the sample demographics of respondents, the second part was further partitioned into five parts to capture all the thematic constructs of the study. LPS was measured with five items. GTA was measured with five items. Likewise, five items were used to measure GPI. More so, five items were used to measure SSP. Finally, GC was measured using five items. The description of the constructs, the related measurement and sources are presented in Table 2.

3.3 Common method and non-response bias

Harman's single-factor test was used to detect the potential threat of common method bias (CMB). This was achieved through the estimation of exploratory factor analysis (EFA). The outcome of the EFA demonstrates that CMB is not a major issue in this study because the single factor explicated 39.3% of the total variance, which is below the tolerable cut-off point of <50. Also, in assessing for non-response bias (NRB), the early wave (53%) responses were matched with the late wave (47%) responses. Through the computation of a t-test, no significant difference was found between early wave and late wave. This, therefore, confirm the claim that NRB has a negligible impact on the data-set.

3.4 Evaluation of measurement model

This study applied structural equation modeling, specifically partial least square as the methodological tool to test all hypotheses. PLS is a robust variance-based multivariate

Constructs	Explanations	Measurement items	Codes	Sources
		Total preventive maintenance	LPS1	
		Total quality management	LPS2	
LPS	The collection of systems and techniques that can be combined effectively to streamline operations via the elimination of waste and other non-value added activities, in an attempt to produce high-quality products that satisfy customer demand	Just-in-time system	LPS3	Agyabeng-Mensah *et al.* (2020) and Shashi *et al.* (2019)
		Supplier partnership and customer involvement	LPS4	
		Set-up time reduction	LPS5	
		Eco-technology change rapidly in our firm	GTA1	
		We are eco-technologically competitive	GTA2	
GTA	The introduction of environmentally-conscious technologies aimed at improving operational efficiencies and dealing with firm's negative externalities	We use up-to-date/new technology in the process	GTA3	Sartal *et al.* (2017) and Lee *et al.* (2014)
		We are fast in adopting the latest technological innovations	GTA4	
		We use cleaner technologies	GTA5	
		We are able to produce products with novelty eco-features	GPI1	
		Recovery of company's end-of-life products and recycling	GPI2	Singh *et al.* (2020)
GPI	The modification of existing products or the introduction of unique green-based products aimed at reducing the disposal impact on the natural environment and improving energy efficiency	Use of materials that consume less energy and resources	GPI3	Chan *et al.* (2016) and Lee *et al.* (2014)
		We produce new eco-products which are first-in-market	GPI4	
		Our new products have superior quality when compared to competitors in relation to environmental features	GPI5	
		Health and safety of employees have improved	SSP1	Chavez *et al.* (2020)
		Improved living quality of surrounding community	SSP2	Afum *et al.* (2020)

(*continued*)

Table 2.
Constructs description and measurement items

Constructs	Explanations	Measurement items	Codes	Sources
SSP	A measure of performance based on aspects that promote employee well-being and translate firms' social targets into reality	Workers satisfaction levels have improved	SSP3	Sajan *et al.* (2017)
		Decrease in rate of consumer complaints	SSP4	
		The amount of stress at work has decreased	SSP5	
		Reduced environmental cost of products	GC1	
		Speed of converting green products is faster than competitors	GC2	
GC	A firm's superior or favorable position over rivalry firms in a given industry regarding its ecological management or green innovation, which makes it possible for such firm to enjoy sustainable benefits	Improved green reputation/image	GC3	Zameer *et al.* (2020) and Chen and Chang (2013)
		Minimize negative environmental impacts better than competitors	GC4	
		Create new market opportunities and increase market shares	GC5	

Table 2.

technique that is used in testing predictive hypothesized relationships. The use of PLS ensured that a two-stepwise approach was followed: evaluation of the measurement model to guarantee that the model is without reliability and validity issues and evaluation of the structural model to confirm predictive accuracy and relevance, determine the strength of the path coefficients of the constructs and significance levels.

