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DOI
10.1108/IJOPM-02-2022-0086

Publication date
2022

Document Version
Final published version

Published in
International Journal of Operations & Production Management

Received 4 February 2022
Revised 17 June 2022
3 October 2022
Accepted 3 October 2022

Beyond efficiency: the role of lean practices and cultures in developing dynamic capabilities microfoundations

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Abstract

Purpose – The purpose of this study is to theorize and test the relationships among lean operations and lean supply chain practices, learning- and innovation-oriented lean cultures and dynamic capabilities (DCs) microfoundations. Further, this study aims to assess the association of DCs microfoundations with process innovation.

Design/methodology/approach – The researchers combine primary data collected from 153 manufacturing firms located in five continents using a survey designed for the purpose of this study with archival data downloaded from the Bureau Van Dijk Orbis database and test the hypothesized relationships using structural equation modelling.

Findings – Results support the contribution of lean operations and lean supply chain practices to the development of DCs microfoundations, which further lead to greater process innovation. Additionally, while a learning-oriented lean culture positively moderates the relationships between both lean operations and lean supply chain practices and DCs microfoundations, an innovation-oriented lean culture only moderates the relationship between lean operations practices and DCs microfoundations.

Practical implications – This study identifies DCs microfoundations as the key mechanisms for firms implementing lean practices to achieve greater levels of process innovation and the important role played by lean cultures. This study provides direction for managers to put in place DCs through lean implementations, enabling their firms to be ready to respond to challenges and opportunities generated by environmental changes.

Originality/value – While previous research has confirmed the positive effects of lean practices on efficiency, the role of lean practices and cultures in developing capabilities for reacting to environmental dynamism has

Funding: This research has been supported by Government of Spain (Research Project PID2021.124725NB.I00), Government of Andalusia and the European Regional Development Fund (European Union) (Research Project B-SEJ74-UGR20).

International Journal of Operations & Production Management
Vol. 42 No. 13, 2022
pp. 506-536
Emerald Publishing Limited
0144-3577
DOI 10.1108/IJOPM-02-2022-0086

received little attention. This study offers an empirically supported framework that highlights the potential of lean to adapt processes in response to environmental dynamics, thereby extending the lean paradigm beyond the traditional focus on operational efficiency.

Keywords Lean, Dynamic capabilities, Microfoundations, Process innovation, Continuous improvement
Paper type Research paper

1. Introduction

Lean has traditionally been conceptualized as a continuous improvement methodology to enhance organizational efficiency (Hopp and Spearman, 2021). More contemporary research on the topic has suggested that efficiency is not necessarily the only outcome and that implementing lean also provides firms with greater adaptability to respond to changes in their environments (Cusumano *et al.*, 2021; Netland and Powell, 2016). The Lean Enterprise Institute asserts that lean organizations are more adaptive to changes in their environments than their non-lean peers (LEI, 2022). However, existing empirical studies have not tackled the questions of whether and how lean facilitates adaptability.

The adaptability of firms can be characterized as dynamic capabilities (DCs), which are defined as abilities "to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece *et al.*, 1997, p. 516). For example, it is through developing its DCs that Samsung overtook Apple as the leading smartphone maker in the world (Park, 2022; Song *et al.*, 2016). Previous researchers have analysed the relationships of continuous improvement initiatives such as lean with DCs (Dobrzykowski *et al.*, 2016; Gutierrez and Antony, 2020) and prescribed elements of continuous improvement organizational infrastructure for DCs (Anand *et al.*, 2009). Mohaghegh *et al.* (2021) found lean practices to be positively associated with systematic problem-solving, agile manufacturing and continuous improvement. What remains unaddressed, however, is whether and how implementing lean can help firms to continuously adapt their processes to environmental changes, such as varying customer requirements (e.g. improved response time and customization), harnessing emerging technologies (e.g. Industry 4.0), meeting sustainability objectives (Tortorella *et al.*, 2019; Yu *et al.*, 2020) and reacting to high impact and low-probability events such as pandemics, climate disasters and political conflicts (Alexander *et al.*, 2022). This research aims to understand the relationship between lean implementation and DCs development, manifested by the adaptation of organizational processes in response to changing external conditions. We hypothesize that lean enables the development of DCs microfoundations, understood as the capacities to (1) *sense* opportunities and threats, (2) *seize* opportunities and ways to combat threats and (3) *transform* intangible and tangible assets to maintain competitiveness (Teece, 2007), leading to higher levels of process innovation.

Process innovation indicates the ability to adapt organizational processes to different contexts, which can be especially valuable in environments characterized by changing technologies, varying customer needs and market uncertainties (Piening and Salge, 2015; Teece *et al.*, 1997). Extant literature has highlighted the importance of capacities related to DCs microfoundations, such as sensing, learning, R&D and training for generating process innovations (Pavlou and El Sawy, 2011; Piening and Salge, 2015).

To analyse the relationships between lean, DCs microfoundations and process innovation, we differentiate between lean operations and lean supply chain practices (Azadegan *et al.*, 2013; Furlan *et al.*, 2011; Hofer *et al.*, 2012; Shah and Ward, 2007). In addition, we include the role of learning- and innovation-oriented lean cultures following previous research (Akmal *et al.*, 2022; Bortolotti *et al.*, 2015; Hardcopf *et al.*, 2021; Onofrei *et al.*, 2019; Yu *et al.*, 2020). We hypothesize that process innovation is supported by lean practices implementation through DCs microfoundations – sensing, seizing and transforming – and strengthened by the presence of organizational learning- and innovation-oriented lean cultures.

Our analysis is based on survey and archival data from 153 lean manufacturing firms located in 34 countries. We address three research questions: (1) how are lean operations and lean supply chain practices associated with DCs microfoundations development? (2) How do learning- and innovation-oriented lean cultures impact the effect of lean operations and lean supply chain practices on DCs microfoundations development? (3) How do DCs microfoundations impact process innovation? Our research contributes to the literature streams on lean and firm environmental adaptation by demonstrating how lean practices and cultural orientations affect DCs microfoundations and process innovation. Our findings reveal how lean firms are more adaptable to their environment, through their enhanced sensing, seizing and transforming capacities. Thus, we provide an extended understanding of the benefits of lean implementation beyond mere operational efficiency.

2. Literature review

2.1 Lean practices

Womack *et al.* (1991) popularized the term "lean" as a management concept (Holweg, 2007) after Krafcik first used the term to describe the Toyota Production System (Krafcik, 1988). Lean thinking and lean practices focus on creating customer value by reducing waste and enhancing product/service features without additional cost. Subsequently, Shah and Ward (2007) categorized lean manufacturing practices into 10 subcategories of practices, which they grouped into 3 constructs (supplier-, customer- and internal practices).

Subsequent research (Azadegan *et al.*, 2013; Chavez *et al.*, 2013; Tortorella *et al.*, 2017) has differentiated between internal lean (operations) practices, comprising setup time reduction, (single-piece) flow, pull production and (employee-based) quality management practices and external lean (supply chain) practices comprising supplier-feedback, -just-in-time, -development and customer involvement. In Table 1, we list numerous papers on lean management topics that have dichotomized lean practices between internal and external. We follow this established categorization in our conceptualization and empirical analysis. Note that we exclude the practices of statistical process control (SPC) and total productive maintenance (TPM) from our definition of lean because SPC is regarded as more central to Six Sigma's approach for variability and defect reduction (Hines *et al.*, 2004; Snee, 2010), and TPM is commonly associated with a philosophy and set of practices in itself (McKone *et al.*, 1999; Nakajima, 1988).

