

Does Digitalization Enhance the Effects of Lean Production on Social Performance?

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Abstract

Purpose – This study investigates whether Industry 4.0 digital technologies can enhance the effects of lean production on social performance.

Design/methodology/approach – Survey data collected from China’s manufacturing industry are used to test research hypotheses.

Findings – The results reveal that the three dimensions of lean production (internal, customer, and supplier) have a significant positive effect on social performance, and that digital technology advancement (DTA) positively moderates these relationships. DTA adds only marginal contribution to social performance.

Practical implications – This study addresses a new challenging question from manufacturing firms: how to integrate lean, technology, and people? The empirical findings provide timely and insightful practical guidance for managers to better understand the role of digital transformation in the traditional lean context.

Original/value – While digitalization is known to complement lean production, this study shows digitalization also complement the effects of lean production on social performance.

Keywords: Lean production; digital technology advancement; social performance; socio-technical system

Paper type: Research paper

1. Introduction

While major manufacturing countries adopt Industry 4.0 technologies, manufacturing faces a new question: how to integrate lean, technology, and people? Lean is not a production system that only targets efficiency; it is a socio-technical system (STS) (Hasle et al., 2012; Soliman et al., 2018; Januszek et al., 2023) that promotes employee motivation, autonomy, and work involvement (Sony et al., 2020). Nowadays, manufacturers are expected to enhance social performance, defined as measures related to well-being of employees, community, and society, e.g., health and safety internally and at a supply chain (SC) level (Marshall et al., 2015; Yu et al., 2020). However, social performance of lean production depends on how lean is practiced (Chavez et al., 2022; Hasle et al., 2012). When lean implementation involves employees and communities in a human-centric manner, it benefits employees' working environment, health, and wellbeing (Hasle et al., 2012; Huo and Boxall, 2018). Lean creates psychological safety that promotes employee learning (Fenner et al., 2023). Similarly, lean transforms innovative ideas into operational improvement (Yu et al., 2020). These behavioural lean elements (e.g., innovativeness and learning) are also key to adopt advanced digital technologies (Åhlström et al., 2021; Tortorella et al., 2018). However, digital technologies are inherently more technical. Thus, it remains unclear whether the social aspect of lean can be enhanced (or diminished) by digitalization.

This study treats the adoption of Industry 4.0 technologies as a contingency factor that may affect the lean-social performance relationship. This perspective complements the view that digitalization is linked to lean practices (Agrawal et al., 2019; Khuntia et al., 2018), which in turn affect social performance (Martinez-Jurado and Moyano-Fuentes, 2014). The study is important as it informs manufacturers who may view lean and digital transformation separately when addressing social performance issues. Though technologies can support lean, the potential synergistic effect depends on how lean practices and technologies are used (Núñez-Merino et al., 2020). Lean production is shown to improve operations performance more for factories that are digitalized (Buer et al., 2021), but there is no evidence this also applies to social performance. To improve social performance, managers wonder whether lean must be a more 'balanced' and whether a more techno-centric STS (by adding more technology) could tip the social and balance of lean.

To clarify the above questions, this study examines whether digital technology advancement (DTA), defined as the degree of proactive adoption and implementation of advance digital

technologies as customer solutions before competitors (Wu et al., 2006), could complement the effects of lean production on social performance. Specifically, this research aims to answer the following key research question: *does DTA enhance the effects of lean production on social performance?* Our main argument is that a proactive posture towards digital technologies can enable accurate information sharing, process integration, automation, and agile response, which support lean practices internally and raise efficiency in the entire SC (Núñez-Merino et al., 2020). From a social perspective, this study argues DTA can motivate employees by encouraging visualization and communication and by giving them the opportunity to innovate, learn and apply digital technologies in lean production settings (Yu et al., 2023a). Thus, we hypothesize DTA positively moderates the effect of lean practices on social performance.

This study contributes to the literature and practice in three respects. Firstly, past studies focused on the relationship between Industry 4.0 technology and lean at an internal level, less is known about this relationship at a SC level (Núñez-Merino et al., 2020). Thus, this study divides lean practices into internal, supplier, and customer components, forming a unified conceptualization of lean production (Shah and Ward, 2007). We examine the effects of multiple dimensions of lean production (internal, customer, and supplier) on social performance, aiming to address concerns from practitioners about the social value of lean practices.

Secondly, by testing the contingency role of DTA, this study reveals whether Industry 4.0 technologies can be integrated into lean practices to create improved social performance. We advance prior studies of lean by conceptualizing it as an STS and by clarifying the role of DTA. By doing so, this study will address the new challenging question from manufacturing firms: how to integrate lean, technology, and people? The empirical findings will provide timely and insightful practical guidance for managers to better understand the role of digital transformation in the traditional lean context.

Thirdly, we test our hypotheses using survey data collected from China's manufacturing industry known as 'the world's factory' which faces numerous hindrances in achieving enhanced social development through the implementation of lean practices while simultaneously being under pressure to adopt Industry 4.0 technologies as mandated by 'Made in China 2025'. Existing studies and anecdotal examples in China have revealed the social value of lean is questionable in China as it has a reputation for flouting occupational and safety precautions (Huo and Boxhall, 2018). Policy makers need to know whether intensifying digitalization could increase/decrease the social

value of lean. In addition, the empirical findings generated from this study can also apply to other research contexts. For example, if manufacturers in China can complement lean production with digitalization to improve social performance, then other countries may learn from them.

2. Theoretical background and hypotheses

2.1. Lean as a socio-technical system (STS)

Recent work has started viewing lean as a socio-technical system (STS) or a complex STS (Januszek et al., 2023; Marcon et al., 2022; Vlachos, 2023). This study uses STS (Avgerou et al., 2004; Cherns, 1987; Clegg, 2000; Trist and Bamforth, 1951) as a theoretical framework for understanding how social and technical sub-systems of lean interact. STS helps avoid a simple cause-and-effect deduction. STS thinking originated from British coal mining extraction methods where new machinery in the workplace undoubtedly resulted in sociological complications if only technical issues were considered; for every new technology there is a need to consider behavioural issues (Trist and Bamforth, 1951). Technology cannot be understood and effectively implemented unless social processes and socio-technical fit are understood (Liu et al., 2006). For this study there are two relevant tenets of STS: (1) there should be congruence between the social and technical systems and (2) the theory takes an ‘open systems’ perspective. As such, work design (routines) and the environment should be aligned (Closs et al., 2008).

Lean is an STS because it is a process-oriented work system that combines people and their interrelationships (socio) and specific tools and techniques (technical) (Hadid et al., 2016). The ‘social’ element of lean refers to human and cultural traits, and the ‘technical’ element to the operating practices and techniques (Cullinane et al., 2012; Soliman et al., 2018). While the social part of lean emphasises greater empowerment, responsibility, and opportunity (Beraldin et al., 2019), which can foster motivation in employees, its technical part includes mechanistic task and work intensification to improve efficiency (Huo and Boxall, 2018; Soliman et al., 2018). From sociotechnical view of operations, lean and digital technologies complement one another when their social and technical subsystems are integrated (Marcon et al., 2022). Despite the clear differentiation of objectives, lean technical sub-systems will not yield full benefit unless the social and technical systems are jointly optimized (Closs et al., 2008; Tortorella et al., 2018).