The reliability of the model was evaluated via Cronbach's alpha (CA) and composite reliability (CR). CA and CR estimates are expected to be ≥ 0.70 and ≥ 0.60, respectively. Based on Table 3, both CA (0.817–0.843) and CR (0.879–0.890) values met the recommended tolerable thresholds. Also, indicator reliability was assessed via factor loadings (FL). Generally, FL estimates are expected to be ≥ 0.70 and per the observation in Table 3, the FL estimates (0.731–0.857) surpassed the suggested threshold. It is imperative to highlight that FL values that were lower than the tolerable thresholds were deleted from the model. To confirm sampling adequacy (check whether the data was suited for factor analysis), the reliability of all five constructs was determined via Kaiser-Meyer-Olkin (KMO) values and Bartlett's test. The result from Table 3 shows that the KMO values (0.780–0.836) were greater than the stipulated threshold of 0.6 and the corresponding Bartlett's test values were all significant at less than 0.05. This, therefore, suggest adequacy of the sample and that there is no problem regarding the high correlation.

Convergent validity is further assessed through average variance extracted (AVE). AVE estimates are expected to be >0.5 and per the result in Table 3, the AVE values (0.602–0.671)

Constructs	Items	FL	CA	CR	AVE	KMO	Bartlett's test
Lean production systems (LPS)	**LPS1**	0.844	0.835	0.890	0.671	0.803	0.000
	LPS2	0.834					
	LPS3	0.751					
	LPS4	0.843					
Green technology adoption (GTA)	**GTA1**	0.771	0.834	0.883	0.602	0.780	0.000
	GTA2	0.731					
	GTA3	0.773					
	GTA4	0.817					
	GTA5	0.786					
Green product innovation (GPI)	**GPI1**	0.781	0.817	0.879	0.646	0.797	0.000
	GPI2	0.847					
	GPI3	0.765					
	GPI4	0.821					
Social sustainability performance (SSP)	**SSP1**	0.857	0.827	0.886	0.660	0.805	0.000
	SSP2	0.827					
	SSP3	0.797					
	SSP4	0.766					
Green competitiveness (GC)	**GC1**	0.741	0.843	0.888	0.614	0.836	0.000
	GC2	0.826					
	GC3	0.792					
	GC4	0.811					
	GC5	0.745					

Table 3. Construct reliability, convergent validity and sampling adequacy

satisfied the recommended threshold. In assessing discriminant validity, Heterotrait-Monotrait (HTMT) ratio is considered. HTMT estimates are expected to be <0.9 and per the result of Table 4, the HTMT estimates (0.675–0.861) met the suggested threshold.

3.5 Evaluation of structural model

After satisfying the reliability and validity criteria, the next stage was to evaluate the structural model. This was done by focusing on the model's explanatory power based on variance explained (R^2), predictive relevance by the computation of Stone–Geisser criterion Q^2, evaluation of effect size (f^2) and the determination of multicollinearity. Regarding the R^2, Table 5 shows that the structural model explains 65.8% of the variance in GC, 45.6% of the variance in GPI, 39.4% of the variance in GTA and 69.1% of the variance in SSP. Additionally, the estimation of Q^2 through a blindfolding procedure shows that the model achieved predictive relevance: green competitiveness ($Q^2 = 0.368$), green product innovation ($Q^2 = 0.273$), green technological adoption ($Q^2 = 0.222$) and social sustainability performance ($Q^2 = 0.426$). It can be aptly indicated that the structural model achieved excellent predictive accuracy and relevance. Moreover, f^2 is estimated to determine whether the exogenous construct made any substantial contribution to the endogenous constructs. Benitez *et al.* (2020) suggest that the thresholds for f^2 values ranges are: small effect ($0.02 \leq f^2 \leq 0.150$), moderate effect ($0.15 \leq f^2 \leq 0.35$) and large effect size ($f^2 \geq 0.35$). Table 5 shows that LPS has a small effect on GPI ($f^2 = 0.071$) and SSP ($f^2 = 0.040$), respectively. However, while LPS has a moderate effect on GC ($f^2 \geq 0.251$), it has a large effect on GTA ($f^2 \geq 0.364$). Finally, multicollinearity was tested via variance inflation factor (VIF). The threshold for VIF values is <3.3 and per Table 5, the VIF ($1.000 \leq \text{VIF} \leq 1.840$) threshold is satisfied. It can satisfactorily be established that the structural model has no multicollinearity issues.