Table 1.
Account of research adopting lean operations and supply chain practices

Lean operations practices	1	2	3	4	5	6	7	8	9
Setup practices	*	*	*	*		*	*	*	
Flow practices	*	*	*	*	*		*	*	*
Pull practices	*	*	*	*		*	*	*	
Employees related practices	*		*	*	*		*	*	*

Source(s): 1. Flynn *et al.* (1999), 2. White *et al.* (1999), 3. Shah and Ward (2003), 4. Shah and Ward (2007), 5. Dal Pont *et al.* (2008), 6. Hofer *et al.* (2012), 7. Filho *et al.* (2016), 8. Panwar *et al.* (2018), 9. Galeazzo *et al.* (2021)

Lean supply chain practices	1	2	3	4	5	6	7	8	9
Suppliers feedback practices	*		*	*	*	*	*	*	*
Suppliers JIT practices	*	*	*	*	*	*	*	*	*
Customer involvement practices	*	*	*		*	*	*	*	
Suppliers development practices			*			*	*		*

Source(s): 1. Stratton and Warburton (2003), 2. Vitasek *et al.* (2005), 3. Shah and Ward (2007), 4. Anand and Kodali (2008), 5. Perez *et al.* (2010), 6. Jasti and Kodali (2015), 7. Tortorella *et al.* (2017), 8. Borges *et al.* (2019), 9. Powell and Coughlan (2020)

2.2 Dynamic capabilities

The DCs view extends the resource-based view (Rumelt, 1984; Wernerfelt, 1984) of sustainable competitive advantage by including an organization's ability to sense and seize new opportunities and reallocate or reconfigure resources to adapt to the environmental changes toward establishing a competitive advantage (Teece, 2007). DCs are positioned as higher-order capabilities for modifying operating routines (Zollo and Winter, 2002) and sustaining competitive advantage across changing environments (Eisenhardt and Martin, 2000; Schilke, 2014; Teece *et al.*, 1997). Extant research has proposed a set of three organizational processes that comprise DCs microfoundations (Teece, 2007). First, *sensing* refers to the capability to search, explore, identify and shape new or emerging opportunities and threats from the internal and external environments. Second, *seizing* refers to the ability of a firm to capture the sensed opportunities by means of an infrastructure to exploit them. Third, *transforming* refers to the capability to reconfigure, change and modify existing resources to succeed with the seized opportunity.

Researchers have described different organizational capabilities as DCs. For example, continuous improvement is a DC that includes developing a vision for managing and improving operations, empowering employees, tapping into tacit knowledge and building a customer-oriented culture (Anand *et al.*, 2009). Similarly, alliance management and new product development are recognized as DCs (Gutierrez-Gutierrez *et al.*, 2018; Schilke, 2014). On the topic of continuous improvement, scholars have recognized the potential of DCs for explaining and understanding how firms achieve and sustain competitive advantages (Anand *et al.*, 2009; Su *et al.*, 2014). In this research, we seek to further explain the role of DCs microfoundations in the context of lean implementations.

3. Theoretical model

3.1 Lean practices and DCs microfoundations

For lean practices to result in sustained competitiveness, firms need to develop the capability to select appropriate lean practices and adjust them based on varying needs dictated by firm–environment interactions (Peng *et al.*, 2011). Past research on relationships between lean/continuous improvement and DCs can generally be defined by two perspectives (Gutierrez and Antony, 2020) – (1) continuous improvement as an enabler of DCs (e.g. Dobrzykowski *et al.*, 2016; Mohaghegh *et al.*, 2021) and (2) continuous improvement as a DC in itself. The first perspective proposes that the search for process improvements includes the need for alignment with opportunities in the environment, as well as the development of capabilities to adapt resources and exploit these opportunities. Hence, Camisón and Puig-Denia (2016) clearly stipulate that continuous improvement practices can function as vehicles for the development of organizational capabilities, such as organizational learning, though it cannot be considered as a bundle of DCs by itself due to its functional orientation. Secondly, research that does propose continuous improvement to be a DC (Anand *et al.*, 2009) takes the view that emergent organizational processes in continuous improvement initiatives can show high similarity with DCs characteristics when these comprise comprehensive organizational contexts and sustainable organizational learning efforts. These associations between continuous improvement capabilities and DCs, however, have not been studied empirically beyond case studies (Gutierrez and Antony, 2020).

3.1.1 Lean operations practices. Lean operations practices facilitate pull production (i.e. demand-triggered delivery), flow (i.e. demand-dictated organization), setup reduction (i.e. demand-based flexibility) and employee involvement (i.e. employee-led improvement) (Shah and Ward, 2007). These practices have in common, the elements of learning from customer interaction, a natural tendency to organize and if needed reorganize operations and decentralized employee-led improvement initiatives. We posit that these lean operations practices positively affect the organizational processes that are identified as DC microfoundations.

The DCs microfoundations of sensing, seizing and transforming are known to be facilitated by specific organizational processes (Teece, 2007). First, a firm's natural openness to new ideas and change, facilitate experimentation and reduce the reliance on path-dependent routines are geared toward sensing and seizing (Teece, 2007; Tushman and Anderson, 1986). Second, a firm's willingness to depart from existing routines when confronted with new business opportunities facilitates transforming. Firms with a tradition of change and improvement are argued to be less susceptible to a "heightened state of anxiety" due to letting go of past routines and more easily engaging in improvement and innovation (Teece, 2007).

Overall, successful implementation of lean operations practices such as pull-based operations that facilitate the production of units needed, at the time needed, and in the quantities needed; improved flow that enhances production movement without frequent stop-and-go operations; and setup reduction that allows firms to predict process output more exactly (Shah and Ward, 2007), warrant ongoing detection and responding to the needs of the firms' environment. Also, implementing pull, flow and setup practices is conditional on employee involvement in improvement efforts (Shah and Ward, 2007) thereby harnessing employee knowledge and experience to materialize on improvement opportunities in reaction to externally driven changes (Teece, 2007). As a result, the implementation of these practices creates an ongoing change orientation (Anand *et al.*, 2009), thereby facilitating the development of the three DCs microfoundations (Teece, 2007; Tushman and Anderson, 1986).

An illustrative example is Volvo Motor Company, which implemented flow and pull practices as part of their lean production system to enable an adequate response to changed product quality and security expectations. As a result, their operations became more flexible and resilient, showcasing the potential of lean practice implementation for DCs microfoundations development (Netland and Aspelund, 2013). In addition, Distelhorst *et al.* (2017) showed how lean mechanisms increased employee involvement in Nike's factories, leading to improved labour relations, thereby positively responding to current external social demands (e.g. inspection, communication, workplace arrangements, industrial hygiene, etc.). Based on our argumentation above, we propose (Figure 1):

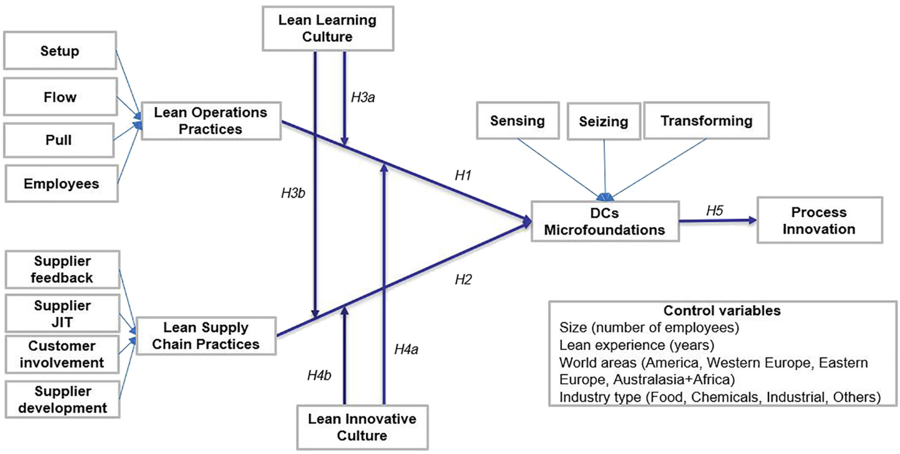


Figure 1.
Proposed model

H1. Implementation of lean operations practices is positively related to DCs microfoundations development.

3.1.2 Lean supply chain practices. Lean supply chain practices comprise supplier feedback (i.e. good relations with frequent feedback cycles), supplier just-in-time delivery (i.e. supplier-involved process design), customer involvement (i.e. frequent interaction about needs and expectations) and supplier development (i.e. supplier-involved process improvement) (Shah and Ward, 2007). The common features of these practices are intensive collaborations with suppliers and engagement with customers, and we posit that these lean supply chain practices positively affect the development of DC microfoundations.

Sensing processes depend on a firm's ability to detect and identify changes in customer needs (Nonaka and Toyama, 2007). Engagements with customers and the learning that takes place through interaction processes must then be synthesized by middle management, so that transformative action can be taken in response. In such processes, it is of utmost importance that "local search" is supplemented by searching for information about what is happening in the business ecosystem. In dynamic environments, where a great deal of innovation stems from sources outside of the firm, firms must be able to monitor not only the core of their business ecosystem but also the peripheries. The example of how innovations in microprocessors created novel possibilities for downstream products such as personal computers and other electronics is a manifestation of why it is important to maintain close ties with suppliers for effective sensing capabilities (Chesbrough, 2003).