To enable optimal functioning of the social and technical sub-systems, lean must be managed from a socio-technical perspective (Minshull et al., 2022). Since these social and technical sub-

systems interact through sharing and exchanging information (Soliman et al., 2018), the relationship between lean and people also depends on the use of information technologies. Lean can be applied to highly complex socio-technical systems (Soliman and Saurin, 2017). Past evidence in Sweden shows lean can be integrated into a management style based on STS (Kosuge, 2014). Many principles of lean and STS are compatible with each other. For example, both socio-technical theory (Avgerou et al., 2004; Cherns, 1987; Clegg, 2000; Trist and Bamforth, 1951) and lean literature suggest measuring variances as close to the source as possible (variance control) and for those dependent on resources to have power to manage the resources (empowerment). However, in practice it is the violation of socio-technical principles that obstructs sustainable development of lean, especially when top management does not have a stake in lean implementations (Lindskog et al., 2016). Thus, explaining the performance effects of lean purely based on a technical perspective may lead to an overly simplified and inaccurate understanding (Hasle et al., 2012). Digitalization involves a systemic change of a sociotechnical nature combining social and technical elements (Marcon et al., 2022). Based on these arguments, we develop a conceptual framework that investigates the moderating effect of digital technology advancement (DTA), a key technical and social element in STS, on the relationships between three dimensions of lean production and social performance.

----- Insert Figure 1 -----

2.2. Lean production

Initially used to study organizations, we contend, and there is some support for the notion that, STS can be extended to supply chains, supplier relationship and networks (Closs et al., 2008; Kull et al., 2013; Marcon et al., 2022; Vlachos, 2023). The lean manufacturing literature has commonly used socio-technical theory to explain the effectiveness of the implementation of lean practices (Marcon et al., 2022; Minshull et al., 2022; Soliman and Saurin, 2017). At a SC level, physical networks, technological infrastructure, and managerial practices reflect the technical sub-systems which provide the infrastructure for the social sub-systems e.g., collaborative relationships, decision-making and complex social interlinks (Siawsh et al., 2021). The SC literature has used STS to explain human resource benefits, SC complexity, and behavioural implication to understand how managerial practices/technology and social behaviour interact at an inter- and intra-organizational level (Bednar and Welch, 2020; Closs et al., 2008; Fantini et al., 2018; Kull

et al., 2013). Lean manufacturing initially centred around internal processes; however, lean practices ‘only acquire meaning, and have an impact, when they are applied as a system’ (Januszek et al., 2023, p.311). We conceptualize the system as a SC. This study argues lean production as a SC concept that should be divided into internal and external lean practices. While internal lean and external lean practices are thought to have similar effects (e.g., Yu et al., 2020), recent evidence shows they vary. For instance, internal lean practices can positively affect social performance in Chile (e.g., Chavez et al., 2020), but not with suppliers in China (Huo et al., 2019). To capture such nuanced differences, this study divides lean production into three main dimensions: internal lean practices (ILP), lean practices with customers (LPC), and lean practices with suppliers (LPS) (Camuffo and Poletto, 2023; Naranjo et al., 2023; Paulraj et al., 2017; Shah and Ward, 2007).

ILP includes techniques and principles that target the elimination of non-value-added activities inside a firm (Chavez et al., 2020). Specifically, ILP relies on methods such as shorter machine and process set-up times, pull-production systems, statistical techniques for process variance, and cellular manufacturing with equipment grouped according to families of products to produce continuous material flows and eliminate overproduction (Kannan and Tan, 2005). However, a greater benefit of lean can be obtained when considering the SC (Camuffo and Poletto, 2023). Lean production matured in industries such as automotive, where components are sourced from suppliers following pull-based demand signals (Womack et al., 1990). If the system is a SC, then the concept of lean suppliers and customers is vital for continuous and synchronised material replenishment, JIT delivery, coordination and optimisation of the flow of material and information, and streamlining quality inspections (Moyano-Fuentes et al., 2020; Núñez-Merino et al., 2020; Wu, 2003). Lean principles and techniques that ensure a seamless flow of material and information between the focal firm and customers and suppliers is thus needed to attain a lean SC (Camuffo and Poletto, 2023). Thus, the focal firm benefits from developing LPC and LPS.

Specifically, with downstream customers, LPC includes direct and continuous customer involvement (e.g., customer visits), joint new product development processes, and the reduction of quality issues and lead time (e.g., inspection reduction of outbound goods) (Anwar et al., 2023; Claycomb et al., 1999), which implies a high level of customer coordination and interaction (Hines et al., 2004). With upstream suppliers, LPS enables inventory reduction, process improvement (e.g., agile ordering system) and reduces unnecessary transportation (e.g., logistics-related operations) by sharing timely and reliable information (Chavez et al, 2015; Yu et al., 2023b). LPS

is vital for continuous and synchronised material replenishment (e.g., participation of suppliers in procurement and production) to enable JIT manufacturing and delivery (Khorasani et al., 2020; Wu, 2003).

2.3. Digital technology advancement (DTA) as a key element in STS

Technology is a key technical element in STS (Avgerou et al., 2004; Cherna, 1987; Clegg, 2000; Trist and Bamforth, 1951). Early research introduced the concept of technology orientation as the ability and willingness to adopt and use new technologies to develop new products (Zhou et al., 2005). However, studies using technology orientation have concentrated on pure technical aspects, omitting essential managerial, human, and organizational views (Khin and Ho, 2020). It is not technology *per se* but also firm postures and orientations that drive technological transformation. Thus, to successfully implement the most sophisticated technology, firms should be innovative, proactive and competitive, and internalize technological innovation as part of their business strategy (Wu et al., 2006). We adopt the STS perspective because companies that focus on developing sociotechnical aspects generally adopt more Industry 4.0 technologies (Marcon et al., 2022). Digitalization involves systemic changes through “a transformation process of social (i.e., individuals and their relationships) and technical aspects” (Marcon et al., 2022, p.260). As a socio-technological resource (Wu et al., 2006), we define digital technology advancement (DTA) as the degree of proactive adoption and implementation of advance digital technologies for the purpose of finding customer solutions before competitors. If lean and DTA become a part of the joint socio-technical system of operations, then they will have more synergies.

2.4. Hypothesis development

Lean practices are often used to reduce waste. While the lean literature has concentrated on operational outcomes, the effects of lean on social dimensions are less understood (Fenner et al., 2023; Martinez-Jurado and Moyano-Fuentes, 2014). Social performance refers to any aspect or measure related to well-being of employee, community, and society, e.g., health and safety issues internally and at a SC level (Marshall et al., 2015; Yu et al., 2020). The processes in which lean practices produce performance involve interactions between social and technical sub-systems. Social performance depends on how an organization or SC treats their workers when implementing lean practices, whether they emphasize social and technical aspects.

When the employees' and societal wellbeing is emphasised, human factors become the 'glue' that binds together lean practices (Martinez-Jurado and Moyano-Fuentes, 2014). Thus, lean encourages social advantage through its social elements, practices, and capabilities (Chavez et al., 2022), which is as STS suggests. The impacts of lean principles on social performance depend on whether management is committed to employee involvement and providing autonomy and skills development (Hasle et al., 2012). This may also extend to external stakeholders as employees also care about their society and community. As an STS, lean can create social performance through several mechanisms: (1) lean promotes employee motivation, autonomy and work involvement (Sony et al., 2020) by improving workplace standards (e.g., wages, benefits), and therefore improves labour relations and (2) lean involves management capabilities that can lower the cost of complying with social performance standards (Distelhorst et al., 2017) and extending societal responsibilities to local communities. Camuffo et al. (2017) argue there should be no trade-off between operational and safety objectives when lean is implemented with a balance between work demands and work energizers (motivation, empowerment, etc.). For example, case studies by Longoni et al. (2013) show implementing lean improves workers' health and safety only when there are human resource and prevention practices.