4. Results and discussion

4.1 Direct Effects

After evaluating the measurement model and structural model, the next stage was to test the hypotheses and make extrapolations based on the results. The analysis of the data after performing a bootstrapping procedure of 5,000 re-samples shows that with the exception of *H1a*, all the hypotheses are supported. As depicted in Table 6, LPS has a positive impact on SSP, but the impact is not significant ($\beta = 0.103$, $t = 1.610$, p-value= 0.107), thus suggesting

Constructs	GC	GPI	GTA	LPS	SSP
GC					
GPI	0.824				
GTA	0.811	0.781			
LPS	0.839	0.675	0.749		
SSP	0.806	0.846	0.861	0.711	

Table 4.
HTMT ratio

Constructs	R^2	Adjusted R^2	Q^2	f^2	VIF
GC	0.658	0.653	0.368	0.251	1.766
GPI	0.456	0.451	0.273	0.071	1.649
GTA	0.394	0.391	0.222	0.364	1.000
SSP	0.691	0.687	0.426	0.040	1.840

Table 5.
Structural model

Hypotheses	Path	Beta coefficient	T-statistics	*p*-values	Conclusion
a. Direct effects					
H1a	LPS → SSP	0.103	1.610	0.107	Not supported
H1b	LPS → GC	0.389	5.107	0.000	Supported
H2a	LPS → GTA	0.627	12.252	0.000	Supported
H2b	LPS → GPI	0.252	3.197	0.001	Supported
H3a	GTA → GPI	0.488	6.998	0.000	Supported
H3b	GTA → SSP	0.319	4.325	0.000	Supported
H3c	GTA → GC	0.236	3.070	0.002	Supported
H3d	GPI → SSP	0.515	8.637	0.000	Supported
H3e	GPI → GC	0.318	3.654	0.000	Supported
b. Mediation effects					
H4a	LPS → GTA → GPI	0.306	5.961	0.000	Supported (partial mediation)
H4b	LPS → GTA → SSP	0.200	3.839	0.000	Supported (full mediation)
H4c	LPS → GTA → GC	0.148	2.891	0.004	Supported (partial mediation)
H4d	LPS → GPI → SSP	0.130	3.381	0.001	Supported (full mediation)
H4e	LPS → GPI → GC	0.080	2.208	0.027	Supported (partial mediation)

Table 6.
Direct effects and indirect effect

that *H1a* is not supported. This result is not consistent with the work of Chavez *et al.* (2020) where the nexus between lean and social performance was found to be significant and positive among manufacturing firms in Chile. The result is further inconsistent with other prior studies (Tenera *et al.*, 2019; Mousavi *et al.*, 2020). However, the result seems to be consistent with the works of Martínez-Jurado and Moyano-Fuentes (2014) and Nordin and Belal (2017), where it was highlighted that lean applications may sometimes lead to negative work outcomes. The predominant reason for the insignificant result unveiled in this study could be that the lean techniques implemented by the selected firms within the Ghanaian context do not focus more on human inclusiveness. Thus, the lean methods do not fully consider human elements, hence likely limiting its potency in predicting social sustainability performance.

However, LPS is found to have a significant positive impact on GC ($\beta = 0.389$, $t = 5.107$, p-value = 0.000), thus proving that *H1b* is supported. This result is reinforced by previous works (Zhu and Lin, 2017; Udokporo *et al.*, 2020) where it was suggested that the implementation of lean systems boost a firm's green competitive advantage. The work of Belhadi *et al.* (2018) strengthens the current result because improving environmental benefits via the deployment of lean techniques is likely to lead to enhanced long-term green competitive advantages. This result adds value to the existing literature by confirming the notion that lean systems naturally help firms to become more ecologically friendly, leading to the achievement of superior green competitiveness.

Also, LPS is found to have a significant positive impact on GTA ($\beta = 0.627$, $t = 12.252$, p-value = 0.000), thus confirming *H2a*. This result is consistent with the work of Gerhard *et al.* (2012) where the implementation of lean methodologies was found as an antecedent for technological development among companies in Germany. The current result is further echoed by the work of Sartal *et al.* (2017) which established that implementing lean management creates opportunities for firms to adopt new technologies. Thus, the outcome of the current study suggests that lean production systems could prompt firms from emergent countries like Ghana to invest in innovative green technologies.