For seizing and transforming capacities, a firm must be open to new ideas and change, which is not limited to the boundaries of the firm. Path dependencies and reliance on existing routines and assets beyond the boundaries of the firm inhibit seizing processes (Teece, 2007). Vice versa, when new opportunities emerge and investments are made in product or service-offering developments that stretch beyond the boundaries of the firm, close supplier collaboration enhances the chances for success (Teece, 2007). Joint innovation processes comprise interfirm interpersonal relationships (Tortorella *et al.*, 2017) that reportedly lead to higher degrees of supply chain flexibility and responsiveness (Teece, 2007). Moreover, interpersonal relations within supply chains enable the exchange of tacit knowledge, thereby enhancing sensing, seizing and transformational capabilities (Eisenhardt and Martin, 2000; Teece, 2007). Additionally, adequately seizing and transforming opportunities may require updating and learning new skills which can be facilitated by alliance arrangements with suppliers or even customers (Branzei and Vertinsky, 2006).

We posit that lean supply chain practices instil intensive collaboration with customers and suppliers strengthening joint capability development, which improves sensing, seizing and transforming capabilities. In support of our argument, earlier research has reported on how lean supply chain practices such as supplier feedback and customer involvement strengthened coordination, integration of information and knowledge transfer within supply chains (Cagliano *et al.*, 2006; Powell and Coughlan, 2020; Tortorella *et al.*, 2017).

An exemplary manifestation of the benefit of close supplier relationships is the case of Philips electronics (currently known as NXP). In March 2000, a fire in a New Mexico-based production site caused severe disruption in the integrated circuit supply chain of several cellphone companies, including Nokia and Ericsson (Sheffi and Rice, 2005). Nokia responded immediately and sent 30 employees to work with NXP to restore operations while solid relationships with other suppliers allowed the negotiation of contracts to ensure that its worldwide production capacity would remain intact (i.e. by means of Nokia's "supplier-feedback and development" lean supply chain practices). Ericsson, on the other hand, was slower in sensing the severity of the problem. By the time it searched for alternative suppliers, their capacities were already committed to Nokia (Sheffi and Rice, 2005). Based upon the reasoning, above we hypothesize:

H2. Implementation of lean supply chain practices is positively related to DCs microfoundations development.

3.2 Lean organizational culture and DCs microfoundations

The contextual effects of cultural traits on the adoption of lean practices in firms have been researched at multiple levels of analysis. At the higher level of societal norms that influence culture, aggregated traits such as higher degrees of individualism, uncertainty avoidance and power distances are found to positively affect the adoption of lean practices adoption (Pakdil and Leonard, 2017). While the impacts of the broadly categorized traits of national culture do matter, our focus, in the present research, is on cultural traits at the organizational level that serve as the context for the implementation of lean practices (Akmal *et al.*, 2022). As such, we emphasize cultural traits that can be moulded by organizations instead of those that are considered relatively fixed based on national origins.

We adopt the definition of organizational culture as "a combination of artifacts (also called practices or forms), values and beliefs, and underlying assumptions that organizational members share about appropriate behaviour" (Detert *et al.*, 2000, p. 851). Existing literature has supported the idea that learning- and innovation-oriented organizational cultures are key ingredients for DCs development, as these orientations support the generation of knowledge that allows a firm to adapt to its competitive environment (Teece *et al.*, 1997; Teece, 2007; Zollo and Winter, 2002). Likewise, existing research has revealed the importance of change-enabling organizational cultural traits, without which firms cannot realize the benefits of lean implementations (Hardcopf *et al.*, 2021; Hines *et al.*, 2004; Onofrei *et al.*, 2019; Yu *et al.*, 2020).

3.2.1 Learning-oriented lean culture. Lean operations and lean supply chain practices are the observable artefacts of lean implementations (Galeazzo *et al.*, 2021; Powell and Coughlan, 2020). The success of these lean practices (and arguably the strength of their effects on DCs microfoundations development), depends on the involvement and commitment of employees and managers in implementing these lean practices; selecting the appropriate practices based on firm-environment dynamics and making ongoing changes to practices so that these fit in the firms' contexts (Anand *et al.*, 2009; Spear and Bowen, 1999).

Lean practices such as pull, setup or suppliers' development are not off-the-shelf solutions. Rather, they are complex to implement and require knowledgeable employees, making learning an imperative to augment lean practice efficacy (De Mast *et al.*, 2021; Onofrei *et al.*, 2019; Powell and Coughlan, 2020; Tortorella *et al.*, 2019). In successful lean implementations, employees improve organizational processes and systems through collaboration, consensus building, suggestion systems and group decision-making, which together constitute a supporting infrastructure for individual and group learning (Spear and Bowen, 1999). Vice versa, an organizational culture characterized by resistance to learning hinders the realization of benefits from implementing lean practices (Wiengarten *et al.*, 2015), both within and outside firms' boundaries (Hines *et al.*, 2004). Examples that substantiate the importance of learning in successful lean practices adoption include Toyota, where learning is a basic part of their day-to-day operations (Spear and Bowen, 1999). Additionally, a learning-oriented culture at software company Wipro is exemplified by the creation of a productivity office based on disciplined learning that increases the effectiveness of lean practices to respond to environmental changes through the identification of best practices and the investigation of new ideas (Staats and Upton, 2011). Hence, we hypothesize that a learning culture enhances the effects of lean operations and lean supply chain practices on DCs microfoundations development:

H3a. A learning-oriented lean culture positively moderates the relationship between lean operations practices implementation and DCs microfoundations development.

H3b. A learning-oriented lean culture positively moderates the relationship between lean supply chain practices implementation and DCs microfoundations development.

3.2.2 Innovation-oriented lean culture. Firms' innovation orientations are known to enhance the adoption of lean operational practices by means of an empowering climate for employees to propose and implement improvements (Anand *et al.*, 2009). This is typically because innovation-oriented firm cultures facilitate the search for solutions to (external) changes and this orientation is an important enabler for employees to share ideas and cooperate in the creation of knowledge (Onofrei *et al.*, 2019). Similarly, and resembling the objectives of lean supply chain practices, innovation-oriented firms typically invest more time in supply chain partners to help them achieve organizational capabilities, through activities such as educational programmes for supply chain partners, inter-firm teams, consulting and problem-solving for- and with suppliers and collaborative R&D activities (Solaimani *et al.*, 2019).

Lean implementations are also innovation-enhancing, manifested by continual (process) innovations (Netland *et al.*, 2015). For example, lean practices like setup, flow and pull, provide progressive insight into required product specifications and technological competencies needed, and reportedly improve time-to-market capabilities, thereby positively affecting a firm's innovative capability (Schniederjans, 2018). Moreover, successful lean practice implementations are known to be based on the creation of an infrastructure for generating and harnessing ideas and a culture of ongoing change and innovation (Anand *et al.*, 2009; Rathore *et al.*, 2020).

An example that reveals the role of innovation orientations in successful lean adoption is Volvo Motor Company, which reportedly has enhanced the success of its lean initiative by means of the company's human-centred production, predominantly based on an innovation-oriented culture that is attuned to responding to (internal and external) changes. Their innovation orientation enabled the replacement of a regular assembly line with a dock assembly setup to increase teams' responsibilities and joint decision powers (thereby achieving setup reduction and increased flow) (Netland and Aspelund, 2013). Hence, we hypothesize the presence of an innovation-oriented lean culture as accentuating the effects of lean operations and lean supply chain practices on DCs microfoundations development:

H4a. An innovation-oriented lean culture positively moderates the relationship between lean operations practices implementation and DCs microfoundations development.

H4b. An innovation-oriented lean culture positively moderates the relationship between lean supply chain practices implementation and DCs microfoundations development.