As core to the lean notion, employee involvement and extensive training and education increase employee motivation, morale and job satisfaction (Fenner et al., 2023; Sony et al., 2020). Lean promotes employee autonomy, internal promotions and a respect-for-humans approach, which encourages creativity and innovation, reduces stress levels and improves quality of work life (Mehri, 2006). From a social perspective, good working relationships motivate employees and reduce tensions (Distelhorst et al., 2017). Poor health and safety issues are considered waste in lean systems because they reduce employee motivation and process capability (Verrier et al., 2016). Lean system emphasises work safety and hazards prevention. For example, lean minimizes the use of dangerous materials and solid waste, thereby preventing internal and external workplace injuries and illnesses (Marshall et al., 2015; Ufua et al., 2018). Toxic fumes and contaminated water are waste that suppliers and customers in lean supply chains aim to reduce. Therefore, the social benefits of lean go beyond the boundary of a single organization and include business networks, industrial ecosystems and the broader community (Huo et al., 2019; Matete and Trois, 2008).

Regarding the external lean practices, some studies found that the implementation of lean with suppliers (LPS) and customers (LPC) improved workplace social standards such as

community health and safety (e.g., Distelhorst et al., 2017; Huo et al., 2019; Wang et al., 2015). Others found that environments that adopt digital technologies, through robotics and the use of multiple sensors, not only improved manufacturing efficiency and collaboration with suppliers but also improved work conditions and bettered workplace safety (Strandhagen et al., 2021; Taehee and Chang, 2017). Similarly, empirical research in China's footwear industry found that lean manufacturing improved employees' health and safety (Brown and O'Rourke, 2007). Furthermore, technologies such as machine learning and mobile robotics in manufacturing supply chains reduced the need for routine and low-skilled jobs, which lead to more meaningful works and the emergence of a virtuous socio technical system that encourage responsibility, proactiveness, learning and empowerment to enrich jobs (Bonekamp and Sure, 2015; Frey and Osborne, 2017). Such environment may also be expanded to the supply chains and communities. Based on STS, we argue that the soft (social) perspective of lean production together with hard (technical) systems produce social performance (Beraldin et al., 2019). Based on this, we hypothesise:

H1: (a) ILP, (b) LPC, and (c) LPS are positively associated with social performance.

The links between digital technologies, lean practices and sustainability remain unclear (Núñez-Merino et al., 2020). The relationship between lean production and social performance varies because it requires an environment that promotes the proper socio-technical alignment (Jabbour et al., 2013). Based on STS, we argue proper socio-technical alignment is required to harness the social values of lean production practices. Although the objectives are clearly differentiated, the full benefits of lean technical sub-systems will not be realized unless there is joint optimization of the social and technical systems (Closs et al., 2008; Tortorella et al., 2018). Therefore, based on STS, we expect that the effect of lean production on social performance depends, to some degree, on the firm's level of DTA. Digital technologies such as Internet of Things (IoT) can aid visualization, communication, and Poka-yoke (Chen et al., 2023). For example, Kanban is essentially an information system, which can be digitalised (Riezebos and Klingenberg, 2009). Previous research has suggested that the adoption of digital technologies can enhance the operational effects of lean (Marodin et al., 2023). For instance, Bokhorst et al. (2022) report that manufacturers that have implemented both lean and smart manufacturing achieved superior operational performance compared to those that have implemented only either lean or smart manufacturing. Several other contributions, though with limited data, suggest lean practices

can be enhanced by implementing Industry 4.0 technologies (Aljawder and Al-Karaghouli, 2022). However, is it purely the technical aspect of technology that enhances the social performance of lean production?

Digitalization is a socio-technical process of converting analogue signals into digital forms, which aims to achieve individual, social and institutional transformation (Kindermann et al., 2020) through integrating technologies such as digital artefacts, platforms, and infrastructures (Nambisan, 2017). Thus, a pure technological view might only motivate a small number of technical employees while other employees will find themselves vulnerable and demotivated (Sony and Naik, 2020; Wu et al., 2006). In China, the government has been committed to transforming its manufacturing sector by increasing digitalization and interconnection through an ambitious 10-year national strategic plan which runs until 2025 (EU's Institute for Security & Development Policy, 2018). This master plan has pressured Chinese manufacturers to swiftly adopt digital technologies, some of which are not well understood and have often failed to deliver the expected benefits (Yu et al., 2023b). The high rate of unsuccessful digital projects may be caused by an overemphasis on technical aspects, while disregarding essential human elements (Khin and Ho, 2020). The result is a malalignment of the STS. Hence, the rapid digitalization of China's manufacturing could adversely affect its labour market and overall employee wellbeing. Evidence shows Chinese state-owned manufacturers have experienced minor effects in comparison to private, multinationals and SMEs, where the negative effect of digital transformation seems to be greater (Lüthje, 2019).

However, there are ways to balance technical dominance, as it can serve as a strategy to drive proactive employee engagement. In addition to its technical elements, DTA includes elements such as proactiveness, competitiveness and innovativeness, which imply a human posture or orientation (Marcon et al., 2022). For example, orientation elements such as a curious and open-minded attitude (innovativeness) towards change and innovation is a necessary capability in digitalisation (Day, 2011). Similarly, a proactive, risk-taking and competitive managerial attitude that spurs innovation processes and organizational culture is a strong determinant in the successful adoption of digital technologies (Quinton et al., 2018; Yu et al., 2023b). Given autonomy and the opportunity to learn and participate, employees can adopt the digital technologies that matter to them, e.g., improving safety and wellbeing inside and outside the organizations (Marcon et al., 2022; Oesterreich and Teuteberg, 2016; Sony, 2020). This suggests a potential fit between DTA and lean. In other words, the socio-technical fit required by lean to harness its social impact is

likely to be strengthened by DTA. Therefore, based on STS, we posit that a manufacturing firm's DTA serves as a necessary complement (sociotechnical environmental subsystem) to its lean production for improving social performance. As a manufacturer achieves higher levels of DTA, its lean production becomes more valuable for social performance (Marcon et al., 2022). Consequently, the stronger the presence of DTA among manufacturing firms, the more robust the positive relationship between lean practices and social performance will be. Hence, we hypothesise:

H2: DTA positively moderates the relationships between (a) ILP and social performance, (b) LPC and social performance, and (c) LPS and social performance.

3. Research method and data

3.1. Sample and data collection

Gathering secondary data (such as panel data) might help address the increasing concern about the validity and reliability of survey research in the operations and supply chain management research community (Krause et al., 2018). However, there is no existing database available in China to measure the theoretical constructs conceptualized in this study, such as the three dimensions of lean production. Thus, conducting survey research to gather primary data from executive managers of manufacturing firms is a more appropriate method to empirically test our theoretical framework, investigating the moderating effect of DTA on the relationship between three dimensions of lean production and social performance (Flynn et al., 2018; Krause et al., 2018).

We gathered survey data from manufacturers in China, using the database provided by the Contemporary Service Alliance for Integration of Informatization and Industrialization in China (CSAIII) to identify potential participants. To obtain a representative sample, we randomly selected 1500 manufacturing firms and sent them questionnaires with a cover letter explaining the main purpose of the study and assuring confidentiality. To gather reliable data and enhance the response rate, we identified one key informant for each chosen manufacturer with the assistance of the CSAIII (Zhao et al., 2011). We selected individuals holding common titles such as CEO, president, director, and managers responsible for production, supply chain management, and information technology as our primary respondents. This choice was made based on their expertise in the fields of operations, supply chains, and digital transformation within their respective firms. After sending multiple reminders, we received 317 returned questionnaires, but ten of them had

missing data and were discarded. This resulted in 307 completed and usable questionnaires, with an effective response rate of 20.47%.

Table 1 presents a summary of the demographic characteristics of the respondents. Most participants held senior-level positions and had been in their current roles for more than five years. Therefore, it is reasonable to expect that the participants possessed sufficient knowledge to complete the survey. Table 1 illustrates that the data were collected from respondents across a diverse range of manufacturing firms, with a wide representation of backgrounds among the participants.