Likewise, LPS is found to have a significant positive impact on GPI (β = 0.252, t = 3.197, p-value = 0.001), thus confirming *H2b*. The current result confirms the assertions of previous scholars (Nicoletti, 2015; Solaimani *et al.*, 2019; Nath and Agrawal, 2020), who unanimously suggested that firms are able to produce innovative products because of the customer-centric nature of lean systems. The result is further congruent with the work of Shashi *et al.* (2019) where it was found that Indian manufacturers that deploy lean methods tend to produce innovative products. Thus, the current result emphasizes the potency of lean production systems in detecting defects and eliminating waste during the production process so as to produce green-based innovative products. This result is very insightful for firms from developing countries like Ghana because such firms are under incessant pressure to develop green-based innovative products.

Additionally, the result shows that GTA has a significant positive impact on GPI (β = 0.488, t = 6.998, p-value= 0.000), thus proving that *H3a* is supported. This result seems compatible with the work of previous studies (Min *et al.*, 2016; Lee *et al.*, 2016; Shi *et al.*, 2018) where it was reiterated that the adoption of new technologies by firms in Malaysia, Korea and China substantially affects the extent to which product innovativeness is achieved. Given the current result, it is, therefore, logical to suggest that adopting green technologies should be a top priority for firms from developing countries if they so wish to produce green-based innovative product. This is because green technology adoption is a significant precursor for green product innovation.

Moreover, GTA is found to have a significant positive impact on SSP (β = 0.319, t = 4.325, p-value= 0.000), thereby confirming *H3b*. Forés *et al.* (2020) strengthen the current result by suggesting that green technologies boost firms' social sustainability performance. The reason for the current result could be that the adoption of green technologies has the tendency to minimize worker fatalities and injuries, thus helping to improve employee social well-being and fulfil social responsibility.

Furthermore, GTA is found to have a significant positive impact on GC (β = 0.236, t = 3.070, p-value = 0.002), thus confirming *H3c*. The work of Zhang *et al.* (2020) supports the current result by indicating that the use of new green-based technologies helps firms improve their green competitiveness. This result is very essential for firms in developing countries because investing in novel green-based technologies can help them gain green competitiveness.

More so, GPI is found to have a significant positive impact on SSP (β = 0.515, t = 8.637, p-value = 0.000), thereby supporting *H3d*. This result is inconsistent with the work of Sezen and Çankaya (2013) which suggested that eco-product innovation has an insignificant impact on social performance. However, Zhang *et al.* (2020) support the current study by indicating that the manufacturing of green products serves as a lasting business solution toward achieving firms' social responsibility targets. This result is very important because firms are likely to improve the quality of life of community members and reduce the rate of customer complaints regarding product defects when they deliver green products. Besides, *H3d* is supported because GPI is found to have a significant positive impact on GC (β = 0.515, t = 8.637, p-value = 0.000). The works of previous scholars (Singh *et al.*, 2020; Chan *et al.*, 2016) confirm the current result by indicating that firms that produce green products tend to improve their environmental performance and green image, thus leading to a significant boost in their green competitiveness. The current result suggests that firms from developing countries can rely on delivering green products to create new market opportunities and become green competitive entities.

4.2 Mediation effect

To test for *H4a-H4e* (hypotheses related to the mediation effects), the procedure submitted by Zhao *et al.* (2010) is strictly followed. The approach focuses on testing and matching the path coefficients and associated significance levels of direct and indirect effects to determine whether there is full mediation (FM) or partial mediation (PM). FM takes precedence when the direct effect is insignificant but the indirect effect is significant. However, PM takes place when both the direct effect and indirect effect are significant. Based on the results from Table 6, GTA plays a partial mediation effect between LPS and GPI (β = 0.306, t = 5.961, p-value = 0.000), as well as between LPS and GC (β = 0.200, t = 3.839, p-value = 0.000). Also, GPI is found to play a partial mediation effect between LPS and GC (β = 0.080, t = 2.208, p-value = 0.027). However, GTA is found to play a full mediation effect between LPS and SSP (β = 0.148, t = 2.891, p-value = 0.004). GPI is further found to play a full mediation effect between LPS and SSP (β = 0.130, t = 3.381, p-value = 0.001). From the results of the mediation analysis, it is logical to suggest that green technology adoption provides a mechanism through which firms can implement lean production systems to produce green-based innovative products. Also, although the direct effect of lean production systems on social sustainability performance was insignificant, green technology adoption and green product innovation as mediators are very potent in enhancing social sustainability performance via the deployment of lean production systems. Moreover, the mediation analysis indicates that green technology adoption and green product innovation provide explanatory links between the deployment of lean production systems and the achievement of green competitiveness.