3.3 Dynamic capability microfoundations and process innovation

Process innovations represent changes in the way sequences of activities (processes) are executed in firms. DCs microfoundations enable activities directed at generating, acquiring, integrating and disseminating knowledge for reconfiguring such organizational processes, enabling sustained competitive advantage (Pavlou and El Sawy, 2011), typically by means of enhanced technologies or systems (Teece, 2007). For example, firms conducting activities for sensing, seizing or transforming such as (1) market research (i.e. sensing customer needs, market developments), (2) scanning of patent databases (i.e. technological opportunities), (3) conducting in-house R&D and prototyping, and (4) R&D outsourcing, typically demonstrate increased process innovation activity (Teece, 2007). Developing DCs microfoundations enhances the ability of firms to recognize the value of new information for knowledge creation (Chatterjee *et al.*, 2022). This knowledge makes the firms aware of potentially useful process innovations (Piening and Salge, 2015). Consequently, we expect firms with strong DCs microfoundations to be more flexible, better able to detect and understand the implications of opportunities and threats and better able to make innovation decisions in response to changed competitive conditions (Chatterjee *et al.*, 2022; Gutierrez-Gutierrez *et al.*, 2018). Therefore, we propose the following hypothesis:

H5. DCs microfoundations development is positively related to process innovation.

4. Research methodology

4.1 Sample data

We collected survey data from mid- and senior level lean-managers and practitioners in manufacturing firms between June 2019 and June 2020 by sending a digital questionnaire to the targeted respondents. As our objective is to make generalizations about theory rather than populations, we applied non-probability heterogeneous purposive sampling to select subjects for the study (Saunders *et al.*, 2009). That is, we aimed for substantial variation in the respondents' organizational contexts (globally scoped, differing-firm sizes, functional domains and occupational titles) to enable us to compare and generalize findings. Table 2 lists the descriptive information for our sample.

The information in Table 2 hints at differences between sample and population distributions (i.e. *all* lean implementing manufacturing firms): a bias towards western countries, large enterprise overrepresentation (average of 82% observed against 35.6% in the European Union alone (Eurostat, 2019), the largest cluster of respondents) and biases in the functions of employment. This suggests that the representativeness of our sample and hence generalizability of our findings are somewhat limited. However, this limitation must be seen in the light of the richness of the data that we achieve through the use of a survey conducted for the express objective of this research study based on carefully constructed scales for pointed measurements of constructs as well as the inclusion of archival data for measuring control variables and the dependent variable.

To enhance research validity and following previous research in operations management (Kortmann *et al.*, 2014), we applied a "key informant approach" (i.e. preference for better-informed respondents having specialized knowledge about the phenomena under research over more but less knowledgeable respondents) (Kumar *et al.*, 1993). Respondents were selected based on two criteria. First, being educated in lean methodology, defined as at least six days of lean training (medium-level competency that is enabling autonomous lean project leadership), and second, a dedication to lean implementation, defined as at least 25% of daily working time spent on lean implementation (more than one full-time equivalent working day per week). We targeted respondents via co-authors' networks, and each respondent was asked for relevant referrals, which were vetted for function, tenure and experience in lean working environments before being invited to participate. This purposive sampling strategy minimized the chance for selection error and assured experienced and knowledgeable respondents (Eisenhardt, 1989).

4.2 Questionnaire design

We used a two-stage scale development procedure following prescriptions by Hensley (1999). First, we put together the questionnaire based on a review of the existing literature and consultations with lean experts for adopting existing scales. Second, we tested the initial questionnaire for clarity and user-friendliness by working with eight lean practitioners based on the principle of saturation (Saunders *et al.*, 2009). This helped in reducing the chances of errors and biases from the perspectives of participants and observers. The research team amended and clarified questions based on these discussions.

		#	%
Region of employment	Western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK)	92	60
	Eastern Europe (Czech Republic, Hungary, Lithuania, Poland, Romania, Serbia)	8	5
	North America (Canada, Mexico, USA)	20	13
	South America *(Brazil)*	12	8
	Central Asia (China, Hong Kong, India, Turkey)	15	10
	South East Asia (Indonesia, Malaysia, Singapore)	3	2
	Oceania (Australia)	2	1
	Africa (South Africa)	1	1
Manufacturing sector	Chemicals	22	14
	Food	19	12
	Industrial	44	29
	Others	68	44
Firm size (employees)	<10	4	3
	10–49	4	3
	50–250	20	12
	>250	125	82
Duration of lean implementation	<3 years	34	22
	3–5 years	35	22
	5–10 years	39	26
	>10 years	45	30
Quality initiatives besides lean (ISO, Six Sigma, EFQM, other)	Yes	147	96
	No	6	4
Function of employment	Administrative	7	4
	Consulting	29	19
	Finance	1	1
	Information Technology	2	1
	Operations and Production	81	53
	R&D and scientific	26	17
	Other	7	4
Lean working experience	<1 years	3	2
	1–3 years	20	13
	3–5 years	18	12
	5–8 years	27	17
	>8 years	85	56
Occupational title	Lean sponsor	41	27
	(Asst.) director/department head	30	19
	Group lead/team lead	4	3
	Lean practitioner/specialist	36	24
	(Asst.) manager	31	21
	Staff	9	6
	Other	2	1

Table 2. Descriptive statistics of survey respondents

The resulting questionnaire comprised two parts. The first section was designed to collect the demographics of the respondents such as country, position, lean experience, economic sector of the firm and number of employees. The second section sought data on constructs of interest based on existing validated 7-point Likert scales (Section 4.3) using reflective items. On one hand, this design assured reliable respondent assessments (Finstad, 2010), and on the other hand, it generated continuous and likely normally behaving response data as a prerequisite for the chosen information-dense methodological technique (Kline, 2015).

We prepared the questionnaire in English and Spanish versions using the standard backward translation method (Brislin, 1970). With this technique, a questionnaire is translated and blindly translated back to the original language by another translator to detect anomalies. This procedure is repeated several times until no more anomalies exist. Finally, we paid special attention to writing concise and clearly understandable items (Noar, 2003).

We took four steps in the design and execution of our survey aimed at increasing the response rate and reducing the concern for non-response bias (Goyder, 2019). First, in the early stages of the development of the survey questionnaire, we conducted pre-tests and collected feedback on its clarity, interpretability and multi-medium deployment. Second, we persisted with the data collection for an extended period of one year during which we sent reminders to the targeted respondents. Third, we assured the respondents that the identities of the firms and respondents would remain confidential. Fourth, as an incentive for participation, we offered to share the results of the research with those who responded. We assessed non-response bias by testing for differences between (1) early and late and (2) complete and incomplete responses. Both sets of two-sample *t*-tests on the construct mean scores revealed no significant differences, indicating that the risk of non-response bias was small (Armstrong and Overton, 1977; Whitehead *et al.*, 1993).

We sent the finalized questionnaire to 510 targeted respondents out of which 195 respondents showed interest by starting to respond. In the process of data preparation, we deleted incomplete responses and imputed missing values for less than 5% of the remaining sample by means of single regression imputation (Kline, 2015). A total sample of 153 useable cases for data analysis remained.

4.3 Measures

The unit of analysis is lean implementation in the respondents' firms. The constructs of "lean operations practices" and "lean supply chain practices" are operationalized using scales based on Shah and Ward (2007). For measuring "learning-oriented lean culture" and "innovation-oriented lean culture", we adapted scales from Hult *et al.* (2007). Our measures for the three microfoundations of DCs – sensing, seizing and transforming – are adapted from Jantunen *et al.* (2018). Finally, we measured the construct for our dependent variable "process innovation" using scale items from Wang and Ahmed (2004). The constructs and items adopted are presented in Appendix 1. We included firm size (Table 1), lean experience (in years) of the firm, industry subtype within the manufacturing sector, and geographical location as control variables in our analysis (Sousa and Voss, 2008).

To alleviate common method bias (CMB) and as a robustness check for our results, we repeated our analyses using an alternative measure of firm performance based on secondary financial company data as our dependent variable. To do this, we merged our survey data which contained company identifying information, with data from the Bureau Van Dijk Orbis database. The Orbis database is a large Moody's Analytics owned global database that includes data on listed and unlisted companies. The data compiled in Orbis is sourced from over 170 different company information providers and standardized to enable comparisons (Bureau van Dijk, 2022). This database provided us with financial information for 100 of the companies represented in our sample. Specifically, we obtained the Return on Capital Employed (ROCE) indicator, which represents how well a firm is generating profit from its capital. ROCE has been used in past studies to measure operations performance (Hernandez-Vivanco *et al.*, 2019; Martins and Lucato, 2018). In addition, we checked the robustness of our results by using scales adopted from Schilke (2014) that were included in our survey questionnaire, measuring strategic and financial performance, instead of process innovation.