----- Insert Table 1 -----

3.2. Non-response bias and common-method bias

Various methods exist for evaluating non-response bias, including testing for differences between respondents and non-respondents (Hair et al., 2010). Unfortunately, demographic information for non-respondents was not available, so we compared the revenue and number of employees of early and late-responding firms to assess potential non-response bias (Hair et al., 2010). Our findings suggest that there were no statistically significant differences between the groups, indicating a lack of non-response bias.

There is a possibility of common method bias (CMB) when obtaining self-reported data from a solitary source at a specific moment in time. To address this issue, we employed a series of procedural and statistical remedies suggested by Podsakoff et al. (2003). Regarding the procedural approach, when designing the questionnaire, we carefully constructed our measurement items to avoid any potential ambiguities. We used different instructions for various scales, and the adjacent variables in the theoretical model were placed in distinct sections of the questionnaire. In addition, in the cover letter accompanying the questionnaire, we ensured the protection of respondent confidentiality and emphasized the equal importance of all provided answers. We encouraged participants to be sincere and honest, emphasizing that there were no ‘good’ or ‘bad’ responses. For the statistical approach, we employed the marker variable technique, selecting respondents’ job titles as a method variance marker theoretically unrelated to at least one theoretical construct used in the analysis (Lindell and Whitney, 2001). Adjusting for inter-construct correlations and statistical significance, we identified the lowest positive correlation ($r = 0.042$) between the marker variable and other variables (Lindell and Whitney, 2001; Sheng et al., 2011). Table 3 shows that,

after this adjustment, no originally significant correlations became insignificant. Thus, it can be concluded that CMB is unlikely to confound the interpretation of the research results.

3.3. Questionnaire design and measures

To develop the measurement items used in this study (see Table 2), we conducted a thorough literature review. To enhance the reliability and content validity of the questionnaire, we carried out a pilot study involving both academics in the operations and supply chain fields and senior executives from manufacturing firms in China. The questionnaire is included in the appendix.

----- Insert Table 2 -----

In this study, we conceptualise lean production as a multidimensional construct, including ILP, LPC, and LPS. To measure ILP, we utilized items from Azadegan et al.'s (2013) work, which concentrated on a set of techniques and principles companies employ to remove activities not adding value to the transformation process. The measures for LPS and LPC were adapted from Azadegan et al. (2013) and Claycomb et al. (1999) and focus on a group of lean principles and techniques targeting material and information flows between suppliers and customers. The items for ILP and LPC were measured using a seven-point Likert scale ranging from “strongly disagree” to “strongly agree”, while a 7-point scale from 1 (not at all) to 7 (extremely extensive) was used for LPS. The measures used for DTA are based on Wu et al.'s (2006) study emphasizing the proactive adoption of advanced digital technologies to provide customers with solutions before competitors do. DTA is measured using a 7-point scale ranging from 1 “strongly disagree” to 7 “strongly agree”. The measures for social performance were adapted from Paulraj (2011) and rated on a 7-point Likert scale (1 = much worse than major competitors; 7 = much better than major competitors). The respondents were asked to evaluate their firms' social performance by comparing it with key industry competitors in terms of employee health and safety, community welfare, stakeholder interests, and the claims and rights of the people served by the community.

We used firm age, firm size, and industry type (as detailed in Table 1) as control variables because larger or more established firms often have greater access to organizational resources, including digital and human resources, which can facilitate the implementation of lean production practices for performance improvement when compared to smaller or newer firms (Yu et al., 2019; 2023b). Additionally, firms in various manufacturing industries may adopt different levels of lean production practices, such as LPC and LPS, to enhance their performance (Yu et al., 2019; 2023b).

Firm size was measured by using the number of employees as a proxy, while firm age was measured by the number of years since the firm was founded. Additionally, a dummy variable was used to account for industry type.

3.4. Reliability and validity analyses

We conducted a CFA to evaluate the reliability, unidimensionality, and validity (including convergent and discriminant validity) of the constructs (see Table 2). Construct unidimensionality is evidenced by the good fit of the measurement model ($\chi^2/df = 2.497$, CFI = 0.930, IFI = 0.930, TLI = 0.919, RMSEA = 0.070 and SRMR = 0.052) (Hair et al., 2010). All measurement items exhibited sufficient convergent validity, with factor loadings surpassing 0.70, except for the last two items related to LPC that had slightly lower loadings of 0.588 and 0.662, respectively. The average variance extracted (AVE) for the theoretical constructs were all above the minimum cut-off of 0.50, except for LPC which had a value of 0.459 (Fornell and Larcker, 1981). Table 3 presents evidence of discriminant validity, as indicated by the fact that the square root of each construct's AVE was greater than the correlations with other latent constructs (Fornell and Larcker, 1981).

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4. Results of hypothesis testing

We performed moderated regression to test the hypotheses. In the analysis, the dependent variable was regressed against independent variables, control variables, moderator variables, and cross-product terms between the independent and the moderator variables (Hair et al., 2010). The moderated regression model hypothesised two-way interaction terms. If all these interaction terms are entered into the model simultaneously, there is a potential for high inter-factor correlations between the cross-product terms associated with the same variable (Sheng et al., 2011; Williams et al., 2013). This high correlation may lead to an 'overinflation of the standard error of the regression coefficient estimates and render them insignificant' (Sheng et al., 2011, p. 8). Therefore, to mitigate multicollinearity, we computed mean-centred scores and included each interaction term (ILP \times DTA, LPC \times DTA, and LPS \times DTA) separately in the model (Williams et al., 2013; Yu et al., 2023b). Table 4 displays the results of the regression analysis. The maximum VIF across all models is 2.872, which is significantly below the critical threshold of 10.0. These findings suggest

that multicollinearity is not a major issue in our study (Hair et al., 2010; Mason and Perreault, 1991). Among the three control variables, only firm size was found to be positively and significantly related to social performance.

Model 2 indicates a significant positive impact of each of the three dimensions of lean production (ILP: $\beta = 0.256, p < 0.01$; LPC: $\beta = 0.122, p < 0.05$; LPS: $\beta = 0.175, p < 0.05$) on social performance. These findings support H1a, H1b, and H1c. However, the result for H1b change when DTA added (Model 3) and further interaction terms are added (Models 4-7). The R^2 increases slightly from 0.266 (Model 2) to 0.275 (Model 3). In Model 3, DTA is marginally and positively associated with social performance ($p < 0.10$) and the p value increases to 0.05 in Models 4-7. The coefficient for LPC is not significant in Models 3 through 7. This suggests ILP and LPS are stronger explanatory variables for social performance than DTA.

Model 4 indicates that the interaction term between ILP and DTA is positively and significantly associated with social performance ($\beta = 0.185, p < 0.001$). Thus, H2a is supported. Model 5 indicates that the interaction between LPC and DTA has a significant positive impact on social performance ($\beta = 0.139, p < 0.01$). Thus, H2b is supported. Model 6 indicates that the interaction between LPS and DTA is positively and significantly related to social performance ($\beta = 0.168, p < 0.001$). Thus, H2c is supported. When including all three interaction terms into Model 7, the direct effects remain largely the same, while the interaction effects become insignificant. These results may not be entirely accurate since there might be interactions among the three dimensions of lean production. As noted above, previous research has raised the concern that entering all the interaction terms into the model simultaneously might cause multicollinearity issues (Sheng et al., 2011; Williams et al., 2013).

----- Insert Table 4 -----

We utilized Aiken and West's (1991) model to perform simple slope analysis to visualize the patterns of the significant moderating effect of DTA on the relationship between the three dimensions of lean production and social performance. The moderation of DTA is displayed in Figures 2a, 2b, and 2c. The stronger the level of DTA, the more pronounced the positive relationship between lean production and social performance. Increasing LPC and LPS does not increase social performance when DTA is low. Increasing ILP, LPC and LPS does increase social performance when DTA is high. This suggests external lean practices relies upon DTA to improve social performance.