5. Conclusions

This study addressed the need to explore the relationships between lean production systems, green technology adoption, green product innovation, social sustainability performance and green competitiveness. The study further investigates the mediation roles of green technology adoption and green product innovation between lean production systems, social sustainability performance and green competitiveness. The outcome of this study suggests that lean production systems have a significant positive impact on green technology adoption, green product innovation and green competitiveness. However, the study's outcome proved that although lean production systems have a positive impact on social sustainability performance, the impact is insignificant. Notwithstanding, the outcome of the study proved that green technology adoption and green product innovation are critical indirect mechanisms through which lean production systems will significantly influence social sustainability performance and green competitiveness.

5.1 Theoretical and managerial implications

This study provides robust and unique evidence that supports theoretical implications and practical ramifications for managers and policymakers, respectively. From the theoretical outlook, this study uniquely develops a comprehensive integrated research model that explores the connections between lean production systems, green technology adoption, green product innovation, social sustainability performance and green competitiveness. This confirms the robustness of the NRBV theory and helps bridge the gap in the existing literature on lean, green management and sustainability. Again, the study offers a unique contribution by exploring the need to combine lean production systems with innovative green technologies to produce green-based products, enhance social sustainability performance and gain green competitiveness. This confirms the notion that the capability of lean production systems to achieve superior social and competitive outcomes lies in a firm's decision to augment lean systems with green-based technologies. Furthermore, this study contributes to the ongoing underexplored discourse between lean production systems and social sustainability performance. Finally, and most importantly, exploring the mediating roles of green technological innovation and green product innovation between lean production systems, social sustainability performance and green competitiveness provides another valuable contribution of the study.

As cited previously, the study provides some insightful ramifications for practitioners (managers) and policymakers. The outcome of the study informs managers (especially those from emergent countries) about the need to complement investment in lean techniques with the adoption of green technologies. Thus, managers should ensure that the justifications for investing in lean production systems are supported by firms' desire to adopt environmentally sound technologies. In the decision-making process of implementing lean production systems within their organizations, managers must either upgrade their existing technologies to accommodate green features or procure reliable new green-based technologies so as to pursue the production of green innovative products, boost their green competitiveness and improve social sustainability performance. Also, given the relevance of the social elements in effective lean systems, it behooves managers to holistically consider the human element when implementing lean production systems to enhance social sustainability performance. Moreover, considering the upsurge in environmental activism for green products and the need for firms to stay competitively green, the outcome of this study is very significant, as it encourages managers to implement lean production systems that guarantee the production of green innovative products so as to drive their green competitive targets. Finally, the outcome of this study offers guidance for policymakers (governments and other parastatal environmental agencies). Policymakers can coordinate with firms to design result-oriented lean-green business models and further offer monetary incentives (e,g tax credits, tax exemptions, subsidies, interest-free loans and environmental grants) to assist lean-based firms in their quest to combine lean production systems with green technologies.

5.2 Limitations and future research directions

Regardless of the significant contributions of the study to both theory and practice, its interpretation must be done with caution because there are some limitations that provide leeway for future research. First, data for the study is garnered from Ghanaian firms within the manufacturing sector, thereby contextualizing the significance of the study. This may, therefore, limit the generalizability of the results to other geographical contexts. A replica study in other national contexts (emergent countries) that uses our research model to either dispute or confirm the results obtained is welcomed. Second, the items for measuring lean production systems are non-exhaustive, hence future studies could consider other dimensions in addition to the ones used in this study to widen the scope and better appreciate the lean concept. Third, this study exclusively undertook mediation analysis. This provides avenues for future studies to consider relevant moderators like green transformational leadership and lean culture and probe their moderating effect on lean production systems, social sustainability performance and green competitiveness. Finally, future studies may rely on qualitative data to explicate the possible associations between the variables used in this study. This will help provide more thought-provoking insights.

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