4.4 Data analysis method

We estimated partial least squares (PLS) based structural equation models (SEM) using the Smart PLS 3 software (Ringle *et al.*, 2015). PLS carries out non-parametric structural equation modelling with interdependent ordinary least squares (OLS), which minimizes residual variances (Henseler *et al.*, 2016). PLS is deemed a suitable method for this research because (1) our research questions call for a predictive study of endogenous variables, (2) the non-parametric character of PLS allows us to analyse variables whose distribution is not normal and (3) PLS allows for the simultaneous estimation of multiple independent equations (Peng and Lai, 2012). Additionally, PLS is particularly recommended over other SEM covariance-based methods for models that use both formative (lean practices and DCs microfoundations) and reflective (cultural orientations and process innovation) constructs (Peng and Lai, 2012). PLS allows for combining the measures for reflective constructs, with their theoretical concepts (i.e. cultural orientations) to serve a certain goal such as revealing its relationship with formative constructs (i.e. lean practices). Due to the constructivist nature of this approach, recent literature suggests operationalizing these constructs by a composite model focusing on explained variance, as employed by PLS (Henseler *et al.*, 2016; Benitez *et al.*, 2020). The use of PLS is increasingly accepted in academic research, demonstrated by numerous recent PLS-based operations management studies (e.g. Blome *et al.*, 2013; Hadid *et al.*, 2016). Table 3 shows the descriptive statistics for the construct variables included in the study.

4.5 Model development

The measurement model was subjected to a validation process consisting of multiple steps. First, we ensured the content validity of our scales by using scales that had been validated and used in previous empirical studies. In addition, we pretested our scales with experienced researchers and firm managers to confirm their face validity and reconfirm content validity. Second, we analysed the reliability and internal validity of the scales using confirmatory factor analysis, for which the first- and second-order details are presented in Appendix 1. Internal consistency was assessed using Cronbach's alpha (Cronbach, 1951) and composite reliability analyses (Netemeyer *et al.*, 2003). All our scales have Cronbach's alpha and composite reliability scores exceeding the minimum recommended threshold of 0.7, except *Setup* (Cronbach's alpha = 0.671). Third, having defined our measurement model in totality, we conducted convergent validity analysis to assess item-factor loadings (Peng and Lai, 2012). All our factor loadings exceed the minimum suggested threshold of 0.7 except two (0.673 for *Flow5* and 0.648 for *SupplierDevelopment4*). With the aim of preserving content validity, we decided not to exclude the *Setup* scale and the scale items *Flow5* and *SupplierDevelopment4* because the factor loadings were only just below the respective thresholds and the other scale reliability and validation requirements were fulfilled. We further evaluated the convergent validity of the scales, checking for values of their average variance extracted (AVE) to be above 0.5 (Hair *et al.*, 2016) (Appendix 1). Finally, the discriminant validity of the constructs was confirmed through compliance with the Fornell and Larcker criterion (Fornell and Larcker, 1981), requiring the value of the square root of the AVE for each construct to be always greater than the corresponding correlations between paired constructs. In addition, the Heterotrait-Monotrait Ratio (HTMT) test showed values lower than the recommended upper limit of 0.9, indicating that the different scale items are not measuring the same construct (Benitez *et al.*, 2020).

For the second-order formative constructs "lean operations practices", "lean supply chain practices" and "DCs microfoundations", we ensured adequate content validity via a rigorous qualitative approach (i.e. literature review) and evaluations of the validity of the constructs by our expert panel (Hair *et al.*, 2016). We checked for multi-collinearity of the first-order constructs by assessing the variance inflation factors (VIFs) in our structural models.

Table 3.
Descriptive statistics and correlations

First-order construct	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Pull	4.74	1.59	1	7	0.86*													
2. Flow	5.38	1.09	2	7	0.57	0.77												
3. Setup	5.54	1.10	2	7	0.41	0.50	0.86											
4. Employees	5.14	1.27	1.5	7	0.49	0.42	0.61	0.82										
5. Supplier feedback	5.40	1.13	1.2	7	0.36	0.36	0.41	0.45	0.83									
6. Supplier JIT	4.33	1.45	1	7	0.48	0.47	0.37	0.42	0.65	0.88								
7. Customer involvement	5.64	1.01	2.75	7	0.16	0.35	0.34	0.31	0.50	0.35	0.78							
8. Supplier development	4.16	1.14	1.25	7	0.47	0.47	0.42	0.36	0.52	0.58	0.30	0.72						
9. Sensing	5.58	0.95	2.4	7	0.40	0.36	0.48	0.44	0.43	0.40	0.39	0.47	0.82					
10. Seizing	5.21	1.17	1.75	7	0.38	0.27	0.44	0.46	0.37	0.40	0.25	0.57	0.67	0.85				
11. Transforming	5.32	1.07	2	7	0.33	0.37	0.44	0.42	0.30	0.24	0.28	0.41	0.59	0.63	0.86			
12. Learning-oriented lean culture	6.26	0.88	3.25	7	0.26	0.31	0.34	0.50	0.28	0.28	0.30	0.29	0.36	0.38	0.40	0.87		
13. Innovation-oriented lean culture	5.58	1.09	2	7	0.36	0.34	0.43	0.50	0.43	0.32	0.39	0.41	0.63	0.64	0.65	0.54	0.85	
14. Process innovation	4.93	1.22	1.75	7	0.57	0.42	0.51	0.60	0.39	0.43	0.33	0.44	0.61	0.67	0.58	0.42	0.67	0.80

Note(s): * Square root of the AVE values along the diagonal

The largest VIF value is 2.23, which is lower than the commonly referenced upper threshold of 3 (Diamantopoulos and Siguaw, 2006). In addition, to test the absolute contribution of each first-order construct to the related second-order formative construct, we verified that their loadings are significant (p-values <0.10) (Cenfetelli and Bassellier, 2009).

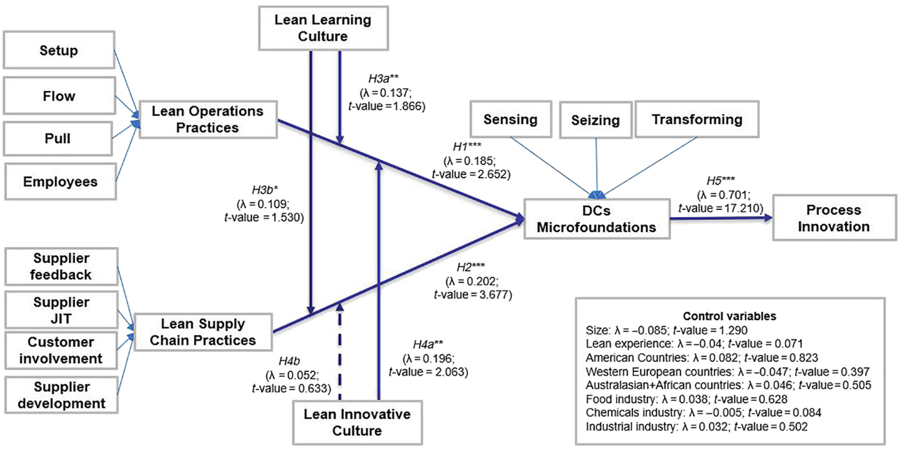
Finally, we evaluated CMB, following tests involving both procedural and statistical methods. First, a survey pre-test was performed to avoid ambiguity (Podsakoff *et al.*, 2003). Second, as a robustness test, we used data from primary and secondary sources (Spector, 2006). Third, we evaluated the possibility of bias using Harman's single-factor test. The results of the principal component analysis, in which all items were loaded on one construct, resulted in a low explained variance of 31.92%, reducing the concern of CMB in our study (Podsakoff *et al.*, 2003). Fourth, we tested for CMB using the correlation marker technique (Lindell and Whitney, 2001). Our questionnaire included the variables of interest for the study and a variable theoretically unrelated to them (marker variable) but equally susceptible to measurement biases. The method assumes that, when the variance of the common method is present, the marker variable will be just as affected as the variables of interest by the effects of the method. The correlations between the latent variables of interest in the study (i.e. lean practices or DCs microfoundations) were greater than the correlation between the marker variable and the variables of interest. The results of these multiple checks alleviate concerns about the potential effects of CMB on our analyses (Podsakoff *et al.*, 2003; Spector, 2006).

5. Results

5.1 Structural model evaluation and hypotheses testing

To estimate the structural model, we employed Smart PLS-SEM 3.0 which uses the PLS algorithm to generate the standardized path coefficients. In addition, we used a bootstrapping re-sampling procedure to estimate the significance of the path coefficients. To perform the moderation effects analyses, we used interaction terms created as the products of the main-effects and moderating variables. Figure 2 shows the output of this estimation.