----- Insert Figures 2a, 2b, and 2c -----

5. Discussion and implications

5.1. Theoretical implication

This study contributes to the understanding of the relationships between lean, technology and people from the STS perspective. The argument lean is an STS (Hasle et al., 2012; Soliman et al., 2018; Januszek et al., 2023) implies that it should emphasize employee motivation, autonomy, and work involvement (Sony et al., 2020). However, obtaining the full social benefits of lean practices depends on how they are implemented (Huo and Boxall, 2018). Our main thesis here is that the emphasis on the social aspect of lean is the key, which significantly extends previous research indicating counterarguments and evidence for the negative effects of lean on social performance (e.g., Chavez et al., 2020; Huo and Boxall, 2018; Zhang, 2015). More importantly, our study significantly contributes to the digitalization, sustainability, and lean literature by demonstrating, for the first time, the moderating effects of DTA – reflecting the technical and social sub-systems – on the relationship between lean production and social performance.

To test the effects of lean production on social performance, we have concentrated on China, where more evidence supporting the negative effects of lean on social performance has been found, and a reputation of emphasizing the technical aspect as opposed to the socio aspect of lean. Countering many inconsistent results in the literature, this study shows that lean practices improve social performance and promotes well-being not only internally (e.g., Beraldin et al., 2019; Chavez et al. 2022) but also with customers and suppliers (e.g., Distelhorst et al., 2017; Wang et al., 2015). This crucial evidence supports our assertion that Chinese manufacturers have embraced the softer or more social elements of lean. This suggests that in the future, researchers must collect new evidence instead of relying on older research and anecdotal evidence (e.g., Huo and Boxall, 2018; Zhang, 2015). Herein we suggest lean may have evolved to show a different balance in technical and social aspects of STS. In fact, there might be different maturity pathways which go beyond whether lean generates positive or negative social performance in China. This means we cannot view lean as a static STS system; it evolves. We suggest that future studies investigate and theorize the evolution pathways of the balance in socio-technical elements of lean.

Evolution also applies to extension of lean to the SC. The results show manufacturers in China are more successful in implementing lean to improve social performance internally than

when they extended the lean practices to suppliers and customers. So, this crucial evidence suggests the implementation of lean upstream and downstream may differ from internal lean. The literature cannot assume lean implementation in any part of the organisation and SC involve the same effect mechanisms. The more mechanistic and technical approach to external lean practices in China can be related to extreme management styles and intensity of work rather than the core of the lean philosophy, which centres on respect for workers and leadership (Chavez et al., 2022; Cullinane et al., 2012; Longoni et al., 2013).

The above results show that the literature might have misunderstood the management style in China that emphasizes hierarchy and authority in production and supply chains. While this seems not ideal from a Western and Toyota Production System (TPS) perspective, either the Chinese manufacturers in our sample have applied lean to improve safety, health and wellbeing, or their management style has changed (as opposed to older evidence discussed earlier). Again, we argue the use of TPS or lean in China has evolved to reflect a more balanced socio-technical aspect of lean.

Another evolutionary aspect concerns how manufacturers constantly upgrade themselves. In this study, we consider the adoption of digital technology. However, STS recommends a balance between social and technical elements, which means the use of more digital technology could tip the STS balance. We suggest that social performance may be the best indicator of such an ‘imbalance’. For example, manufacturers could use digital technology to stimulate employee involvement in the innovation process thereby giving them more autonomy. Since adding the DTA construct to our regression added significant explanatory power to our models, we show social performance comes from a balanced advancement in technology that emphasize employee (societal) wellbeing. So, digitalizing lean is not tipping the STS balance. Perhaps Chinese manufacturers in our samples have learned to use digital technologies to also improve social performance like wellbeing, health and safety. This is possible as China is known for expanding the application of digital technologies and Internet into all aspects of society and business.

Another crucial bit of evidence this study provides is that lean and technology complement one another. The interaction effects between lean and DTA become more pronounced in internal lean and lean with customers. Some scholars argue external aspects of lean do not necessarily focus on social performance (e.g., Distelhorst et al., 2017; Huo et al. 2019; Wang et al., 2015). It seems a more balanced technical approach (DTA) in China has helped lean to improve social

performance. As mentioned, many digital tools for human resource management have been developed in China. The building of a digital economy in China has driven manufacturers to expand the use of digital technologies for employee wellbeing. Here we argue lean principles that emphasize continuous improvement, innovation and employee involvement might have played significant roles in developing lean-digital tools for social performance management. That means we cannot simply treat digital technology as a ‘pure’ technical element of STS.

As a theoretical extension, our findings reveal the unique Chinese manufacturing industry and SC context, which may differ from other newly industrializing nations. As the world’s largest contributor to manufacturing output, China has gained a negative reputation of lean implementation practices and social performance (Huo and Boxall, 2018). Research (e.g., Zhang, 2015) and business examples (e.g., BBC, 2022) have shown that lean production, with certain Chinese management characteristics (e.g., lack of unions and intensity of tasks), may negatively affect social performance. Our findings show lean leads to social performance through a more balanced technical (digital) approach. Chinese firms have learned and created lean production systems with culturally rooted characteristics that better suit their environment through different approaches to worker participation, working conditions and employment security (Zhang, 2015) in digital-lean implementation.

The above results extend our theoretical understanding. We cannot treat lean as a pure ‘technical’ system, e.g., JIT is simply about variation reduction (Cullinane et al., 2012). The social component of lean emphasises greater empowerment, responsibility, and opportunity which can foster motivation in employees, its technical dimension includes mechanistic task and work intensification which target efficiency (Huo and Boxall, 2018). The STS perspective suggests lean technical propositions will not be fully adopted and yield their full potential benefit unless socio-cultural aspects are also addressed and *vice versa* (Tortorella et al., 2018). Prior studies have found that the technical dimension and related practices can have a negative impact on psychological and physical aspects and thus reduce employee’s wellbeing (Chavez et al., 2020; Huo and Boxall, 2018; Zhang, 2015). Perhaps the social component of lean in a non-unionised China works different from the many Western economies. Our results show lean in China has a softer (social) side that can integrate digital technology into lean systems to improve social performance.

5.2. Managerial implications

Our findings provide insightful implications for practitioners who struggle to use lean to create social performance. Our study suggests that in China lean practices prioritizing social performance, specifically in areas such as health and safety, are crucial. In this regard, lean practices have proven to be a valuable production system to enhance social performance. In terms of developing lean systems, our findings show managers in China that ILP are a good starting point to first improve employee welfare. Many lean techniques and principles can be used to improve OHS. In China, labour relation is a contentious issue. If employees and managers do not have a good labour relationship, showing care and support for employee wellbeing can backfire. So, using lean and digitalization to empower workers to take care of their wellbeing can improve labour relation. Since China is driving digitalization by adopting proactive and competitive cutting-edge digital technologies, manufacturers can use various incentives and policies to develop lean production practices for social performance improvement.

Our results trigger further debates on management styles to enhance social performance. Past studies argue lean requires a task-oriented managerial approach due to its highly practical and technical focus (Spear and Bowen, 1999). Some managers misunderstood that lean leadership is about task orientation. Relational-oriented types of leadership can have a harmful effect on lean since lean requires specific guidance on activities, its sequence, timing and outcomes, which are more in line with task-oriented management approaches (Tortorella et al., 2018). However, in today's competitive and digital environment, managers realize they need a more human-centric approach, while they also need to be more technology-savvy. To face these new challenges, managers need to encourage proactiveness in employees and problem-solving skills to better cope with potential job stressors, and thus ameliorate the potential negative effect of work intensification (Huo and Boxall, 2018; Karasek and Theorell, 1990). Adopting digital technology provides a good opportunity to get employees involved in solving problems and innovating. The challenge is to allow them to develop tools that can benefit their well-being, health and safety as the motivation to also developing tools for improving their tasks.