Results show positive and significant relationships between lean operations practices and DCs microfoundations ($\lambda = 0.185, p < 0.01$) and between lean supply chain practices and DCs microfoundations ($\lambda = 0.202, p < 0.01$), supporting H1 and H2. In addition, learning-oriented lean culture positively moderates both relationships between lean operations practices and



Note(s): *p-value < 0.1, **p-value < 0.05, ***p-value < 0.01

Figure 2. Structural model estimation

DCs microfoundations ($\lambda = 0.137$, $p < 0.05$), and lean supply chain practices and DCs microfoundations ($\lambda = 0.109$, $p < 0.1$), supporting H3a and H3b. Similarly, H4a is supported as innovation-oriented lean culture positively moderates the relationship between lean operations practices and DCs microfoundations ($\lambda = 0.196$, $p < 0.01$). However, the moderating effect of innovation-oriented lean culture on the relationship between lean supply chain practices and DCs microfoundations (H4b) is not supported ($\lambda = 0.052$). Finally, results support the positive and significant relationship between DCs microfoundations and process innovation ($\lambda = 0.701$, $p < 0.01$), supporting H5.

Relationships between the control variables and process innovation were not significant. We conducted additional analyses of inter-group differences. Feasible group comparisons based on (1) alike contextual economic conditions (European Union membership) combined with (2) the degree of economic, social and political dimensions of globalization (Gygli *et al.*, 2018) (Western European ($n = 92$) vs non-Western European ($n = 61$)) resulted in consistently and significantly slightly higher mean values measured in the non-Western European group for the constructs sensing and transforming (DCs microfoundations), innovation-oriented lean culture (moderator) and process innovation (dependent variable). As measures for only a few of the constructs are partially different between the groups and are all consistent (comparatively higher in the non-western European group), no distorting effect of the geographical location-bound influences are indicated.

To evaluate the significance of the results, we interpret the model's explanatory power through the path coefficients, significance level and Cohen's f^2 and adjusted R^2 values (Benitez *et al.*, 2020). The path coefficients of the proposed relationships are all significant (except H4b) and range between 0.137 and 0.701. Adjusted R^2 values for the model predicting DCs microfoundations (0.762) and for the model predicting process innovation (0.551) show high predictive power above the 0.36 threshold (Wetzels *et al.*, 2009). Cohen's f^2 statistic measures the relative size of each incremental relationship in the model. Values higher than 0.020 (weak), 0.150 (medium) and 0.350 (large) indicate effect sizes (Benitez *et al.*, 2020). The f^2 values of the confirmed relationships in the model ranged from 0.043 to 1.043. Consequently, good explanatory power is obtained through the model.

Furthermore, based on the proposed relationships in our model, our sample size exceeds the minimum required observations ($n = 144$) to make estimations with a minimum statistical power of 80%, a significance level of 5% and with the possibility of estimating R^2 values from 0.10 and higher (Hair *et al.*, 2016). Additionally, we conducted a predictive power analysis for the statistical model, using PLSpredict, to observe how adequate the results are for generating out-of-sample predictions. The results satisfy the established requirements and show high predictive power for the dependent variables (DCs microfoundations $Q^2_{predict} = 0.524$; Process innovation $Q^2_{predict} = 0.436$) (Shmueli *et al.*, 2019).

Finally, the standardized root mean squared residual (SRMR) shows the discrepancy between the sample covariance matrix and the model covariance matrix, which allows us to evaluate the goodness of fit for the structural model. The estimate shows an SRMR = 0.07 lower than the upper threshold (0.08) (Benitez *et al.*, 2020) thus ensuring a good model fit.

5.2 Robustness analyses

To assess the robustness of our results, we carried out additional estimations of the structural model. First, we used an independently collected secondary measure of firm performance obtained from the Orbis company database to replace process innovation as the dependent variable. Specifically, we used ROCE, a financial ratio that measures firm's profitability and capital efficiency, as the alternative dependent variable, as this is an accepted measure of a firm's growth opportunities (Hernandez-Vivanco *et al.*, 2019; Martins and Lucato, 2018). The availability of data in the Orbis database reduced the sample size for this test to 100 firms. The results obtained showed similar significance supporting the hypotheses of the proposed model, including the positive and significant relationship between DCs microfoundations and ROCE ($\lambda = 0.129, p < 0.05$). This result confirms the positive relationship of DCs not only with process innovation, but also with long-term financial measures.

Second, to analyse potential endogeneity issues, we used an instrumental variable two-stage least squares (2SLS) approach (Lu *et al.*, 2018). For the relationships between lean operations and lean supply chain practices and DCs microfoundations, we selected a single plausibly exogeneous variable that measures the firm's lean experience as an instrumental variable. Lean experience suffices the "relevancy condition" as it directly and strongly relates to the implementation of lean practices but does not necessarily relate to DCs microfoundations. For the relationship between DCs microfoundations and process innovation, we selected a four-item variable that measures product innovation as an instrumental variable that is directly related to DCs microfoundations but not necessarily to process innovation. We used the Wu-Hausman F test and the Durbin-Wu-Hausman χ^2 test for assessing the 2SLS estimator and endogeneity (Lu *et al.*, 2018) and conducted Stock-Yogo to assess instrument variable relevancy (Lu *et al.*, 2018). All the tests show that endogeneity is not a significant concern (Appendix 2).

Third, we re-estimated the model by replacing the dependent variable, process innovation, with two alternative variables constructed from questionnaire scales measuring strategic and financial performance and related to DCs in previous literature (Jantunen *et al.*, 2018; Schilke, 2014). The results confirmed our main analysis results along with significant and positive relationships of DCs microfoundations with both strategic and financial performance ($\lambda = 0.532, p < 0.01; \lambda = 0.420, p < 0.01$). These results provide assurances of the robustness of our results.

Fourth, we estimated an alternative model that considers DCs microfoundations as an exogenous rather than a mediating variable. This alternative model shows a fit index with less explanatory power than our original model (SRMR = 0.089).

Fifth, we tested the direct effect of lean operations and lean supply chain practices on process innovation. With bootstrapping, our results show significant positive relationships for both cases (lean operations practices-process innovation $\lambda = 0.130$ t-value = 2.524***; lean supply chain practices-process innovation $\lambda = 0.142$ t-value = 3.843***), confirming the existence of partial mediating effects through DCs microfoundations.

Finally, as noted in the model development section, we retained two scale-items that had slightly lower factor loadings than the recommended minimum of 0.7. To check for spurious results based on that inclusion, we carried out the estimation of the model without those indicators. The significances of the relationships obtained in these alternative models were not different from those in the original model.

6. Discussion

The main goal of this study is to analyse the relationships between lean operations and lean supply chain practices, learning- and innovation-oriented lean cultures, DCs microfoundations and process innovation. In this section, we discuss the main implications of this study for research and practice.

6.1 Lean practices and DCs microfoundations development

H1 and H2 propose positive impacts of lean operations and lean supply chain practices on DCs microfoundations. Our results support these hypotheses and add to existing empirical evidence of the value of lean practices for operational performance (Dal Pont *et al.*, 2008; Onofrei *et al.*, 2019; Shah and Ward, 2003). Our findings show that lean practices improve the capabilities for sensing opportunities and threats, seizing them and transforming resources to respond to them. These capabilities enhance process innovation that facilitates firm adaptation to environmental changes. Our research offers empirical evidence for the DCs framework explaining the adaptive capacity resulting from lean implementations (Anand *et al.*, 2009; Dobrzykowski *et al.*, 2016). By providing evidence of the positive relationships between lean practices and DCs microfoundations, our research sheds light on the mechanisms through which lean firms respond to environmental changes.

Related to lean operations practices, our conclusions extend previous literature on the benefits of lean, which include lower response time, higher quality, increased flexibility (Chavez *et al.*, 2013; Dal Pont *et al.*, 2008), pollution prevention and employee health improvement (Yu *et al.*, 2020). Further, DCs development through lean operations practices corroborates DCs literature that suggests that better firm responses to outside changes are based on improved internal (quality) systems, how these have been utilized, deployed and enhanced (Dobrzykowski *et al.*, 2016; Teece *et al.*, 1997). "Competitive advantage is not just a function of how one plays the game; it is also a function of the "assets" one has to play with, and how these assets can be deployed and redeployed in a changing market" (Teece *et al.*, 1997, p. 529). Lean operations practices comprise tools and work programmes that, through information sharing and knowledge accumulation, facilitate knowledge codification, articulation and experience, the three predominant requirements for DCs development (Barrales-Molina *et al.*, 2013; Zollo and Winter, 2002).

Similarly, our results extend previously recognized benefits of lean supply chain practices such as collaboration, integration and quality improvement (Cagliano *et al.*, 2006; Powell and Coughlan, 2020; Tortorella *et al.*, 2017) to DCs development within firms, which enables better adaptation to change environments. The outcome of our study is in line with the literature on DCs, which states that alliance management represents one of the clearest examples of DCs that facilitates environmental adaptation through inter-organizational collaboration (Schilke, 2014). Similar to the impact of alliance management, lean supply chain practices enhance the inter-organizational knowledge derived from customers and suppliers' collaboration, leading to higher levels of firm responsiveness to environmental changes (Gligor *et al.*, 2015).

6.2 The moderating effects of learning- and innovation-oriented lean cultures

Our results show that both cultural orientations – strengthen the relationships between most lean practices and DCs microfoundations development. This shows that understanding lean exclusively as an implementation of practices is short-sighted; it is necessary to incorporate lean-supportive cultural elements. These results confirm contemporary views on lean implementation (Åhlström *et al.*, 2021; Cusumano *et al.*, 2021). Our results support the notion that learning- and innovation-oriented lean cultures strengthen the relationship between lean practices and the firm's capacity to be on the lookout for and be ready to react to changes in the environment. This resembles the concept of a "lean competitor" that operates in highly dynamic and complex contexts (Ward *et al.*, 2007), thereby departing from an exclusive focus on operational efficiency.

Our results describe how learning amplifies the effectiveness of lean practices (Onofrei *et al.*, 2019; Tortorella *et al.*, 2019). Nevertheless, our empirical analysis did not support the existence of a positive moderating effect of an innovation-oriented lean culture on the relationship between lean supply chain practices and DCs development (H4b). This can be interpreted as suggesting that lean supply chain practices are, by nature, externally oriented and help create an understanding of the competitive environment. Hence, these practices already enable customer- and supplier feedback and the exchange of new ideas, thereby diminishing the moderating impact of a lean cultural innovation-orientation. On the other hand, lean operations practices such as pull systems and setup up time reductions, with their internal focus, are predisposed more than lean supply chain practices, to target efficiency while overlooking customer and supplier requirements.

This result agrees with previous literature such as Azadegan *et al.* (2013) who, contrary to hypothesized, found that lean supply chain practices – unlike lean operations practices – improve performance in dynamic environments, thanks to "intangible benefits" (Kaynak and Pagan, 2003), which include real-time information sharing or collective problem-solving. We propose that these intangible benefits of lean supply chain practices, such as close contact with customers and suppliers, feedback, information sharing or joint development of new ideas, facilitate an innovative orientation, explaining that an innovation-oriented culture does not significantly strengthen the relationships between these practices and the environmental adaptation suggested by DCs microfoundations. On the contrary, according to our results, this innovation-orientation is beneficial for realizing DCs from lean operations practices (Spear and Bowen, 1999).

6.3 DCs microfoundations and process innovation

Finally, our results provide support for H5, which asserts a positive relationship between DCs microfoundations and process innovation and thereby corroborate the previously explored relationship between process innovation and its DCs microfoundations antecedents (Piening and Salge, 2015).

Direct correlations between enhanced process innovation capabilities and lean implementations have been explored (Möldner *et al.*, 2020). Our research provides evidence for the organizational processes in lean implementations that ultimately lead to process innovation. Specifically, lean operations and lean supply chain practices, strengthened by learning- and innovation-oriented lean cultures, facilitate sensing, seizing and transforming capacities, which benefits process innovation. These results provide insights into the "black box" of DCs (Pavlou and El Sawy, 2011) and add to the results of the few previous studies (e.g. Jantunen *et al.*, 2018; Nikookar and Yanadori, 2021) that examine the outcomes of sensing, seizing and transforming capabilities.

6.4 Theoretical contributions

We make three contributions to the theoretical perspective of continuous improvement as DC. First, by assessing the impact of lean practices combined with lean cultures on DCs microfoundations, we extend the benefits of lean implementation identified in previous studies beyond operational performance. Second, this study provides empirical evidence on how lean cultures oriented towards learning and innovation strengthen the relationship between lean practices and DCs development. Third, while DCs are hard to measure without having incidents of changes that activate them, our results do show that DCs microfoundations – sensing, seizing and transforming – are associated with process innovation, which can be useful for firms in reacting to a variety of environmental changes.

Most importantly, our research brings out the importance of microfoundations of DCs as mechanisms for sustainable results from lean practices. Our findings highlight the importance of lean practices and supportive cultural orientations in firms pursuing successful DCs development. We show that lean practices are important for firms' strategic orientation in response to environmental changes. This conception of lean, as an initiative that facilitates firm adaptation, supports the phenomenon-based perspective on lean (Cusumano *et al.*, 2021), thereby expanding lean's myopic goal of merely improving efficiency. This view holds that the rigid application of lean practices reduces value creation from it and that it is necessary to allow for flexibility in lean practice adoption. Flexibility (i.e. learning and innovating) in the process of lean practice diffusion allows lean practices to take different forms in different contexts (Netland and Powell, 2016). Our results provide evidence that lean practices adoption in learning- and innovation-oriented settings hold significant potential for opportunities and threats detection and consequent assessment and action capabilities (process innovation). This aspect has relevance for environmental changes that lead to widespread disruptions such as those caused by the Covid-19 pandemic or the Russian invasion of Ukraine. These contexts demand from firms an extraordinary capacity to adapt. Previous views that remark on the potential of lean to respond to environmental changes (Van Hoek, 2020) align with our findings, which indicate that it is not only about reducing inventory levels or increasing efficiency, but rather it is about adopting lean practices and harnessing a supportive cultural orientation that fosters capabilities for adaptation to (extreme) environmental changes.

6.5 Managerial implications

Our results show managers that when implemented in full, lean positively contributes to the development of DCs microfoundations, which in turn fosters higher levels of process innovation. DCs microfoundations and process innovation enable the firm to respond appropriately to environmental dynamism. Further, in describing the issue of firms not being able to realize the complete benefits of lean by implementing its practices, Spear and Bowen (1999) emphasized the importance of the supportive cultural aspects needed to embrace the lean philosophy. Our research makes that advice practical for managers by pointing to actionable items in practices and cultural orientations that are critical for a holistic implementation of lean. We offer three specific insights for managers:

First, we highlight the importance of holistic approaches to adopting lean practices. Our results suggest that long-term sustainable benefits require managers to implement lean as collections of both internally and externally oriented lean practices. Second, we emphasize the importance of learning- and innovation-orientations in lean implementations. Lean implementation leaders should actively influence the creation of such cultural orientations and remove obstructions to nurturing supportive contextual conditions. Third, managers should be cognizant of the value of building DCs when implementing lean. DCs microfoundations development, through lean practices and supporting cultures, help to maintain readiness to respond to dynamic environments. By maintaining a complete repertoire of lean practices and nurturing learning- and innovation-oriented cultures, managers and frontline employees can select the right combination of tools and adopt appropriate directions for responses to gradual changes as well as sudden perturbations in volatile and uncertain environments.

7. Conclusion, limitations and future research implications

Overall, our adaptive-enabling perspective on lean implementation, as a long-term, DCs developing, strategic approach, shows the potential of lean to fit firms' strategies and competitive environments, thereby providing a perspective on lean beyond the traditional focus on consistent standardized operations and waste and variability reduction. Our findings reveal how lean implementation enables the development of firm-specific processes for the functioning of continuous improvement systems, which subsequently facilitate responding to environmental dynamism, thereby increasing firms' chances of sustaining their competitive advantages.

Our research has limitations, some of which are related to the sampling and analysis. First, the response rate possibly limits the generalizability of the findings and the robustness of the conclusions. Second, our data were obtained from single respondents in each organization and are self-reported. Third, although informed and experienced respondents across the globe responded to our survey, a majority of our sample (65%) consists of European companies. Finally, the cross-sectional nature of this research does not allow observation of the relationships between variables over time, thereby limiting the understanding of the results.