If Western economies were to learn from China, then there are several issues to address. There is a strong institutional environment to achieve digital advancement in China. The use of internet and digital technology in China can be described as a revolution. So, Western economies would need to drive Industry 4.0 more seriously. But this could work only when the foundation of

lean is strong. In fact, it is time to expand the efforts to Industry 5.0 because it is possible to improve social performance through driving digital innovation in a human-centric manner (Sindhwani et al., 2022). Solving demands under lean settings have technological and motivational properties, and DTA can be complementary to lean for improving or alleviating social issues. DTA provides essential vision and mobilisation to implement digital endeavours in lean practices that aim at improving social performance.

Furthermore, in the final years of its 10-year national strategic plan and industrial policy ‘Made in China 2025’, China has committed to transform its manufacturing sector into a digital powerhouse, moving away from low-cost and labour-intensive work to technology-driven manufacturing. Policy makers need to know whether intensifying digitalization could increase or decrease the social value of lean. Our study informs policymakers on how to make lean, social development and digital advancement work at the same time in China.

6. Conclusions, limitations, and directions for future research

Drawing upon the STS perspective, this study clarifies the moderating effect of digital technology advancement (DTA) on the relationships between the three dimensions of lean production and social performance. By analysing survey data collected from China’s manufacturing industry, we found that all lean production practices have a significant positive effect on social performance, and the relationship was moderated by DTA. The study makes a novel contribution to the lean, SC, and digital transformation literature by demonstrating the importance of DTA in strengthening the effects of lean production on social performance in China. Managers can benefit from the practical guidance offered by our empirical findings, which highlight the importance of lean-socio-digital aspect in enhancing the social benefits of lean.

Identified limitations in this study can serve as potential areas for future research and guide its direction. First, digital technologies are expected to dramatically change the ways firms manage their SC (Yu et al., 2021; 2023b), but different countries might rely on different balance in social and technical aspects. Thus, future research is encouraged to examine the impacts of advanced digital technologies on lean production in other countries. Second, in this study, we focused on one specific performance dimension of the triple bottom line. Future research could explore the impacts of lean production on all three dimensions (i.e., social, financial, and environmental performance). Third, another point to consider is that the analysis presented in this study focuses

on relationships at a specific moment in time. The cross-sectional design of the study imposes limitations on the extent of insights that can be drawn on the associations between lean, human and technological factors, and performance. To gain further insights into the moderation model examined in this study, a longitudinal study would be necessary. In addition, while we have diligently addressed potential CMB and endogeneity issues, we acknowledge that completely eliminating endogeneity is unlikely. This recognition serves as a limitation of our study, which utilizes a cross-sectional research design.

Appendix: questionnaire

1. Internal lean practices. Please indicate the degree to which you agree to the following statements related to lean practices implemented within your company (1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Neutral; 5 = Somewhat agree; 6 = Agree; 7 = Strongly agree).

- We use statistical techniques to reduce process variance.
- We have low set up times of equipment in our plant.
- We use a “pull” production system.
- Equipment is grouped to produce a continuous flow of families of products.

2. Lean practices with customers. Please indicate the degree to which you agree to the following statements related to lean practices implemented with your customers (1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Neutral; 5 = Somewhat agree; 6 = Agree; 7 = Strongly agree).

- Inspection of outbound goods has been reduced.
- Customers visit our plants on an informal basis.
- Customers are involved in new product development.

3. Lean practices with suppliers. Please rate the following statements related to lean practices implemented with your suppliers (1 = Not at all; 2 = Very slight; 3 = Slight; 4 = Moderate; 5 = Extensive; 6 = Very extensive; 7 = Extremely extensive).

- The participation level of suppliers in the process of procurement and production.
- Real-time searching of the level of inventory.
- Real-time searching of logistics-related operating data.
- Integrative inventory management.
- The agility of ordering process.

4. Social performance. Please evaluate the scale below in terms of social performance how your company compares to your major industrial competitors over the last three years (1 = Much worse than your major competitors; 2 = Worse than your major competitors; 3 = Slightly worse than your major competitors; 4 = About the same as your major competitors; 5 = Slightly better than your major competitors; 6 = Better than your major competitors; 7 = Much better than your major competitors).

- Improvement in overall stakeholder welfare or betterment.

- Improvement in community health and safety.
- Reduction in environmental impacts and risks to general public.
- Improvement in occupational health and safety of employees.
- Improved awareness and protection of the claims and rights of people in community served.

5. Digital technology advancement. Please indicate the degree to which you agree to the following statements related to your company's digital technology advancement (1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Neutral; 5 = Somewhat agree; 6 = Agree; 7 = Strongly agree).

- We use the most advanced digital technologies (e.g., IoT, artificial intelligence, advanced robotics) for smart manufacturing.
- Compared to our industrial competitors, our digital technologies adopted for supply chain and manufacturing operations are more advanced.
- We are always the first to use sophisticated digital technologies in our industry.
- We are regarded as a digital technology leader in our industry.

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Table 1: Sample profiles (n = 307)

	Percent (%)		Percent (%)
Manufacturing industry types		Geographical locations	
Automobile	35.8	Pearl River Delta	4.6
Chemicals and petrochemicals	5.9	Yangtze River Delta	11.7
Electronics and electrical	10.4	Bohai Sea Economic Area	3.6
Fabricated metal product	17.3	Northeast China	3.3
Food, beverage and alcohol	3.3	Central China	9.4
Rubber and plastics	2.6	Southwest China	65.5
Textiles and apparel	2.0	Northwest China	2.0
Others	22.8	Job titles of respondents	
Number of employees		President / Chief executive officer (CEO)	5.9
1 – 100	6.2	Vice President	7.5
101 – 200	11.1	Director	15.0
201 – 500	17.6	Manager	45.3
501 – 1000	10.4	Other senior executive	26.4
1001 – 3000	28.7	Firm age (in years)	
> 3000	26.1	≤ 10	16.6
Tenure of respondents (in years)		11 – 20	30.6
≤ 5	30.9	21 – 30	22.5
6 – 10	29.0	> 30	30.3
> 10	40.1		

Source(s): Authors' own creation

Table 2: Results of measurement model analysis

Constructs and items	Factor loadings	α	CR	AVE
1. Internal lean practices		0.859	0.859	0.604
We use statistical techniques to reduce process variance	0.811			
We have low set up times of equipment in our plant	0.721			
We use a “pull” production system	0.774			
Equipment is grouped to produce a continuous flow of families of products	0.802			
2. Lean practices with customers		0.711	0.716	0.459
Inspection of outbound goods has been reduced	0.775			
Customers visit our plants on an informal basis	0.583			
Customers are involved in new product development	0.661			
3. Lean practices with suppliers		0.912	0.915	0.684
The participation level of suppliers in the process of procurement and production	0.742			
Real-time searching of the level of inventory	0.850			
Real-time searching of logistics-related operating data	0.881			
Integrative inventory management	0.855			
The agility of ordering process	0.802			
4. Social performance		0.914	0.916	0.685
Improvement in overall stakeholder welfare or betterment	0.767			
Improvement in community health and safety	0.862			
Reduction in environmental impacts and risks to general public	0.867			
Improvement in occupational health and safety of employees	0.826			
Improved awareness and protection of the claims and rights of people in community served	0.813			
5. Digital technology advancement		0.914	0.915	0.731
We use the most advanced digital technologies (e.g., IoT, artificial intelligence, advanced robotics) for smart manufacturing	0.765			
Compared to our industrial competitors, our digital technologies adopted for supply chain and manufacturing operations are more advanced	0.805			
We are always the first to use sophisticated digital technologies in our industry	0.930			
We are regarded as a digital technology leader in our industry	0.909			
Model fit statistics: $\chi^2 = 440.146$; $df = 179$; $\chi^2 / df = 2.459$; CFI = 0.942; IFI = 0.942; TLI = 0.932; RMSEA = 0.069; SRMR = 0.053				

Source(s): Authors' own creation

Table 3: Inter-correlation matrix

	Mean	SD	ILP	LPC	LPS	SP	DTA
Internal lean practices (ILP)	5.099	1.049	0.777	0.507**	0.764**	0.441**	0.471**
Lean practices with customers (LPC)	4.658	1.134	0.528**	0.678	0.499**	0.314**	0.508**
Lean practices with suppliers (LPS)	5.127	1.097	0.774**	0.520**	0.827	0.412**	0.461**
Social performance (SP)	5.332	0.917	0.464**	0.343**	0.437**	0.828	0.335**
Digital technology advancement (DTA)	3.928	1.424	0.493**	0.529**	0.484**	0.363**	0.855
Participant's job title (marker variable)	3.788	1.096	-0.109	-0.133*	-0.112	-0.042	-0.091

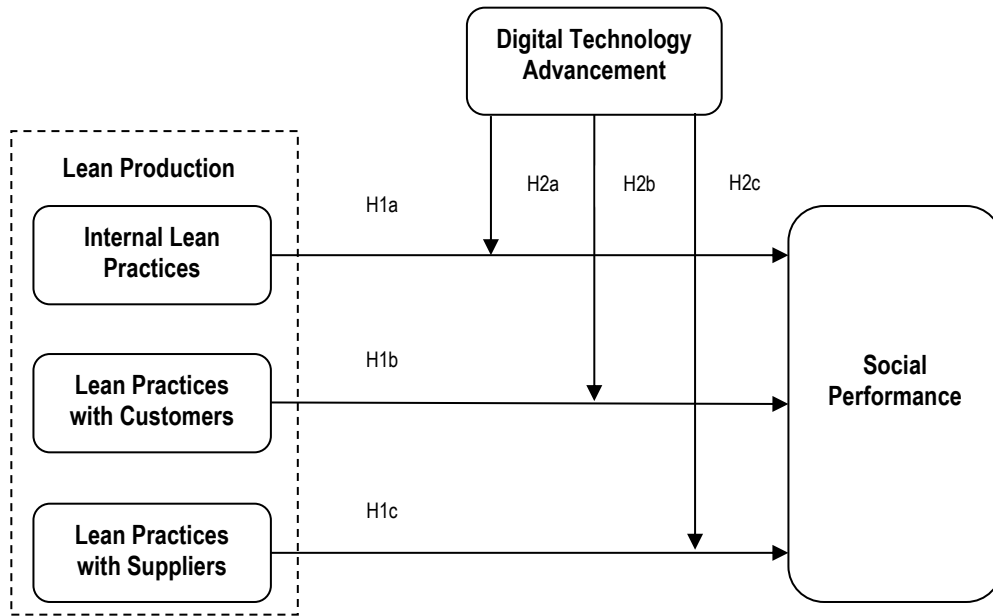
Note: Unadjusted correlations appear below the diagonal; adjusted correlations for potential common method variance appear above the diagonal; Square root of AVE is on the diagonal; ** $p < 0.01$; * $p < 0.05$; Source(s): Authors' own creation

Table 4: Moderated regression results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Control variables							
Firm age	-0.023 (-0.347)	0.052 (0.869)	0.065 (1.086)	0.042 (.709)	0.055 (0.928)	0.060 (1.021)	0.044 (0.745)
Firm size	0.225 (3.465)***	0.117 (2.000)*	0.092 (1.553)	0.082 (1.400)	0.097 (1.654)†	0.079 (1.341)	0.084 (1.436)
Industry1 (automobile)	-0.035 (-0.538)	-0.048 (-0.840)	-0.050 (-.890)	-0.030 (-0.542)	-0.042 (-0.749)	-0.044 (-0.797)	-0.032 (-0.573)
Industry2 (electronics and electrical)	-0.044 (-0.709)	0.019 (0.341)	0.019 (.343)	0.032 (0.595)	0.022 (0.399)	0.021 (.389)	0.030 (0.543)
Industry3 (fabricated metal product)	-0.026 (-0.423)	-0.058 (-1.058)	-0.069 (-1.267)	-0.055 (-1.028)	-0.058 (-1.081)	-0.056 (-1.039)	-0.052 (-0.978)
Independent variables							
Internal lean practices (ILP)		0.256 (3.144)**	0.237 (2.908)**	0.235 (2.944)**	0.228 (2.819)**	0.255 (3.169)**	0.236 (2.916)**
Lean practices with customers (LPC)		0.122 (2.038)*	0.080 (1.251)	0.049 (.775)	0.083 (1.311)	0.066 (1.058)	0.057 (0.901)
Lean practices with suppliers (LPS)		0.175 (2.148)*	0.156 (1.917)†	0.176 (2.205)*	0.156 (1.943)†	0.149 (1.859)†	0.168 (2.079)*
Moderator							
Digital technology advancement (DTA)			0.123 (1.950)†	0.131 (2.115)*	0.123 (1.978)*	0.126 (2.036)*	0.129 (2.085)*
Interaction effect							
ILP × DTA				0.185 (3.733)***			0.125 (1.360)
LPC × DTA					0.139 (2.831)**		0.056 (0.970)
LPS × DTA						0.168 (3.423)***	0.036 (0.396)
R^2	0.047	0.266	0.275	0.308	0.295	0.303	0.311
<i>Adjust R²</i>	0.031	0.247	0.254	0.285	0.271	0.280	0.283
<i>F-value</i>	2.941*	13.514***	12.548***	13.178***	12.361***	12.873***	11.062***
<i>Max VIF</i>	1.434	2.691	2.729	2.732	2.734	2.740	3.599

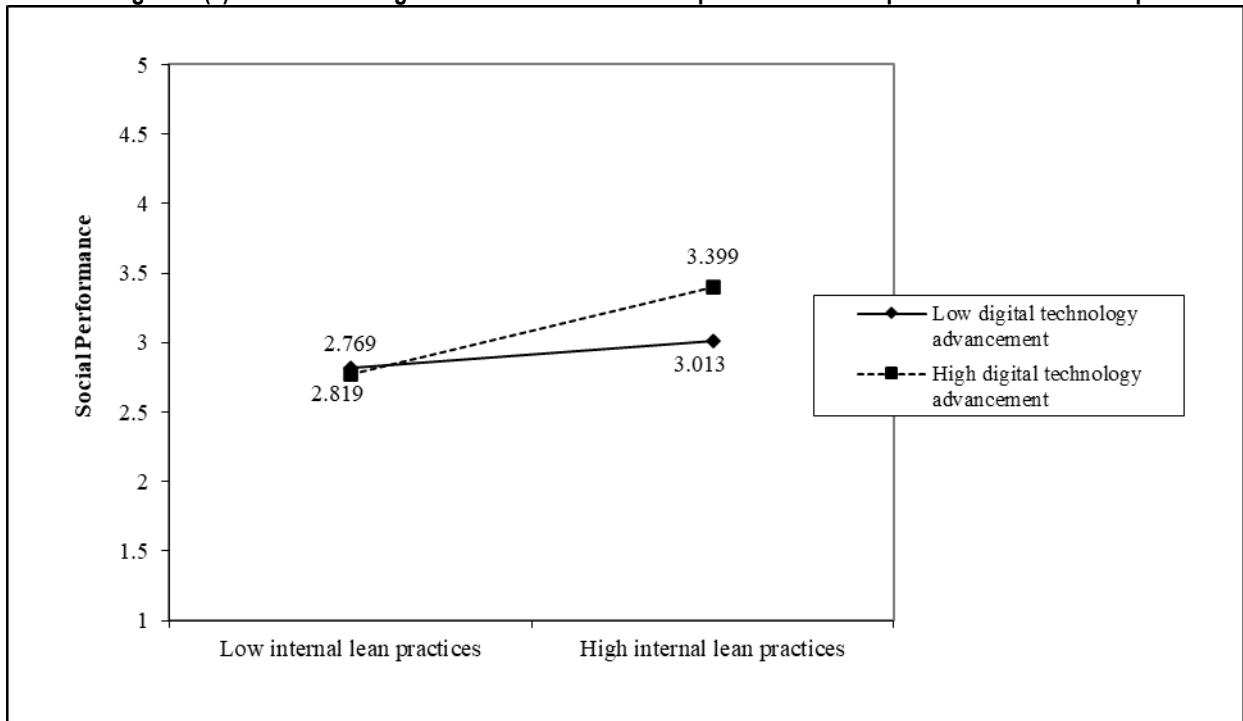
Note: Standardized coefficients and t-values are reported; Dependent variable is social performance; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; † $p < 0.10$; Source(s): Authors' own creation