Toward future opportunities for related research, DCs are built for responding to environmental changes. Thus, future research can include the dynamism of the environment as a moderating factor in the relationships analysed and perhaps differentiate pre- and post-Covid-19 contexts. Including dynamism would lead to more complete analyses of lean practices implementation for DCs development under changing environments and would allow drawing stronger and perhaps different conclusions about the potential of lean implementation to contribute to organizational success. Further, a study of the organizational routines that develop DCs would provide a more in-depth understanding of the relationships suggested in this study.

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(The Appendix follows overleaf)

Appendix 1

Table A1. Measurement model validation

Construct	Item		Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)	Second order factor: VIF	Second order factor Loadings
These practices show how much lean and its principles are being implemented in your organization. Please indicate your degree of agreement with the following statements								
Pull *First-order construct forming lean operations practices second-order construct*	Production/service is pulled by the shipment of finished units	Pull1	0.876	0.888	0.923	0.751	1.685	0.713***
	Production/service at stations is pulled by the current demand of the next station	Pull2	0.899					
	We use a pull production/service system	Pull3	0.900					
	We use Kanban, squares or containers of signals for production/service control	Pull4	0.786					
Flow*First -order construct forming lean operations practices second-order construct*	Products/services are classified into groups with similar processing requirements	Flow1	0.817	0.835	0.884	0.604	1.732	0.653***
	Products/services are classified into groups with similar routing requirements	Flow2	0.809					
	Equipment is grouped to produce a continuous flow of families of products/services	Flow3	0.819					
	Families of products/services determine our layout	Flow4	0.760					
	Pace of production/service is directly linked with the rate of customer demand	Flow5	0.673					
Setup*First- order construct forming lean operations practices second-order construct*	Our employees try to reduce the time required in their processes	Setup1	0.909	0.671	0.856	0.749	1.829	0.880***
	We are working to lower process times	Setup2	0.819					
	We have low equipment times	Setup3*						
	Short production/service cycle times prevent responding quickly to customer requests (Reverse coded)	Setup4*						
	Short supply lead times prevent responding quickly to customer requests (Reverse coded)	Setup5*						
Employees*First- order construct forming lean operations practices second-order construct*	Shop-floor employees are key to problem-solving teams	Empl1	0.795	0.844	0.895	0.683	1.814	0.849***
	Shop-floor employees drive suggestions programmes	Empl2	0.848					
	Shop-floor employees lead product/process improvement efforts	Empl3	0.899					
	Shop-floor employees undergo multifunctional training	Empl4	0.755					

(*continued*)

Table A1.

Construct	Item		Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)	Second order factor: VIF	Second order factor Loadings
Supplier feedback*First-order construct forming lean supply chain practices second-order construct*	We frequently are in close contact with our suppliers	SFeed1	0.853	0.887	0.917	0.689	2.152	0.697***
	Our suppliers frequently visit our organization	SFeed2	0.771					
	We frequently visit our suppliers' organizations	SFeed3	0.830					
	We give our suppliers feedback on their quality and delivery performance	SFeed4	0.867					
	We strive to establish long-term relationships with our suppliers	SFeed5	0.826					
Supplier JIT*First-order construct forming lean supply chain practices second-order construct*	Suppliers are directly involved in the new product development process	SJIT1	0.872	0.725	0.879	0.784	2.029	0.671***
	Our key suppliers deliver to our organization on a JIT basis	SJIT2	0.898					
	We have a formal supplier certification programme	SJIT3*						
Customer involvement*First-order construct forming lean supply chain practices second-order construct*	We frequently are in close contact with our customers	Cust1	0.796	0.794	0.865	0.615	1.366	0.602***
	Our customers frequently visit our organization	Cust2	0.825					
	Our customers give us feedback on our quality and delivery performance	Cust3	0.776					
	Our customers are actively involved in current and future product offerings	Cust4	0.738					
	Our customers frequently share current and future demand information with our marketing department	Cust5*						
	We regularly conduct customer satisfaction surveys	Cust6*						
Supplier development*First-order construct forming lean supply chain practices second- order construct*	Our suppliers are contractually committed to annual cost reductions	SDev1	0.774	0.705	0.817	0.529	1.646	0.942***
	Our key suppliers are located in close proximity to our organization	SDev2*						
	We have corporate-level communication on important issues with key suppliers	SDev3*						
	We take active steps to reduce the number of suppliers in each category	SDev4	0.648					
	Our key suppliers manage our inventory	SDev5	0.718					
	We evaluate suppliers on the basis of total cost and not per unit price	SDev6	0.764					

(*continued*)

Table A1.

Construct	Item		Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)	Second order factor: VIF	Second order factor Loadings
This section presents statements to evaluate organizational lean culture in your organization. Please indicate your degree of agreement with the following statements								
Learning-oriented lean culture	According to our lean experience, our ability to learn is the key to improve	Learn1	0.880	0.902	0.932	0.773		
	Learning is key to improvement	Learn2	0.923					
	Learning culture guarantees a better organizational future	Learn3	0.848					
	Employee learning is an investment, not an expense	Learn4	0.865					
Innovation-oriented lean culture	Technical innovation, based on research results, is readily accepted in lean management	Inn1	0.828	0.874	0.913	0.725		
	We actively seek innovative ideas	Inn2	0.864					
	Innovation is readily accepted in lean management	Inn3	0.855					
	People are not penalized for new ideas that do not work	Inn4*						
	Innovation in our lean management approach is encouraged	Inn5	0.859					
This section includes a series of questions on the degree of development of different capabilities. Please indicate to what extent the following activities occur in your organization								
Sensing capability*First-order construct forming DCs microfoundations second- order construct*	Observing trends in the topic area of the organization	Sens1	0.797	0.885	0.916	0.685	2.014	0.869***
	Observing changes in customers' values and preferences	Sens2	0.822					
	Looking for new opportunities in the operating environment	Sens3	0.830					
	Searching for new practices	Sens4	0.840					
	Conceptualizing new ways of doing business	Sens5	0.848					
Seizing capability *First-order construct forming DCs microfoundations second-order construct*	We react to changes in our operating environment	Seiz1	0.821	0.873	0.913	0.725	2.227	0.893***
	We actively develop new ways of doing business	Seiz2	0.890					
	We continuously build complementary know-how	Seiz3	0.896					
	We try to actively influence the direction of our business sector	Seiz4	0.796					
Transforming capability *first-order construct forming DCs microfoundations second-order construct*	Acquired know-how is integrated into our organization	Transf1	0.814	0.825	0.896	0.741	1.920	0.860***
	Existing resources are used in new areas and for new purposes	Transf2	0.880					
	Existing know-how is used in new areas	Transf3	0.886					

(continued)

Table A1.

Construct	Item		Factor loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)	Second order factor: VIF	Second order factor Loadings
Process innovation	We are constantly improving our business processes	ProcInn1	0.781	0.821	0.882	0.651		
	Our company changes production methods at a great speed in comparison with our competitors	ProcInn2	0.846					
	During the past five years, our company has developed many new management approaches	ProcInn3	0.819					
	When we cannot solve a problem using conventional methods, we improvise on new methods	ProcInn4	0.779					
Please evaluate the performance of your organization with respect to the competition								
Financial performance	Our EBIT (earnings before interest and taxes) is continuously above the industry average	FP1	0.950	0.956	0.971	0.918		
	Our ROI (return on investments) is continuously above the industry average	FP2	0.964					
	Our ROS (return on sales) is continuously above the industry average	FP3	0.961					
Strategic performance	We have gained strategic advantages over our competitors	SP1	0.877	0.827	0.896	0.743		
	We have a large market share	SP2	0.809					
	Overall, we are more successful than our major competitors	SP3	0.897					

Note(s): *Item removed due to validation process; ***$p < 0.000$

Appendix 2

Table A2.
Endogeneity tests

	Lean experience - DCs microfoundations for lean operations practices	Lean experience - DCs microfoundations for lean supply chain practices	Product innovation - process innovation for DCs microfoundations
Wu-Hausman F test	1.31076 (p = 0.2541)	0.390482 (p = 0.5330)	0.499013 (p = 0.4819)
Durbin-Wu-Hausman χ^2 test	1.34315 (p = 0.2465)	0.402612 (p = 0.5257)	0.525912 (p = 0.4683)
Instrumental variable robustness	F = 23.299 (p = 0.000)	F = 9.79742 (p = 0.002)	F = 49.2735 (p = 0.000)

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