Figure 1: Proposed theoretical model



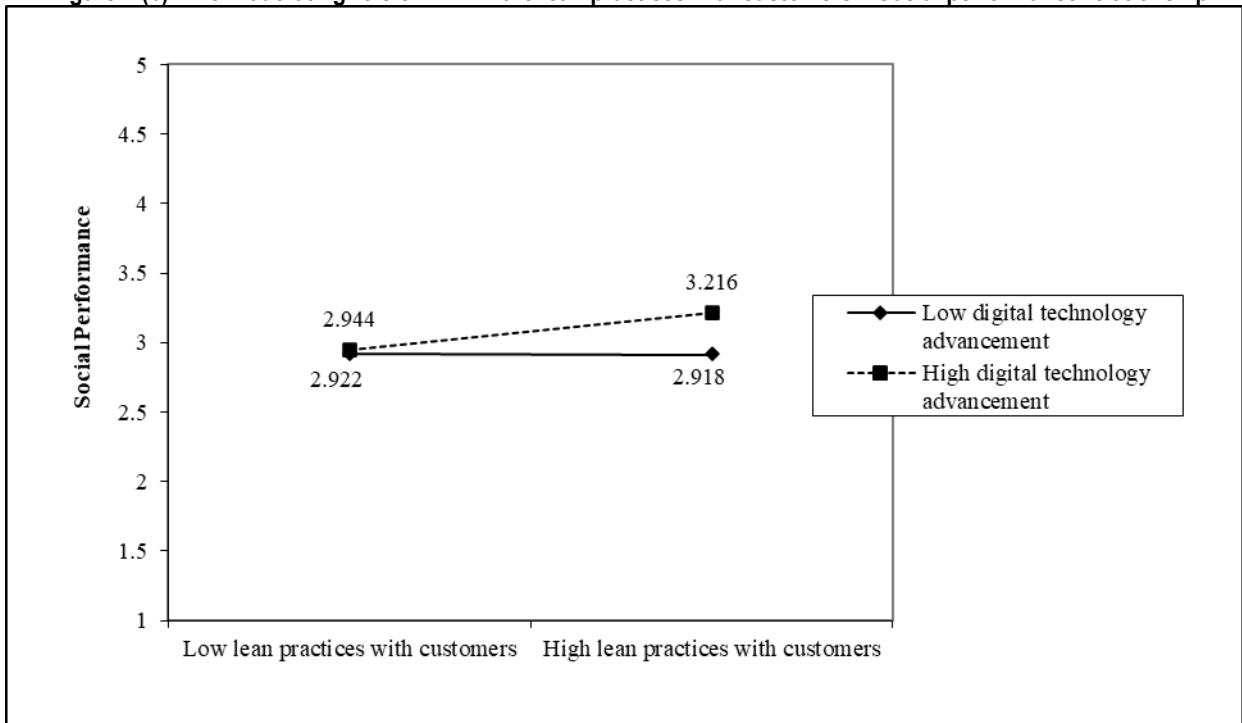
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Figure 2 (a): The moderating role of DTA in internal lean practices – social performance relationship



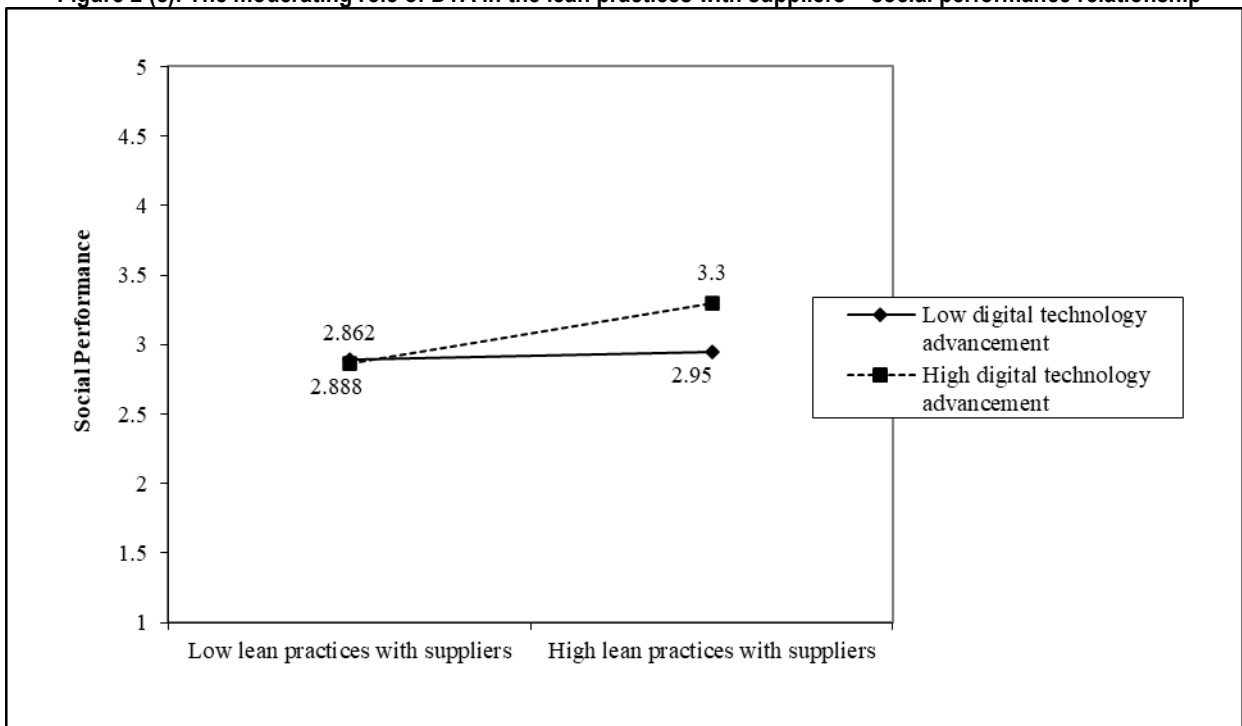
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Figure 2 (b): The moderating role of DTA in the lean practices with customers – social performance relationship



Source(s): Authors' own creation

Figure 2 (c): The moderating role of DTA in the lean practices with suppliers – social performance relationship



Source(s): Authors' own creation